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SOLAR PHOTOVOLTAIC ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACT OF 1978

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HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES

UNITED STATES SENATE

NINETY-FIFTH CONGRESS

SECOND SESSION

ON

S. 3392

A BILL TO PROVIDE FOR AN ACCELERATED PROGRAM OF RESEARCH, DEVELOPMENT, AND DEMONSTRATION OF SOLAR PHOTOVOLTAIC ENERGY TECHNOLOGIES LEADING TO EARLY COMPETITIVE COMMERCIAL APPLICABILITY OF SUCH TECHNOLOGIES TO BE CARRIED OUT BY THE DEPARTMENT OF ENERGY, WITH THE SUPPORT OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, THE NATIONAL BUREAU OF STANDARDS, THE GENERAL SERVICES ADMINISTRATION, AND OTHER FEDERAL AGENCIES

H.R. 12874

AN ACT TO PROVIDE FOR AN ACCELERATED PROGRAM OF RESEARCH, DEVELOPMENT, AND DEMONSTRATION OF SOLAR PHOTOVOLTAIC ENERGY TECHNOLOGIES LEADING TO EARLY COMPETITIVE COMMERCIAL APPLICABILITY OF SUCH TECHNOLOGIES TO BE CARRIED OUT BY THE DEPARTMENT OF ENERGY, WITH THE SUPPORT OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, THE NATIONAL BUREAU OF STANDARDS, THE GENERAL SERVICES ADMINISTRATION, AND OTHER FEDERAL AGENCIES

SEPTEMBER 19, 1978

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SOLAR PHOTOVOLTAIC ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACT OF 1978

TUESDAY, SEPTEMBER 19, 1978

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
OF THE COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9 a.m. in room 3110, Dirksen Office Building, Hon. Spark M. Matsunaga, presiding.

Present: Senators Matsunaga, Durkin, and Domenici.

Also present: Pete Smith, professional staff member.

OPENING STATEMENT OF HON. SPARK M. MATSUNAGA, A U.S. SENATOR FROM THE STATE OF HAWAII

Senator MATSUNAGA. The Subcommittee on Energy Research and Development of the Committee on Energy and Natural Resources will come to order.

This morning the subcommittee will hear testimony on Senate bill S. 3392, the Solar Photovoltaic Research, Development, and Demonstration Act of 1978. This bill commits the Nation to a 10-year research, development, and demonstration program in solar photovoltaic technologies and it sets clear goals for the program to meet. I am pleased to report that a similar bill, H.R. 12874, has already been adopted by the House, which passed the measure without opposition on June 28, 1978, under the able leadership of Congressmen McCormack, Teague, and Goldwater.

I would like to comment briefly on why I have introduced this bill. Solar photovoltaic cells, as we all know, convert sunlight into electricity. Why is it important to build an industry for converting sunlight into electricity? Allow me to use my State of Hawaii as an example.

The Hawaiian Island chain stretches across 350 miles of the Central Pacific. No electric grid connects us to other States or even interconnects our separate islands. Our electrical power comes almost exclusively from small generating units operating primarily on imported petroleum. As a consequence my State has one of the highest electricity rates in the Nation.

On the other hand, Hawaii has a high level of solar insulation so that photovoltaic devices present a remarkable opportunity to bring electricity to our widely dispersed population without further dependence on imported oil or the development of very costly electrical distribution systems. We see clearly in Hawaii the virtues of commercializing this technology.

The problems faced by Hawaii are not unique. Many regions on the mainland face similar high electricity rates, and are not able to or do not want to construct central power facilities. These regions too would benefit greatly from solar-produced electricity.

Unfortunately, these benefits are not likely to be realized very soon because these solar systems are still very expensive and not yet efficient. However, from the testimony which we will hear this morning, I think that you will conclude that it would benefit our country greatly to assist the photovoltaics industry even if the initial markets are entirely foreign markets.

But I do not want to preempt this testimony except to mention that I have received testimony for the record from the Solar Energy Industries Association and from the Optical Coating Laboratory who support the immediate implementation of this legislation. I expect that other companies will also submit testimony for the record after this hearing and for that purpose the record will be held open for the remainder of this week.

This morning we have with us the Department of Energy which has ongoing a photovoltaic program, three solar photovoltaic companies, who are directly concerned with the commercialization of photovoltaics; Congressman McCormack and Congressman Goldwater who will comment on their findings during their hearings on photovoltaics, and Senator Hart, who has been and continues to be a strong advocate in the Senate and the Nation for the development of solar energy.

I will place in the record the texts of S. 3392 and H.R. 12874.

[The bills follow:]

95TH CONGRESS
2D SESSION

S. 3392

IN THE SENATE OF THE UNITED STATES

AUGUST 9 (legislative day, MAY 17), 1978

Mr. MATSUNAGA (for himself, Mr. ANDERSON, Mr. DOMENICI, Mr. DURKIN, Mr. MARK O. HATFIELD, and Mr. MATHIAS) introduced the following bill; which was read twice and referred to the Committee on Energy and Natural Resources

A BILL

To provide for an accelerated program of research, development, and demonstration of solar photovoltaic energy technologies leading to early competitive commercial applicability of such technologies to be carried out by the Department of Energy, with the support of the National Aeronautics and Space Administration, the National Bureau of Standards, the General Services Administration, and other Federal agencies.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Solar Photovoltaic Energy Research, Development, and Demonstration Act of 1978".

