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**DOE Project Review
Massachusetts Photovoltaic Program**

**ANNUAL REPORT
June 1989 - July 1990**

**Prepared for the U.S. Department of Energy
Cooperative Agreement No. DE-FC04-87AL42558**

**The Massachusetts Photovoltaic Center
The University of Lowell Photovoltaic Program**

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MASTER

OVERVIEW

This is the third year of operations for work under the Cooperative Agreement between the Commonwealth of Massachusetts Photovoltaic Center and the U.S. Department of Energy. As a collaborative effort with shared resources, the activity at the Photovoltaic Center and the University of Lowell Photovoltaic Program has continued to advance the utilization and implementation of photovoltaic-powered systems into society. The programs and activities developed over the past three years have supported strategies that cover both international utilization as well as domestic application.

Three major areas of activities have centered around the following themes:

- The identification of market opportunities to enlarge sales potential for the photovoltaic industry.
- The development of a knowledgeable infrastructure to support PV diffusion in Massachusetts, in the United States, and around the world.
- The analysis of the physical, economic, and regulatory environment in which PV must compete with mature energy technologies.

This past year has been an experience of contrasts for the Photovoltaic Center. Projects and activities have resulted in the successful completion of programs goals. However, there have also been setbacks due to major fiscal reductions and the loss of resources. As many state governments across the country face monetary shortfalls, programs have been dramatically cut, reduced, or eliminated. Signs of the times have become diminished budgets, limited resources, and program consolidation.

The Massachusetts Photovoltaic Center has met legislative-mandated budget cuts by eliminating program divisions, by reducing

personnel, and by eliminating the rental obligation. Yet, there have been opportunities through the structural reorganization that now places the Photovoltaic Center under the Executive Office of Economic Affairs.

The Massachusetts Photovoltaic Center is no longer a full service center. However, projects are still operational that meet the objectives of the Cooperative Agreement. As the following pages detail, work covers training, testing, and coordination tasks. The Massachusetts Photovoltaic Center continues to target projects that highlight the value of photovoltaic-generated electricity as an environmentally benign contributor to the energy mix using indigenous resources with predictable costs.

INTERNATIONAL INFRASTRUCTURAL DEVELOPMENT

The Massachusetts Photovoltaic Center has consistently targeted activities that support the development of a knowledgeable infrastructure of decision makers and technicians capable of choosing photovoltaics for its appropriate applications. Continuing its work with technology transfer and educational outreach, the Massachusetts Photovoltaic Center has been involved with three major activities:

- The United Nations Photovoltaic Resources Document: Applications, Utilization, and Assessment. Guidebook for Policy Planners.
- International Visitors Program.
- Photovoltaic Workshops/Seminars.

United Nations Photovoltaic Guidebook

The Massachusetts Photovoltaic Center has once again been involved in a collaborative effort with the United Nations Institute for Training and Research (UNITAR). Along with the UNITAR/UNDP Centre on Small Energy Resources (Rome, Italy), the University of Lowell Photovoltaic Program, and the U.S. Department of Energy/PV Design Assistance Center at Sandia National Laboratories, the Massachusetts Photovoltaic Center has been the primary administrator and managing editor in the compilation and preparation of this document.

Our purpose in developing this document is to assist policy planners in understanding the issues to consider when evaluating photovoltaics for their program goals. *The Guidebook for Policy Planners* is addressed to ministerial level decision-makers and their assistants who direct policy and are responsible for the generation and supervision of development programs. These individuals typically solicit and manage development funds that

are obtained through national budgets and grants and loans from international sources.

This document provides an evaluation tool for these decision makers. Current thinking on development strategy, and the potential role that PV can play in this context, is presented. Issues pertinent to the implementation of a national photovoltaic strategy is also discussed. The steps necessary to develop a technology-specific infrastructure is addressed in order to explain the sustainability of a PV strategy.

A balanced view has been presented. From the vantage point of development officials, PV is but one item on a menu of energy choices with potential in specific circumstances. Evaluation criteria for the selection of photovoltaics and other energy choices is presented in the *Guidebook*. The current status of the technology, as well as the present and future potential of photovoltaic-powered systems, has also been discussed. This includes a discussion of representative costs of systems, and the impact of shrinking costs on the range of applications. Also, the document outlines the necessary parameters that suggest PV viability, as well as those that weigh against it.

The main emphasis of the *Guidebook* is the role that photovoltaic-powered systems can play in the criteria used by policy planners for judgement about development options. The guidebook offers a vision of an environmentally safe, economically viable energy option to policy planners throughout the developing world.

This project evolves from previous efforts to transfer information about the technology to high level decision makers from developing countries. In July, 1988, for example, a workshop was held by the sponsors of this current project. The Workshop was intended to provide hands-on and in-depth training to a limited number of decision makers with an immediate need for information about the technology. The manual, by contrast, is intended to be a broad based resource for decision makers on the increasing opportunity for successful applications, as well as to direct them to specific resources to realize their goals. It is expected that the

manual will reach many more decision makers than could a workshop, and will act in conjunction with future training programs and other resources, both governmental and corporate, to accelerate developing country use of PV. The publication date is scheduled for the fall of 1990.

**Photovoltaic Resources:
Applications, Utilization, And Assessment
Guidebook For Policy Planners**

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International Visitors Program

International delegations and visitors have met with the staff at the Photovoltaic Center throughout this past year. Delegations have represented many countries including China, India, Argentina, Austria, Yugoslavia, Uganda, Somalia, and Holland.

Perhaps the highlight of our International Visitor program was the November, 1989 high level meeting with the Vice President of Ecuador and his delegation.

CENTRO FOTOVOLTAICO DE MASSACHUSETTS
Jueves 2 de noviembre de 1989

Introducción de bienvenida
Jane M. Weissman, Directora

En nombre de la Oficina de Energía del Estado del Massachusetts, tengo el agrado de darles la bienvenida al Centro Fotovoltaico de Massachusetts. Es para mí un honor poder estar reunida con ustedes esta mañana. Les agradecemos muchísimo el interés y el tiempo dedicados a nuestro Centro y a nuestro trabajo en energía fotovoltaica.

El estado de Massachusetts ha respaldado activamente desde hace mucho la tecnología fotovoltaica. Nosotros estamos orgullosos de la visión de nuestro gobernador, Michael Dukakis. Su liderazgo nos ha comprometido en el desarrollo de esta fuente de energía. Actualmente, este tipo de energía está siendo usada en aplicaciones en Massachusetts y estamos invirtiendo en ella teniendo presente su futura contribución a la mezcla de energías. Al presente, se han establecido programas gubernamentales que fomentan el uso de energía fotovoltaica y promueven su desarrollo y aplicaciones. Nosotros sabemos que la energía fotovoltaica jugará un rol sumamente importante en nuestro futuro común.

La disponibilidad de energía, específicamente de energía eléctrica, es una de las claves de la calidad de vida. A pesar de ello, para una gran parte de la población mundial la ausencia de energía es una realidad cotidiana. Hoy, un siglo después de la aparición de prácticos dispositivos eléctricos, las fuentes de energía convencional siguen siendo incapaces de atender las necesidades de millones de personas. Los sistemas alimentados a energía fotovoltaica juegan un rol crítico y viable en el desarrollo socioeconómico de las áreas rurales de varios países.

Al convertir la luz de sol en electricidad, la energía fotovoltaica representa una tecnología simple y ambientalmente segura.

Ing. Luis Parodi Valverde, the Vice Presidente De La Republica of Ecuador and Energy Minister Diego Tamariz met with the Massachusetts Photovoltaic Center, representatives from Spire Corporation, Mobil Solar Corporation, and the University of Lowell. Our primary goal was to provide a forum for our visitors, local businesses, and the Commonwealth of Massachusetts to meet and learn about photovoltaic applications and opportunities.

**Photovoltaic
Workshops/Seminars**

Along with presenting educational and instructional material to schools, visitors, and the public, the Massachusetts Photovoltaic Center held 2 major events over the past year.

**OPPORTUNITIES
IN PRIVATE ELECTRIC
POWER GENERATION
&
ENERGY CONSERVATION
IN DEVELOPING
COUNTRIES**

Thursday, June 29, 1989
8:00 A.M. - 5:00 P.M.

Massachusetts Photovoltaic Center
One Massachusetts Technology Center
Logan International Airport
Boston, Massachusetts

SPONSORED BY

U.S.-ASEAN CENTER FOR
TECHNOLOGY EXCHANGE, INC.

U.S. AGENCY FOR
INTERNATIONAL DEVELOPMENT
Bureau for Asia/Near East
Office of Energy, Bureau for Science & Technology

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COMMONWEALTH OFFICE OF
INTERNATIONAL TRADE
INTERNATIONAL COORDINATING COUNCIL
MASSACHUSETTS PHOTOVOLTAIC CENTER
U.S. DEPARTMENT OF COMMERCE
U.S. EXPORT COUNCIL FOR
RENEWABLE ENERGY

The all-day seminar called Private Power Opportunities in Asean and Other Developing Countries was a co-sponsored event with U.S. Asean Center for Technology Exchange, Inc. and the U.S. Agency for International Development (USAID). The objective of this program was to introduce American energy companies to the expanding markets for private power and energy conservation equipment and services in developing countries including the Philippines, Indonesia, Malaysia, Thailand, Singapore, Costa Rica, the Dominican Republic, and Pakistan. The projects discussed covered services and equipment not only related to photovoltaics but also to conservation, facilities management, cogeneration, waste energy, other renewable energy technologies, and transmission.