FINDINGS AND POLICY

SEC. 2. (a) The Congress hereby finds that—

(1) the United States of America is faced with a finite and diminishing resource base of native fossil fuels, and as a consequence must develop as quickly as possible a diversified, pluralistic national energy capability and posture;

(2) the current imbalance between supply and demand for fuels and energy in the United States is likely to grow for many years;

(3) the early demonstration of the feasibility of using solar photovoltaic energy systems for the generation of electricity could help to relieve the demand on existing fuel and energy supplies;

(4) the use of solar photovoltaic energy systems for certain limited applications has already proved feasible;

(5) there appear to be no insoluble technical obstacles to the widespread commercial use of solar photovoltaic energy technologies;

(6) an aggressive research and development program should solve existing technical problems of solar photovoltaic systems; and, supported by an assured and growing market for photovoltaic systems during the next decade, should maximize the future contribution of solar photovoltaic energy to this Nation's future energy production;

(7) it is the proper and appropriate role of the Federal Government to undertake research, development, and demonstration programs in solar photovoltaic energy technologies and to supplement and assist private industry and other entities and thereby the general public, so as to hasten the general commercial use of such technologies;

(8) the early development and export of solar photovoltaic energy systems, consistent with the established preeminence of the United States in the field of high technology products, can make a valuable contribution to the well-being of the people of other nations and to this Nation's balance of trade;

(9) the widespread use of solar photovoltaic energy systems to supplement and replace conventional methods for the generation of electricity would have a beneficial effect upon the environment;

(10) to increase the potential application of solar photovoltaic energy systems in remote locations, and to minimize the need for backup systems depending on fossil fuel, programs leading to the development of inexpensive and reliable systems for the storage of electricity should be pursued as part of any solar photovoltaic energy research, development, and demonstration program;

(11) evaluation of the performance and reliability of solar photovoltaic energy technologies can be expedited by testing of prototypes under carefully controlled conditions;

(12) commercial application of solar photovoltaic energy technologies can be expedited by early commercial demonstration under practical conditions;

(13) innovation and creativity in the development of solar photovoltaic energy components and systems can be fostered through encouraging direct contact between the manufacturers of such systems and the architects, engineers, developers, contractors, and other persons interested in utilizing such systems; and

(14) it is contemplated that the ten-year program established by this Act will require the expenditure of $1,500,000,000 by the Federal Government.

(b) It is therefore declared to be the policy of the United States and the purpose of this Act to establish during the next decade an aggressive research, development, and demonstration program involving solar photovoltaic energy systems. Further, it is declared to be the policy of the United States and the purpose of this Act that the objectives of this research, development, and demonstration program are—

(1) to double the production of solar photovoltaic energy systems each year during the decade starting

with fiscal year 1979, measured by the peak generating capacity of the systems produced, so as to reach a total annual United States production of solar photovoltaic energy systems of at least two million peak kilowatts, and a total cumulative production of such systems of four million peak kilowatts by fiscal year 1988;

(2) to reduce the average cost of installed solar photovoltaic energy systems to $1 per peak watt by fiscal year 1988; and

(3) to stimulate the purchase by private buyers of at least 90 per centum of all solar photovoltaic energy systems produced in the United States during fiscal year 1988.

DEFINITIONS

SEC. 3. For purposes of this Act—

(1) a "solar photovoltaic energy system" is a system of components which generates electricity from incident sunlight by means of the photovoltaic effect, and which shall include all components, including energy storage devices where appropriate, necessary to provide electricity for individual, industrial, or governmental use;

(2) the term "solar photovoltaic energy system" may be used interchangeably with the term "photovoltaic system";

(3) a "hybrid solar photovoltaic energy system" is a system of components that generates electricity from incident sunlight by means of the photovoltaic effect and, in conjunction with electronic and, if appropriate, optical, thermal and storage devices, provides electricity, as well as heat and/or light for individual, commercial, industrial, or governmental use;

(4) "photovoltaic effect" refers to the physical phenomenon exhibited under certain circumstances by some materials in which a portion of the light energy striking the material is directly converted to electrical energy;

(5) "facility" means any building, commercial or industrial complex or other device constructively employing photovoltaic systems; and

(6) "Secretary" means the Secretary of Energy.

RESEARCH, DEVELOPMENT, AND DEMONSTRATION OF SOLAR PHOTOVOLTAIC ENERGY SYSTEMS

SEC. 4. (a) The Secretary is directed to establish immediately and carry forth such research, development, and demonstration programs as may be necessary to meet the objectives of this Act as set forth in section 2(b), and as a part of any such program shall—

(1) conduct, and promote the coordination and acceleration of, research, development, and demonstra-

tions relating to solar photovoltaic energy systems and components thereof, and

(2) conduct, and promote the coordination and acceleration of, research, development, and demonstrations for systems and components to be used in applications that are dependent for their energy on solar photovoltaic energy systems.

(b) In carrying out the provisions of subsection (a), the Secretary is authorized—

(1) to establish procedures whereby any public or private entity wishing to install solar photovoltaic components and systems in any new or existing facility may apply for Federal assistance in purchasing and installing, in such facility, photovoltaic components or systems which are certified under subsection (c) as meeting the performance criteria prescribed under such subsection;

(2) to select, as soon as he deems it feasible, a number of the applicants under paragraph (1) and enter into agreements with them for the design, purchase, fabrication, testing, installation, and demonstration of photovoltaic components and systems. Such selection shall be based on the need to obtain scientific, technological, and economic information from a variety of such systems under a variety of circumstances and conditions; and

(3) to arrange, as part of any agreement entered

into under paragraph (2), to provide up to 75 per centum of the purchase and installation costs of photovoltaic components or systems. Such arrangements shall be contingent upon terms and conditions prescribed by the Secretary, including an express agreement that the entity with whom the agreement is entered into shall, in such manner and form and on such terms and conditions as the Secretary may prescribe, observe and monitor (or permit the Secretary or his agents to observe and monitor) the performance and operation of such system for a period of five years, and that such entity (including any subsequent owner of the property) shall regularly furnish the Secretary with such reports thereon as the agreement may require.