Once again, the Massachusetts Photovoltaic Center, the John F. Kennedy School of Government at Harvard University, and the Coolidge Center for Environmental Leadership jointly sponsored the Photovoltaic Center's half-day workshop. This partnership has worked extremely. Most of the audience were planners, managers, and economists from foreign countries.

THE MASSACHUSETTS PHOTOVOLTAIC CENTER
AND
THE COOLIDGE CENTER FOR ENVIRONMENTAL LEADERSHIP
AND
THE JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

OCTOBER 20, 1989

PROGRAM

2:30 pm - 2:40 pm

GREETINGS

Jane M. Weissman, Executive Director
Massachusetts Photovoltaic Center

Dr. Robert Singer, Executive Director
Coolidge Center for Environmental Leadership

Dr. Shanta Devarajan, Professor
Kennedy School of Government

2:40 pm - 2:50 pm

PHOTOVOLTAIC APPLICATIONS FOR RURAL DEVELOPMENT

Mr. Richard Sellers, International Program Manager
Massachusetts Photovoltaic Center

2:50 pm - 3:00 pm

PHOTOVOLTAIC SYSTEM DISPLAY

Mr. Bill Berg, Coordinator, Photovoltaic Program
University of Lowell

3:00 pm - 4:30 pm

PANEL DISCUSSION - "PVs and Sustainable Development"

Moderator: Richard Sellers, Mass PV Center

Panel: Dr. Ghazi Darkazalli, Vice President
Spire Corporation

Dr. John Hammond, Executive Director
Oxfam America

Dr. Saleemul Huq, Executive Director
Bangladesh Center for Advanced Studies

Dr. Jose Martin, Department of Mechanical
Engineering, University of Lowell

TRADE LEADS AND MARKET OPPORTUNITIES

Building on five years of experience, the Massachusetts Photovoltaic Center assists the photovoltaic business community in gaining access in the international market place. The PV Center offers the Photovoltaic Market Information Service (PV-MIS) which is a bi-weekly bulletin that identifies advanced PV research, trade, and sales leads worldwide.

The PV-MIS is a state-operated information exchange microcomputer-based system designed to link subscribing organizations with numerous sources of photovoltaic market opportunities in the developing world and across the United States. Customized programming allows the system to scan selected on-line databases, and to store the information retrieved under guidelines established by a key word strategy. A portion of the trade leads are selected by the PV Center for follow-up and are then generated in a standard reporting format. Over 50 firms, inside and outside of Massachusetts, subscribe to this service.

PV-MIS Bulletin Subscribers 1989 - 1990

Acheval Wind Electronics Corp.	Lowell, MA	Kyocera America, Inc.	San Diego, CA
Alternative Energy Engineering	Redway, CA	Levitt & Company, Inc.	Cambridge, MA
Applied Resources Group Inc.	Brookline, MA	Luxtron, Inc.	Haverhill, MA
Arthur D. Little Enterprises	Cambridge, MA	Mass. Institute of Technology	Cambridge, MA
Ascension Technology	Lincoln, MA	Mobil Solar Energy Corporation	Billerica, MA
AstroPower Division	Newark, DE	Parker Solar	Reading, MA
Atlantic Battery Company	Watertown, MA	Photocomm, Inc.	Lakewood, CO
BTU Engineering Corp.	N. Billerica, MA	Remote Power Inc.	Fort Collins, CO
BTUs Unlimited Inc.	Marblehead, MA	Sandia National Laboratories	Albuquerque, NM
Cambridge Solar Enterprises	Cambridge, MA	Second Wind, Inc.	Somerville, MA
Christopher Associates Inc.	Sherborn, MA	Solar Design Associates	Still River, MA
Coastal Technology Inc.	Newbury, MA	Solar Power International	Ipswich, MA
Colorado Mountain College	Glenwood, CO	Solar Engineering Services	Lacey, WA
Crystal Systems, Inc.	Salem, MA	Solar Wave Construction Co.	Charlestown, MA
Development Sciences Inc.	Sagamore, MA	Solarex Corporation	Rockville, MD
EIC Laboratories	Norwood, MA	SPIRE Corporation	Bedford, MA
Electronic Space Systems Corp.	Concord, MA	Stone & Webster Engineering	Boston, MA
Endeco Inc.	Marion, MA	Strategies Unlimited	Mountain View, CA
Enersol Associates, Inc.	Somerville, MA	SunWize Energy Systems, Inc.	Glendale Hts., IL
Florida Solar Energy Center	Canaveral, FL	TPV Energy Systems	Waltham, MA
Fowler Solar Electric Inc.	Worthington, MA	U.S. Department of Energy	Washington, DC
Glasstech Solar, Inc.	Golden, CO	Under The Sun	Quincy, MA
I. T. Power, Inc.	Oakland, CA	University of Lowell	Lowell, MA
Integrated Power Corporation	Rockville, MD	Worcester Polytechnic Institute	Worcester, MA
InterAmer. Development Bank	Washington, DC	The World Bank	Washington, DC
Kopin Corporation	Taunton, MA		

There are four major program activities that are part of this PV-MIS system which contribute to the final product -- the PV bi-weekly bulletin. These steps are the identification of appropriate information sources; the collection of electronic data; the modification of this data; and follow-up outreach and correspondence. These four phases produce an information system that efficiently gathers, integrates, synthesizes, and disseminates international and domestic PV-specific and PV-potential marketing leads. Special care was taken in the design of the PV-MIS so that information sources provide early identification and comprehensive coverage of marketing opportunities for specified PV products as well as developing projects and activities that may be potential opportunities for PV applications.

As a service to the United States Export Council for Renewable Energy (US/ECRE), the Massachusetts Photovoltaic Center produces the Renewable Energy Data Service report (REDS). REDS expands on the PV-MIS system by utilizing the computer system capabilities to scan electronic data bases for renewable energy marketing and distribution leads in the international market.

The Massachusetts Photovoltaic Center has been careful to monitor the changes in the relationship between the major donors and developing countries and what that will mean for trade. Debt and debt restructuring, new innovations for financing projects and trade, and the new players in international lending all have an impact on trade leads and services.

To supplement the export services offered by the Massachusetts Photovoltaic Center, the PV Center is working closely with the Massachusetts Office of International Trade (MOIT). MOIT was established to address the exporting needs of Massachusetts firms. This office has the lead role in promoting and delivering trade services to the Commonwealth's business community. Working with MOIT, the PV Center is able to expand its resources and available services to the Massachusetts photovoltaic community.

COORDINATION

A priority at the Photovoltaic Center has always been to keep in contact with other state government photovoltaic programs as well to coordinate efforts with national photovoltaic programs and activities. For the past three years, the Massachusetts Photovoltaic Center has undertaken the task of monitoring activities going on in other states and state agencies

State Monitoring

When we first set out three years ago to survey states' photovoltaic activities we had some basic questions about what other states were doing toward the encouragement of photovoltaics. We were interested in learning who was using photovoltaics, how PV and its applications were being promoted, and how PV projects were funded.

Over the past years, we have focused on six specific areas of interest: the key contact within state government; state and municipal use of photovoltaics; utility programs which used photovoltaics; tax incentives for photovoltaics; technical and business assistance programs for photovoltaics; and public information programs.

The 1990 report is a compilation of three years of questionnaires and the responses from forty-three states and the District of Columbia. There are some notable changes in this report compared with the 1989 Report. Most significant is the change in status of a number of State energy offices, where most photovoltaic programs originate and develop. The Massachusetts Executive Office of Energy Resources was reorganized from a cabinet level agency to a division within the Executive Office of Consumer Affairs. Under the reorganization the Photovoltaic Center was moved to the Executive Office of Economic Affairs. Maine's Energy Office is also now a Division within the Department of Economic and Community Development. In Kentucky, the

former cabinet level Energy Office is now the Division of Energy. Vermont's Energy Office is now part of the Conservation and Renewable Energy Unit within the Public Service Department. New Jersey's energy efforts have moved from the Department of Commerce and Economic Development to a Division of Energy Planning and Conservation.

1990 State Responses	State and Municipal Programs	Utility Programs	Tax Incentives	Technical/Business Assistance	Public Information Programs
Alabama	•	•		•	
Arizona	•	•		•	•
Arkansas	•				
California	•	•	•	•	•
Colorado	•	•		•	•
Connecticut	•		•	•	
Florida	•	•		•	•
Georgia	•	•			•
Hawaii	•	•	•	•	•
Idaho	•		•	•	•
Illinois	•	•	•	•	•
Indiana	•				
Iowa	•				
Kentucky					•
Louisiana					
Maine		•			•
Maryland	•	•	•	•	
Massachusetts	•	•	•	•	•
Michigan		•	•	•	•
Minnesota			•		
Mississippi					
Missouri	•				•
Montana	•		•		•
Nebraska	•				
Nevada	•		•		•
New Jersey	•		•	•	•
New Mexico	•	•		•	
New York	•	•		•	•
North Carolina	•	•	•	•	•
North Dakota			•		
Ohio					
Oklahoma			•	•	•
Oregon		•	•		
Pennsylvania		•			•
South Carolina				•	
Tennessee					
Texas	•	•	•	•	•
Utah	•		•		
Vermont					
Virginia		•			
West Virginia					•
Wisconsin		•			
Wyoming	•			•	
D.of Columbia	•			•	

• State responded affirmatively to program activity.