(c) The Secretary shall determine, prescribe, and publish in the Federal Register, after notice and hearing in accordance with the applicable provisions regarding rulemaking prescribed under section 553 of title 5, United States Code—

(1) within twelve months after the date of the enactment of this Act, interim performance criteria for photovoltaic components and systems to be used in appropriate applications, and procedures whereby manufacturers of photovoltaic components and systems shall have their products tested in order to provide certifica-

tion that such products conform to the performance criteria established under this paragraph; and

(2) within thirty months after the date of the enactment of this Act, definitive performance criteria for photovoltaic components and systems to be used in appropriate applications, and procedures whereby manufacturers of photovoltaic components and systems shall have their products tested in order to provide certification that such products conform to the performance criteria established under this paragraph. Such criteria may be annually revised by the Secretary, as he deems appropriate, subject to the same procedural requirements as those applicable to the initial determination of these criteria.

(d) (1) The Secretary is authorized, as soon as possible after the publication of the performance criteria prescribed under subsection (c) (1) or (c) (2), to select on the basis of open competitions—

(A) a number of readily available photovoltaic components and systems meeting the performance criteria prescribed under such subsection;

(B) a number of design concepts for various types of applications which demonstrate adaptability to the utilization of photovoltaic components and systems and

which meet such performance criteria as described in such subsection; and

(C) a number of designs for applications selected under subparagraph (B), so that each design includes specific provisions for the utilization of solar photovoltaic components and systems selected under subparagraph (A).

(2) The Secretary, in accordance with the applicable provisions of sections 7, 8, and 9 of the Federal Nonnuclear Energy Research and Development Act of 1974, and with such program guidelines as the Secretary may establish, shall—

(A) enter into such contracts and grants as may be necessary or appropriate for the development for commercial production and utilization of photovoltaic components and systems meeting the performance criteria prescribed under subsection (c) (1) or (c) (2), including any further planning and design which may be required to conform with the specifications set forth in such criteria;

(B) select, as being compatible with the design concepts chosen under paragraph (1) (B) of this subsection, a reasonable number of photovoltaic components and systems meeting the performance criteria prescribed under such subsection; and

(C) enter into contracts with a number of persons or firms for the procurement of photovoltaic components and systems meeting the performance criteria prescribed under subsection (c) (1) or (c) (2), including adequate numbers of spare and replacement parts for such systems.

(e) The Secretary is authorized to award contracts for the design integration between the application concepts and the photovoltaic systems procured by the Secretary under subsection (d) (2) (C), and for the demonstration of prototype solar photovoltaic systems, and, when appropriate, for the utilization of such systems in existing facilities. Title to and ownership of the facilities so constructed and of photovoltaic systems installed hereunder may be conveyed to purchasers of such facilities under terms and conditions prescribed by the Secretary, including an express agreement that any such purchaser shall, in such manner and form and on such terms and conditions as the Secretary may prescribe, observe and monitor (or permit the Secretary to observe and monitor) the performance and operation of such systems for a period of five years, and that such purchaser (including any subsequent owner) shall regularly furnish the Secretary with such reports thereon as the agreement may require.

(f) The Secretary, in consultation with the Administrator of General Services or the Secretary of Defense or both

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(as may be appropriate) shall enter into arrangements with appropriate Federal agencies concurrently with the conduct of the programs under this section and section 5 of this Act, to carry out such projects and activities (including demonstration projects), with respect to Federal buildings, and facilities, as may be appropriate for the demonstration of photovoltaic systems suitable and effective for use in such applications.

(g) The Secretary shall, as he deems appropriate, undertake any projects or activities (including demonstration projects) to further the attainment of the objectives of this Act.

TEST PROCEDURES AND DEFINITIVE PERFORMANCE CRITERIA

SEC. 5. (a) The Secretary shall conduct a program for the development and demonstration of prototype photovoltaic systems, including collectors, controls, power conditioning, and energy storage systems for use in a program of testing photovoltaic systems. This program shall be managed by the Solar Energy Research Institute in Golden, Colorado.

(b) Data obtained from the testing program under subsection (a) shall be evaluated and used in establishing definitive performance criteria. These performance criteria shall be used in the demonstration program described in section 4 of this Act.

COORDINATION MONITORING, AND LIAISON

SEC. 6. (a) The Secretary, in coordination with such Government agencies as may be appropriate, shall—

(1) monitor the performance and operation of photovoltaic systems installed under this Act;

(2) collect and evaluate data and information on the performance and operation of photovoltaic systems installed under this Act; and

(3) from time to time carry out such studies and investigations and take such other actions, including the submission of special reports to the Congress when appropriate, as may be necessary to assure that the programs for which the Secretary is responsible under this Act effectively carry out the policy of this Act.

(b) In the development of the performance criteria and test procedures required under section 4 of this Act, the Secretary shall work closely with the appropriate scientific, technical, and professional societies and industry representatives in order to assure the best possible use of available expertise in this area.