There were other changes as well. Idaho's Bureau of Energy was upgraded to the Division of Energy, and in Indiana, the Energy Division to is now the Energy Office. Additionally, a number of states listed energy hotline numbers for the first time. New York, Colorado, and New Jersey offer customer assistance energy hotlines and there are 800 phone numbers at each of Pennsylvania's 7 regional energy centers. We also received new and comprehensive brochures from Illinois, "Illinois Alternative Energy Development Program" and from New Mexico, "Programs in Energy Conservation."

The most consistent message we have received over the three years of reporting on the states' photovoltaic activities is the importance of PV advocates in the development and encouragement of photovoltaics in state government. All of the programs listed in this report are based on the contributions of many individuals and their belief in photovoltaics.

Conference Attendance

Along with tracking and monitoring programs and activities taking place in other states, the PV Center attends as many conferences and technology meetings as possible. Though out-of-state travel has been significantly reduced this past year for government personnel, representatives from the Photovoltaic Center and the PV Program attended and/or participated in the following conferences and national meetings.

Renewable Energy in the Americas

May 30-June 3, 1989

Miami, Florida

This conference provided a forum for the exchange of information about renewable energy and renewable energy projects in Latin America and the Caribbean. The focus was on the incorporation of renewable technologies into existing projects as a power source for water pumping, communications, refrigeration, and village electrification.

Forum on Renewable Energy and Climate Change

June 14-15, 1989

Washington, D.C.

The meeting addressed the issues surrounding the greenhouse effect and how the renewable energy industry could respond to this climatic change as well as to market acceleration policies. Participants included representatives from the renewable energy industry, energy officials, environmental officials, and legislators.

A Growth Management Forum: Sustaining the Economic and Environmental Future of New England

November 4-5, 1989

This conference was sponsored by Tufts University. The Director of the Photovoltaic Center delivered a presentation at the workshop on "Air Pollution, Energy, and the Greenhouse Crisis."

New England Environmental Conference
March 17-18, 1990
Tufts University, Medford, Massachusetts

The PV Center was one of the co-sponsors for this annual environmental event.

Solar 90/Soltech 90
March 19-22, 1990
Austin, Texas

Representatives from the University of Lowell's Photovoltaic Program attended these two major solar conferences.

Energy and the Environment in the 21st Century
Massachusetts Institute of Technology
March 26-28, 1990
Cambridge, Massachusetts

This conference addressed the larger issues of energy technology and environmental policy and discussed the complex interrelationships between energy supply and usage and environmental effects.

New England Technology Transfer Conference
April 3-4, 1990
Boston, Massachusetts

The Massachusetts Photovoltaic Center was active in the preliminary planning sessions for this conference that was cosponsored by the U.S. Department of Energy Boston Support Office and by Argonne National Laboratory.

New England Environmental Expo
April 10-12, 1990
Boston, Massachusetts

The Photovoltaic Center chaired a session on Photovoltaics in the Energy Mix. This was a major conference with technical sessions and workshops as well as an industry trade show.

TECHNOLOGY TESTING AND MONITORING THE UNIVERSITY OF LOWELL PHOTOVOLTAIC PROGRAM

Battery Testing

A common cause of failure in stand alone photovoltaic (PV) powered systems is battery failure. Battery failures occur for a number of reasons including failure of devices which protect against overcharging and over discharging, use of the system not anticipated by the designer, adverse environmental conditions and lack of battery performance data under the expected operating conditions available to the designer.

Extensive data is available for lead acid battery performance in uninterruptible power supply (UPS) systems, in electric vehicle applications, in industrial applications, and for starting, lighting and ignition (SLI) systems. For a variety of reason, very little data is available for battery performance in photovoltaic systems. Much work has been done in battery modeling, but most models are based on manufacturer data or data taken in a single set of environmental circumstances.