(c) The Secretary shall also maintain continuing liaison with related industries and interests, and with the scientific and technical community, during and after the period of the programs carried out under this Act, in order to as-

sure that the projected benefits of such programs are and will continue to be realized.

SOLAR PHOTOVOLTAIC ENERGY ADVISORY COMMITTEE

SEC. 7. (a) There is hereby established a Solar Photovoltaic Energy Advisory Committee, which shall study and advise the Secretary on—

(1) the scope and pace of research and development with respect to solar photovoltaic energy systems;

(2) the need for and timing of solar photovoltaic energy systems demonstration projects;

(3) the need for change in any research, development, or demonstration program established under this Act; and

(4) the economic, technological, and environmental consequences of the use of solar photovoltaic energy systems.

(b) The Committee shall be composed of thirteen members, including eleven members appointed by the Secretary from industrial organizations, academic institutions, professional societies or institutions, and other sources as he sees fit, and two members of the public appointed by the President. The Chairman of the Committee shall be elected from among the members thereof. The members of the Committee, while attending conferences or meetings of the Committee or while otherwise serving at the request of the Chairman

shall be allowed travel expenses, including per diem in lieu of subsistence, as authorized by law (5 U.S.C. 5703) for persons in the Government service employed intermittently.

(c) The heads of the departments, agencies, and instrumentalities of the executive branch of the Federal Government shall cooperate with the Committee in carrying out the requirements of this section, and shall furnish to the Committee such information as the Committee deems necessary to carry out this section.

DISSEMINATION OF INFORMATION AND OTHER ACTIVITIES TO PROMOTE PRACTICAL USE OF SOLAR PHOTOVOLTAIC TECHNOLOGIES

SEC. 8. (a) The Secretary shall take all possible steps to assure that full and complete information with respect to the demonstrations and other activities conducted under this Act is made available to Federal, State, and local authorities, relevant segments of the economy, the scientific and technical community, and the public at large, both during and after the close of the programs under this Act, with the objective of promoting and facilitating to the maximum extent feasible the early and widespread practical use of photovoltaic energy throughout the United States.

(b) The Secretary shall—

(1) study the effect of the widespread utilization of photovoltaic systems on the existing electric utility

system at varying levels of photovoltaic contribution to the system;

(2) study and investigate the effect of utility rate structures, building codes, zoning ordinances, and other laws, codes, ordinances, and practices upon the practical use of photovoltaic systems;

(3) determine the extent to which such laws, codes, ordinances, and practices should be changed to permit or facilitate such use, and the methods by which any such changes may best be accomplished; and

(4) determine the necessity of a program of incentives to accelerate the commercial application of photovoltaic technologies.

(c) In carrying out his functions under this section, the Secretary shall consult with the appropriate government agencies, industry representatives, and members of the scientific and technical community having expertise and interest in this area.

SOLAR ENERGY DATA BANK

SEC. 9. The Secretary shall establish at the Solar Energy Research Institute in Golden, Colorado, a solar energy data bank which shall be a national solar data collection center including information pertaining to photovoltaic energy systems.

INTERNATIONAL PARTICIPATION AND COOPERATION

SEC. 10. (a) Within one year after the date of the enactment of this Act, the Secretary shall submit to the House Committee on Science and Technology and the Senate Committee on Energy and Natural Resources a plan for demonstrating applications of solar photovoltaic energy systems and facilitating their widespread use in other nations, especially those with agreements for scientific cooperation with the United States.

(b) The Secretary is authorized to encourage, to the maximum extent practicable, international participation and cooperation in the development and maintenance of programs established under this plan.

ENCOURAGEMENT AND PROTECTION OF SMALL BUSINESS

SEC. 11. (a) In carrying out his functions under this Act, the Secretary shall take steps to assure that small-business concerns will have realistic and adequate opportunities to participate in the programs under this Act to the maximum extent practicable.

(b) The Secretary shall, to the maximum extent practicable, use all authority provided by law to protect trade secrets and other proprietary information submitted by small business under this Act and to avoid the unnecessary disclosure of such information.

PRIORITIES

SEC. 12. The Secretary shall set priorities, as far as possible consistent with the intent and operation of this Act, in accordance with the following criteria:

(1) The application utilizing photovoltaic systems which will be part of the research, development, and demonstration program and testing and demonstration programs referred to in sections 4 and 5 shall be located in a sufficient number of different geographic areas in the United States to assure a realistic and effective demonstration of the use of photovoltaic systems and of the applications themselves, in both rural and urban locations and under climatic conditions which vary as much as possible.

(2) The projected costs of commercial production and maintenance of the photovoltaic systems utilized in the testing and demonstration programs established under this Act should be taken into account.

(3) Encouragement should be given in the conduct of programs under this Act to those projects in which funds are appropriated by any State or political subdivision thereof for the purpose of sharing costs with the Federal Government for the purchase and installation of photovoltaic components and systems.

AUTHORIZATION OF APPROPRIATIONS

SEC. 13. There is hereby authorized to be appropriated to the Secretary, for the fiscal year ending September 30, 1979, $125,000,000, inclusive of any funds otherwise authorized, (1) to carry out the functions vested in the Secretary by this Act, and (2) for transfer to such other agencies of the Federal Government as may be required to enable them to carry out their respective functions under this Act. Funds appropriated pursuant to this section shall remain available until expended: *Provided,* That any contract or agreement entered into pursuant to this Act shall be effective only to such extent or in such amounts as are provided in advance in appropriation Acts.