Tests have been devised and a laboratory has been created for testing batteries in order to provide information regarding battery performance under a number of conditions for use by photovoltaic system designers. PV system and energy storage designs vary widely. Some systems cycle batteries deeply on a daily basis; some systems, such as vaccine refrigerators, provide many days of storage, cycling 10% to 20% daily, though occasionally cycling deeply during long periods of inclement weather. In many PV systems, the batteries are not given a regularly scheduled equalization charge, as, for example, electric vehicle batteries are.

Laboratory

The battery stores electric charge. In the University of Lowell laboratory a charge/discharge controller is connected to each battery and acts as a current source and sink to the battery. The amount and direction of current is controlled by a computer. Batteries under test can be charged and discharged between two limit voltages at any currents up to 25 amps, held at a voltage, or idled under control by a computer. Test variables are set by the experimenter from the keyboard.

The battery can be charged and discharged at constant current or as a current varying in time according to any formula. For example, an algorithm was developed to charge or maintain a battery at constant voltage.

The batteries are tested in temperature controlled environments. In the University of Lowell laboratory, two chest freezers, one equipped with a low power heater, are used.

The computer stores the following data on magnetic disk: time, battery voltage, battery current, battery temperature, battery environment temperature, and the stage (charge, discharge, idle, etc.) of a test. The time interval between data points may be set by the experimenter. The computer screen displays the sample data plus useful information for experiment control.

Battery experiments can be defined through a straightforward menu driven operator-computer interface.

Testing

Eight Sears DieHard deep discharge marine 110 Amp hour batteries were procured for battery characterization testing. Johnson Controls is the manufacturer of Sears DieHard Batteries. They recommended three to five charge-discharge cycles be performed before the actual testing to allow the batteries to reach full capacity. The batteries were cycled four times.

Battery capacity amp-hour efficiency and watt-hour efficiency were determined as functions of five variables: ambient temperature, charge rate, discharge rate, charge termination voltage and discharge termination voltage.

MassPUP Monitoring

In order to test for dependence on five variables, two test points were chosen for each variable and a total of thirty two cycle tests were performed. The data from these tests are being analyzed.

Site visits were made to the Penikese Island School, to Peddocks Island, to deer fences operated by the MDC at the Quabbin reservoir, and to the boat launch facilities at Quabbin reservoir.

Nine 35 Watt Solec modules and three 93 Amp hour Absolyte 500 sealed lead acid batteries provide power and energy storage for a 16 cubic foot refrigerator freezer and a two way radio at the Penikese Island school. Dave Dilts, MassPUP Program Manager for the State Office of Energy Resources, Myoung Lee, a University of Lowell graduate student, and Jim Aken, site manager, participated in the visit.

There are two operational systems at Peddocks Island. One provides power for visitor center lights, a low pressure Sodium security light, and a twelve volt slide projector. The other system, on another building, was intended to provide power for the island caretakers, but due to a change in agency plan between installing the system and installing the loads, some of the heavy loads, such as a television and refrigerator, were not acquired.

Photovoltaic charged deer fences at the Quabbin reservoir are used to prevent deer from browsing tree seedlings.

PV at the Quabbin boat launch facilities provide power for pumping water to the rest rooms, lights and fan in the rest rooms, lights and amenities in the rental offices, and parking lot illumination.

**Papers Presented
and Published**

S.Frye and J. Duffy

Optimal Control of Stand-Alone Photovoltaic Systems,
Annual Meeting of American Solar Energy Society, March, 1990

Z. Salameh and W. Lynch

PV Powered Health Clinic Using Single-Stage Dual Priority Regulator,
Annual Meeting of American Solar Energy Society, March, 1990

W. Berg

Operating Experience with MassPUP-Sponsored Photovoltaic Powered Systems,
1990 New England Environmental Expo, Boston, April, 1990

Z. Salameh and Chaozi Liang

Optimum Switching Points for Array Reconfiguration Controller,
IEEE Photovoltaics Specialists Conference, Orlando, May 1990

Z. Salameh and W. Lynch

Performance Analysis of a PV-Powered Health Clinic with Multi-Stage Dual Priority Regulator,
IEEE Power Engineering Society Summer Meeting, July 1990

Z. Salameh and F. Dagher

The Effect of Electrical Array Reconfiguration on the Performance of a PV-Powered Volumetric Water Pump,
IEEE Power Engineering Society Summer Meeting, July 1990

W. Lynch and Z. Salameh

Simple Electro-Optically Controlled Dual-Axis Sun Tracker,
Solar Energy, Solar Energy, Vol 454 No.2 pp. 65-69, 1990

Z. Salameh and D. Taylor

Step-Up Maximum Power Point Tracker for Photovoltaic Arrays,
Solar Energy, Vol 44, No.1 pp. 57-61, 1990

Z. Salameh, A. Mulpur, and F. Dagher

Two-Stage Electrical Array Reconfiguration Controller for PV-Powered Water Pump
Solar Energy, Vol 44, No.1 pp. 51-56, 1990

ENVIRONMENTAL TRENDS

Efforts continue at the Photovoltaic Center to promote PV within the context of environmental issues.