95TH CONGRESS
2D SESSION

H. R. 12874

IN THE SENATE OF THE UNITED STATES

JUNE 29 (legislative day, MAY 17), 1978

Read twice and referred to the Committee on Energy and Natural Resources

AN ACT

To provide for an accelerated program of research, development, and demonstration of solar photovoltaic energy technologies leading to early competitive commercial applicability of such technologies to be carried out by the Department of Energy, with the support of the National Aeronautics and Space Administration, the National Bureau of Standards, the General Services Administration, and other Federal agencies.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Solar Photovoltaic Energy Research, Development, and Demonstration Act of 1978".

FINDINGS AND POLICY

SEC. 2. (a) The Congress hereby finds that—

(1) the United States of America is faced with a finite and diminishing resource base of native fossil fuels, and as a consequence must develop as quickly as possible a diversified, pluralistic national energy capability and posture;

(2) the current imbalance between supply and demand for fuels and energy in the United States is likely to grow for many years;

(3) the early demonstration of the feasibility of using solar photovoltaic energy systems for the generation of electricity could help to relieve the demand on existing fuel and energy supplies;

(4) the use of solar photovoltaic energy systems for certain limited applications has already proved feasible;

(5) there appear to be no insoluble technical obstacles to the widespread commercial use of solar photovoltaic energy technologies;

(6) an aggressive research and development program should solve existing technical problems of solar photovoltaic systems; and, supported by an assured and growing market for photovoltaic systems during the next decade, should maximize the future contribution of

solar photovoltaic energy to this Nation's future energy production;

(7) it is the proper and appropriate role of the Federal Government to undertake research, development, and demonstration programs in solar photovoltaic energy technologies and to supplement and assist private industry and other entities and thereby the general public, so as to hasten the general commercial use of such technologies;

(8) the early development and export of solar photovoltaic energy systems, consistent with the established preeminence of the United States in the field of high technology products, can make a valuable contribution to the well-being of the people of other nations and to this Nation's balance of trade;

(9) the widespread use of solar photovoltaic energy systems to supplement and replace conventional methods for the generation of electricity would have a beneficial effect upon the environment;

(10) to increase the potential application of solar photovoltaic energy systems in remote locations, and to minimize the need for backup systems depending on fossil fuel, programs leading to the development of inexpensive and reliable systems for the storage of electricity should be pursued as part of any solar photo-

voltaic energy research, development, and demonstration program;

(11) evaluation of the performance and reliability of solar photovoltaic energy technologies can be expedited by testing of prototypes under carefully controlled conditions;

(12) commercial application of solar photovoltaic energy technologies can be expedited by early commercial demonstration under practical conditions;

(13) innovation and creativity in the development of solar photovoltaic energy components and systems can be fostered through encouraging direct contact between the manufacturers of such systems and the architects, engineers, developers, contractors, and other persons interested in utilizing such systems; and

(14) it is contemplated that the ten-year program established by this Act will require the expenditure of $1,500,000,000 by the Federal Government.

(b) It is therefore declared to be the policy of the United States and the purpose of this Act to establish during the next decade an aggressive research, development, and demonstration program involving solar photovoltaic energy systems. Further, it is declared to be the policy of the United States and the purpose of this Act that the objectives of this research, development, and demonstration program are—

(1) to double the production of solar photovoltaic energy systems each year during the decade starting with fiscal year 1979, measured by the peak generating capacity of the systems produced, so as to reach a total annual United States production of solar photovoltaic energy systems of at least two million peak kilowatts, and a total cumulative production of such systems of four million peak kilowatts by fiscal year 1988;

(2) to reduce the average cost of installed solar photovoltaic energy systems to $1 per peak watt by fiscal year 1988; and

(3) to stimulate the purchase by private buyers of at least 90 per centum of all solar photovoltaic energy systems produced in the United States during fiscal year 1988.

DEFINITIONS

SEC. 3. For purposes of this Act—

(1) a "solar photovoltaic energy system" is a system of components which generates electricity from incident sunlight by means of the photovoltaic effect, and which shall include all components, including energy storage devices where appropriate, necessary to provide electricity for individual, industrial, or governmental use;

(2) the term "solar photovoltaic energy system"

may be used interchangeably with the term "photovoltaic system";

(3) a "hybrid solar photovoltaic energy system" is a system of components that generates electricity from incident sunlight by means of the photovoltaic effect and, inconjunction with electronic and, if appropriate, optical, thermal and storage devices, provides electricity, as well as heat and/or light for individual, commercial, industrial, or governmental use;

(4) "photovoltaic effect" refers to the physical phenomenon exhibited under certain circumstances by some materials in which a portion of the light energy striking the material is directly converted to electrical energy;

(5) "facility" means any building, commercial or industrial complex or other device constructively employing photovoltaic systems; and

(6) "Secretary" means the Secretary of Energy.

RESEARCH, DEVELOPMENT, AND DEMONSTRATION OF SOLAR PHOTOVOLTAIC ENERGY SYSTEMS

SEC. 4. (a) The Secretary is directed to establish immediately and carry forth such research, development, and demonstration programs as may be necessary to meet the objectives of this Act as set forth in section 2(b), and as a part of any such program shall—

(1) conduct, and promote the coordination and acceleration of, research, development, and demonstrations relating to solar photovoltaic energy systems and components thereof, and

(2) conduct, and promote the coordination and acceleration of, research, development, and demonstrations for systems and components to be used in applications that are dependent for their energy on solar photovoltaic energy systems.

(b) In carrying out the provisions of subsection (a), the Secretary is authorized—

(1) to establish procedures whereby any public or private entity wishing to install solar photovoltaic components and systems in any new or existing facility may apply for Federal assistance in purchasing and installing, in such facility, photovoltaic components or systems which are certified under subsection (c) as meeting the performance criteria prescribed under such subsection;

(2) to select, as soon as he deems it feasible, a number of the applicants under paragraph (1) and enter into agreements with them for the design, purchase, fabrication, testing, installation, and demonstration of photovoltaic components and systems. Such selection shall be based on the need to obtain scientific, technological, and economic information from a variety of such

systems under a variety of circumstances and conditions; and

(3) to arrange, as part of any agreement entered into under paragraph (2), to provide up to 75 per centum of the purchase and installation costs of photovoltaic components or systems. Such arrangements shall be contingent upon terms and conditions prescribed by the Secretary, including an express agreement that the entity with whom the agreement is entered into shall, in such manner and form and on such terms and conditions as the Secretary may prescribe, observe and monitor (or permit the Secretary or his agents to observe and monitor) the performance and operation of such system for a period of five years, and that such entity (including any subsequent owner of the property) shall regularly furnish the Secretary with such reports thereon as the agreement may require.

(c) The Secretary shall determine, prescribe, and publish in the Federal Register, after notice and hearing in accordance with the applicable provisions regarding rulemaking prescribed under section 553 of title 5, United States Code—

(1) within twelve months after the date of the enactment of this Act, interim performance criteria for photovoltaic components and systems to be used in ap-

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propriate applications, and procedures whereby manufacturers of photovoltaic components and systems shall have their products tested in order to provide certification that such products conform to the performance criteria established under this paragraph; and

(2) within thirty months after the date of the enactment of this Act, definitive performance criteria for photovoltaic components and systems to be used in appropriate applications, and procedures whereby manufacturers of photovoltaic components and systems shall have their products tested in order to provide certification that such products conform to the performance criteria established under this paragraph. Such criteria may be annually revised by the Secretary, as he deems appropriate, subject to the same procedural requirements as those applicable to the initial determination of these criteria.

(d) (1) The Secretary is authorized, as soon as possible after the publication of the performance criteria prescribed under subsection (c) (1) or (c) (2), to select on the basis of open competitions—

(A) a number of readily available photovoltaic components and systems meeting the performance criteria prescribed under such subsection;

(B) a number of design concepts for various types

of applications which demonstrate adaptability to the utilization of photovoltaic components and systems and which meet such performance criteria as described in such subsection; and

(C) a number of designs for applications selected under subparagraph (B), so that each design includes specific provisions for the utilization of solar photovoltaic components and systems selected under subparagraph (A).

(2) The Secretary, in accordance with the applicable provisions of sections 7, 8, and 9 of the Federal Nonnuclear Energy Research and Development Act of 1974, and with such program guidelines as the Secretary may establish, shall—

(A) enter into such contracts and grants as may be necessary or appropriate for the development for commercial production and utilization of photovoltaic components and systems meeting the performance criteria prescribed under subsection (c) (1) or (c) (2), including any further planning and design which may be required to conform with the specifications set forth in such criteria;

(B) select, as being compatible with the design concepts chosen under paragraph (1) (B) of this subsection, a reasonable number of photovoltaic components

and systems meeting the performance criteria prescribed under such subsection; and

(C) enter into contracts with a number of persons or firms for the procurement of photovoltaic components and systems meeting the performance criteria prescribed under subsection (c) (1) or (c) (2), including adequate numbers of spare and replacement parts for such systems.

(e) The Secretary is authorized to award contracts for the design integration between the application concepts and the photovoltaic systems procured by the Secretary under subsection (d) (2) (C), and for the demonstration of prototype solar photovoltaic systems, and, when appropriate, for the utilization of such systems in existing facilities. Title to and ownership of the facilities so constructed and of photovoltaic systems installed hereunder may be conveyed to purchasers of such facilities under terms and conditions prescribed by the Secretary, including an express agreement that any such purchaser shall, in such manner and form and on such terms and conditions as the Secretary may prescribe, observe and monitor (or permit the Secretary to observe and monitor) the performance and operation of such systems for a period of five years, and that such purchaser (including any subsequent owner) shall regularly furnish the Secretary with such reports thereon as the agreement may require,

(f) The Secretary, in consultation with the Administrator of General Services or the Secretary of Defense or both (as may be appropriate) shall enter into arrangements with appropriate Federal agencies concurrently with the conduct of the programs under this section and section 5 of this Act, to carry out such projects and activities (including demonstration projects), with respect to Federal buildings, and facilities, as may be appropriate for the demonstration of photovoltaic systems suitable and effective for use in such applications.

(g) The Secretary shall, as he deems appropriate, undertake any projects or activities (including demonstration projects) to further the attainment of the objectives of this Act.

TEST PROCEDURES AND DEFINITIVE PERFORMANCE CRITERIA

SEC. 5. (a) The Secretary shall conduct a program for the development and demonstration of prototype photovoltaic systems, including collectors, controls, power conditioning, and energy storage systems for use in a program of testing photovoltaic systems. This program shall be managed by the Solar Energy Research Institute in Golden, Colorado.

(b) Data obtained from the testing program under subsection (a) shall be evaluated and used in establishing definitive performance criteria. These performance criteria shall

be used in the demonstration program described in section 4 of this Act.