With concern for the condition of our global environment gaining momentum, the Photovoltaic Center is examining the role that energy plays in the relationship between economic growth and the environment. In particular, photovoltaics is one strategy to provide energy without negative environmental consequences. In fact, the only externalities that accrue to photovoltaics are positive.

The environmental debate is being conducted in a number of arenas. The scientific community is engaged in developing an understanding of the physical aspects of pollution effects. The legislative community is debating policy and regulatory programs that will respond to the growing threat. The public is increasingly aware of the issue, and seeks solutions that will not effect their quality of life. PV is one such solution.

An analysis of externalities performed by the PV Center in late 1988 indicates that photovoltaics is already generally competitive with coal, oil and nuclear generated power, if one adds social costs to traditional capital costs of conventional power. Social costs include the health and economic consequences of CO₂, SO₄, assorted particulates, and radiation. Also included are such risks as fuel cost and availability, nuclear fuel and waste containment, and global warming. Finally, such subsidized costs as our military capability to protect oil supplies, the underwriting of nuclear insurance, and assorted tax breaks for conventional power technologies, all effect the true value of energy.

However, these externalities are not included when power facilities are permitted. How, then, can PV compete?

Our strategies to create a more level playing field for energy technologies are based on generating and distributing information about the true cost of power, and suggesting programs for PV power that accord value to PV's benefits. It is not our intention to cause conventional sourced power to cost more. Rather, it is to obtain similar benefits for PV's attributes of generating power without pollution, free of the risk of price escalation, and with a supply curve that is closely attuned to utility peak load curves. This information is needed by groups currently contemplating regulatory policy initiatives that consider externalities.

An additional purpose for our work with externalities is in the information we disseminate to international decision makers. A regard for hidden costs must be incorporated into policy decisions for rural development and utility planning in developing countries. A section of the United Nations Photovoltaics *Guidebook* includes such a discussion.

Public Utilities

The Massachusetts Department of Public Utilities (D.P.U.) has been investigating issues of resource diversity and environmental externalities. In the final comments directed at D.P.U. 86-36-G/D.P.U. 89-239 by the Massachusetts Division of Energy Resources, submitted on May 4, 1990, Point 4 deserves repeating here in this context of photovoltaics and externalities.

4. "Innovation should be allowed for, particularly for renewable resources (which could suffer under a strictly competitive process). Renewable resources can offer important advantages, which go beyond price and near-term environmental criteria. In the long run, there are important benefits to be obtained from the development of innovative technologies. Project proposals which will lead to cost reductions or environmental benefits in the long run, by demonstrating new economical and/or clean energy resources, should be encouraged.

We [Division of Energy Resources] recommend that the benefits of innovation be recognized in evaluating project proposals, preferable through the use of explicit credit expressed as a cost per kwh (as we recommend for direct environmental externalities). The direct environmental benefits of such projects would already be accounted for in the environmental externalities scoring sheet that we have proposed; the innovation credit would be in addition to these. So as to avoid a problem of double counting, the innovation credit should be designed to represent only the value of the long-term economic and environmental benefits that are likely to be realized as a result of demonstration of the innovative process."

Environmental Exposition

A significant part of the PV Center's activities has been to present information and material at conferences with environmental themes. Being the year of "Earth Day - 20th Anniversary," the PV Center has participated at numerous meetings and conferences. The highlight of this activity was the technical session at the Environmental Exposition, held in April 1990 at the Hynes Auditorium in Boston, Massachusetts.

The session was titled "Energy and the Environment: Photovoltaics in the Energy Mix." Six papers were presented at this seminar. The theme of the session was to discuss strategies that successfully introduce photovoltaics into the region. Elimination of existing perceived barriers to photovoltaic installations in the Northeast will foster the rapid development of this environmentally safe, non-fossil fuel based technology. Perceived misconceptions include lack of available space for the equipment; lack of sufficient sunlight; and excessive cost. The speakers provided technical information supporting photovoltaic applications. This forum also presented the utilization and installation of photovoltaics in the Northeast.