COORDINATION MONITORING, AND LIAISON

SEC. 6. (a) The Secretary, in coordination with such Government agencies as may be appropriate, shall—

(1) monitor the performance and operation of photovoltaic systems installed under this Act;

(2) collect and evaluate data and information on the performance and operation of photovoltaic systems installed under this Act; and

(3) from time to time carry out such studies and investigations and take such other actions, including the submission of special reports to the Congress when appropriate, as may be necessary to assure that the programs for which the Secretary is responsible under this Act effectively carry out the policy of this Act.

(b) In the development of the performance criteria and test procedures required under section 4 of this Act, the Secretary shall work closely with the appropriate scientific, technical, and professional societies and industry representatives in order to assure the best possible use of available expertise in this area.

(c) The Secretary shall also maintain continuing liaison with related industries and interests, and with the scientific and technical community, during and after the period

of the programs carried out under this Act, in order to assure that the projected benefits of such programs are and will continue to be realized.

SOLAR PHOTOVOLTAIC ENERGY ADVISORY COMMITTEE

SEC. 7. (a) There is hereby established a Solar Photovoltaic Energy Advisory Committee, which shall study and advise the Secretary on—

(1) the scope and pace of research and development with respect to solar photovoltaic energy systems;

(2) the need for and timing of solar photovoltaic energy systems demonstration projects;

(3) the need for change in any research, development, or demonstration program established under this Act; and

(4) the economic, technological, and environmental consequences of the use of solar photovoltaic energy systems.

(b) The Committee shall be composed of thirteen members, including eleven members appointed by the Secretary from industrial organizations, academic institutions, professional societies or institutions, and other sources as he sees fit, and two members of the public appointed by the President. The Chairman of the Committee shall be elected from among the members thereof. The members of the Committee, while attending conferences or meetings of the Committee

or while otherwise serving at the request of the Chairman shall be allowed travel expenses, including per diem in lieu of subsistence, as authorized by law (5 U.S.C. 5703) for persons in the Government service employed intermittently.

(c) The heads of the departments, agencies, and instrumentalities of the executive branch of the Federal Government shall cooperate with the Committee in carrying out the requirements of this section, and shall furnish to the Committee such information as the Committee deems necessary to carry out this section.

DISSEMINATION OF INFORMATION AND OTHER ACTIVITIES TO PROMOTE PRACTICAL USE OF SOLAR PHOTOVOLTAIC TECHNOLOGIES

SEC. 8. (a) The Secretary shall take all possible steps to assure that full and complete information with respect to the demonstrations and other activities conducted under this Act is made available to Federal, State, and local authorities, relevant segments of the economy, the scientific and technical community, and the public at large, both during and after the close of the programs under this Act, with the objective of promoting and facilitating to the maximum extent feasible the early and widespread practical use of photovoltaic energy throughout the United States.

(b) The Secretary shall—

(1) study the effect of the widespread utilization of

photovoltaic systems on the existing electric utility system at varying levels of photovoltaic contribution to the system;

(2) study and investigate the effect of utility rate structures, building codes, zoning ordinances, and other laws, codes, ordinances, and practices upon the practical use of photovoltaic systems;

(3) determine the extent to which such laws, codes, ordinances, and practices should be changed to permit or facilitate such use, and the methods by which any such changes may best be accomplished; and

(4) determine the necessity of a program of incentives to accelerate the commercial application of photovoltaic technologies.

(c) In carrying out his functions under this section, the Secretary shall consult with the appropriate government agencies, industry representatives, and members of the scientific and technical community having expertise and interest in this area.

SOLAR ENERGY DATA BANK

SEC. 9. The Secretary shall establish at the Solar Energy Research Institute in Golden, Colorado, a solar energy data bank which shall be a national solar data collection center including information pertaining to photovoltaic energy systems.

INTERNATIONAL PARTICIPATION AND COOPERATION

SEC. 10. (a) Within one year after the date of the enactment of this Act, the Secretary shall submit to the House Committee on Science and Technology and the Senate Committee on Energy and Natural Resources a plan for demonstrating applications of solar photovoltaic energy systems and facilitating their widespread use in other nations, especially those with agreements for scientific cooperation with the United States.

(b) The Secretary is authorized to encourage, to the maximum extent practicable, international participation and cooperation in the development and maintenance of programs established under this plan.

ENCOURAGEMENT AND PROTECTION OF SMALL BUSINESS

SEC. 11. (a) In carrying out his functions under this Act, the Secretary shall take steps to assure that small-business concerns will have realistic and adequate opportunities to participate in the programs under this Act to the maximum extent practicable.

(b) The Secretary shall, to the maximum extent practicable, use all authority provided by law to protect trade secrets and other proprietary information submitted by small business under this Act and to avoid the unnecessary disclosure of such information.

PRIORITIES

SEC. 12. The Secretary shall set priorities, as far as possible consistent with the intent and operation of this Act, in accordance with the following criteria:

(1) The application utilizing photovoltaic systems which will be part of the research, development, and demonstration program and testing and demonstration programs referred to in sections 4 and 5 shall be located in a sufficient number of different geographic areas in the United States to assure a realistic and effective demonstration of the use of photovoltaic systems and of the applications themselves, in both rural and urban locations and under climatic conditions which vary as much as possible.

(2) The projected costs of commercial production and maintenance of the photovoltaic systems utilized in the testing and demonstration programs established under this Act should be taken into account.