Paper #1.	<i>Energy and the Environment – Looking to the 1990's and Beyond.</i>
Speaker Jane M. Weissman, Director
Massachusetts Photovoltaic Center.
Paper #2.	<i>What Utilities Can Do to Use Renewable Energy to Reduce Global Warming and Pollution.</i>
Speaker Dr. Ghazi Darkazalli, Vice President,
Spire Corporation.
Paper #3.	<i>New England Electric's Residential Commercial PV Installations.</i>
Speaker Dr. John J. Bzura, Senior Engineer
New England Power Service Company.
Paper #4.	<i>Operating Experience with MASSPUP-Sponsored PV-Powered Systems.</i>
Speaker Dr. Bill Berg, Coordinator
University of Lowell Photovoltaic Program.
Paper #5.	<i>Solar Electricity for the 90's.</i>
Speaker David Dilts, Photovoltaic Program Manager
Division of Energy Resources.
Paper #6.	<i>A Value Program for Utility Photovoltaics.</i>
Speaker Richard Sellers, International Marketing Manager,
Massachusetts Photovoltaic Center.

NEW INITIATIVES: UTILITY EXPERIENCE AND RESTRUCTURED FINANCIAL ANALYSIS

One of the major concerns at the Photovoltaic Center has been to assure that all potential applications for photovoltaics are explored in Massachusetts. In identifying utility markets in which PV has economic viability, the PV Center has targeted demand side leveling as one market niche that appears promising. By using photovoltaics as a power source for high efficiency DC appliances, PV can contribute to alleviating peak load management problems. The Massachusetts Photovoltaic Center, the University of Lowell Photovoltaic Program, and the Division of Energy Resources have designed a field test of a 5 KW photovoltaic-powered demand leveling system. We are enlisting the partnership of a major utility company in Massachusetts to prove the system's ability to contribute to load management programs.

Photovoltaic Assisted Lighting System

The uniqueness of the Photovoltaic Assisted Lighting (P.A.L.) system is that it combines the efficiency of modern electronic ballasts with the utilization of clean solar energy while avoiding the cost, complexity, and unreliability of power conditioning systems usually required to match PV to the utility grid.

Modern electronic ballasts for fluorescent lamps operate on either alternating current as provided by the utility grid or direct current provided by PV (or batteries). The proposed P.A.L. system uses an efficient, reliable switching power supply to convert AC utility line power to DC. The PV produces DC. Both the power supply and the PV are connected to the lighting system. Whenever there is sun, the PV will displace as much utility power as it can produce. By design, the PV will never provide power for the entire load. This permits the DC power supply to control the voltage. Because of the good match of solar power with utility

daily peaks, P.A.L. acts as a peak shaver. Preliminary results at the University of Lowell indicate that P.A.L. functions as a conservation measure at all times when lighting is used and as a peak clipper on sunny days.

The P.A.L. field test has been designed as a conservation tool, a peak shaving tool, and a renewable energy supplement, all in one system. In addition, P.A.L. has the potential for reducing customer demand charge, through the reduction of HVAC loads at all times and drastic reduction in lighting load when the sun is shining.

The goals of the PV Assisted Lighting System are:

- To learn the capability of combined energy efficient lighting retrofit and PV retrofit to serve existing buildings.
- To evaluate scale-up effect of PV on utility peaks.
- To evaluate potential for direct connected (no energy storage) PV system to reduce user energy cost through existing incentive programs.
- To demonstrate PV to be competitive with other peak power sources.
- To transfer the information and technology developed through this test.

A Framework for Evaluation

Although certain features of photovoltaic technology, such as high fixed costs coupled with low marginal costs, provide strategic and risk advantages, they are ignored in traditional project evaluation methodologies which tend to understate the benefits of PV technology. Traditional cost-accounting and project evaluation (benefit-cost) techniques are consistently biased against the adoption of high-technology innovations such as PV.

Previous evaluations of photovoltaic power have not identified the attributes of the technology so that they may be qualitatively and quantitatively evaluated to see how they affect relative price, competitiveness, and strategy. Analytic failures have included using an incorrect discount rate (usually too high); inaccurately recognizing and quantifying the benefits of the new technology; using incorrect accounting-based cost data; failure to recognize the risk of not acting; and failure to recognize that a new technology can eliminate old dichotomies.

These past evaluations suggest that a more carefully considered analytic framework needs to be developed so we don't repeat the strategic errors made in manufacturing which led to the loss of global preeminence. The discount rate must correct for the potential risk-differentials among competing generation technologies being evaluated. The discount rate must also reflect societal preferences and benefits that accrue with the use of relatively benign generation technologies. A new analysis must reflect the risk-interaction of the renewable energy (PV) technology with other generation options in a utility power-pool setting.

In evaluating an analytic framework, the following issues will be addressed: Correct discount rate estimation which reflects societal benefits and the lower risk of PV technology; correct use of marginal cost data; externalities; and correctly dealing with differential useful lives.

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