(3) Encouragement should be given in the conduct of programs under this Act to those projects in which funds are appropriated by any State or political subdivision thereof for the purpose of sharing costs with the Federal Government for the purchase and installation of photovoltaic components and systems.

AUTHORIZATION OF APPROPRIATIONS

SEC. 13. There is hereby authorized to be appropriated to the Secretary, for the fiscal year ending September 30, 1979, $125,000,000, inclusive of any funds otherwise authorized, (1) to carry out the functions vested in the Secretary by this Act, and (2) for transfer to such other agencies of the Federal Government as may be required to enable them to carry out their respective functions under this Act. Funds appropriated pursuant to this section shall remain available until expended: *Provided,* That any contract or agreement entered into pursuant to this Act shall be effective only to such extent or in such amounts as are provided in advance in appropriation Acts.

Passed the House of Representatives June 28, 1978.

Attest: EDMUND L. HENSHAW, JR.,

Clerk.

Senator MATSUNAGA. Believe it or not I have—I dreamed that I witnessed an accident last night, and lo and behold I did witness an accident. Two Metro buses squeezing right in a compact car, on Military Road and 30th Place. Boy, I felt so sorry for those people in that compact car, one from each direction.

Compact cars are dangerous things to ride. They may save energy, but—[Laughter.]

Our opening witness was to be Senator Hart. I understand he had to go into another meeting and his statement will be inserted into the record.

[The prepared statement of Senator Hart follows:]

STATEMENT OF HON. GARY HART, A U.S. SENATOR FROM THE STATE OF COLORADO

Mr. Chairman, I appreciate the opportunity to testify today in support of legislation to accelerate the widespread use of an important new energy technology—photovoltaics.

Photovoltaics is, quite simply, the direct conversion of sunlight into electricity. Photovoltaic cells have no moving parts, consume no fuel, and produce no lethal materials. They have been used since the 1950's for a variety of applications—from powering space satellites to providing electricity for specialized needs in isolated areas.

Most photovoltaic cells today are made of silicon—the second most abundant substance in the earth's crust.

Photovoltaic cells are modular by nature, and can be sensibly used for a number of decentralized applications which minimize transmission and storage costs. For example, they can be efficiently combined with compatible technologies to use waste heat for space heating and cooling, water, heating and refrigeration. The Mississippi County Junior College in Arkansas, recently put such a system into operation, at a substantial anticipated cost savings over the economic lifetime of the structure's energy systems.

During the next 50 years, the use of electricity will almost certainly grow more rapidly than energy use in general. This assumption is based in part on the likelihood that electricity will become available to hundreds of millions of people throughout the world who do not currently have access to it. It is also based on the assumption that more of the increased demand for energy that emerges in the next 50 years will—as in the last 50 years—call for electricity more than other energy sources.

However, the cost of electricity derived from conventional fuels has risen astronomically in recent years. In my own state of Colorado, homeowners have experienced a 68 percent increase in the cost of electricity in the five years since the Arab oil embargo. And this trend shows no sign of abating. It has become painfully apparent that we must begin to develop sustainable energy technologies which will meet the world's seemingly insatiable appetite for electricity.

That is why the promise of the photovoltaic technology is so important. While the cost of utility-generated electricity continues to rise, recent breakthroughs in the development of photovoltaic energy systems have resulted in dramatic reductions in the cost of these systems. And there appear to be no technical barriers to the development of photovoltaic energy systems which would be competitive with electricity derived from fossil and nuclear fuels.

In a report released last spring entitled "Solar Energy: Progress and Promise," the President's Council on Environmental Quality estimated that a concerted national effort to develop photovoltaic energy systems would result in a savings of 1 to 4 million barrels of oil per day, or as much as half of the oil this nation currently imports. By the year 2020, potential savings through utilization of photovoltaic energy systems would be 5 to 15 million barrels of oil.

Unfortunately, the current Federal photovoltaics program might best be described as the "business as usual" approach to the development of this energy technology. That is a wholly inappropriate response in light of the remarkable potential of this energy technology to meet our near-term and long-term energy needs. Present and past Administrations have fallen into a disturbing habit of submitting unrealistically low budget requests for this program in the interest of demonstrating fiscal restraint, leaving Congress to authorize and appropriate this program at levels consistent with the developmental needs of this tech-

nology. The unfortunate result has been the evolution of a Federal photovoltaics program which lacks coherence, a sense of mission and priorities, and the commitment of the Department of Energy.

We still possess a unique opportunity to chart the course of this technology—to preempt many of the economic, social and environmental problems which have historically plagued other energy technologies.

Along these lines, the House Science and Technology Committee and, in particular, Congressmen McCormack and Goldwater, are to be commended for their leadership in establishing a coherent Federal Photovoltaics Program. I fully support their efforts—and your efforts, Mr. Chairman—to bring this important legislation to fruition.

However, I believe that there are a number of ways in which the McCormack-Matsunaga bill can be improved. The Senate Energy Committee is not encumbered with the jurisdictional conflicts which prevented the House of Representatives from passing a truly comprehensive photovoltaics bill. It is of the utmost importance that we establish a legislative framework now which will facilitate the timely development of this technology and keep us on track to achieve the aggressive goals we are setting for this technology.

Our first priority, then, must be to determine what the objectives and approach of a Federal photovoltaics program should be.

The "National Photovoltaic Program Plan" proposed by the Department of Energy on May 3rd of this year would establish a timetable for the development of photovoltaic energy systems. This strategy, which is articulated in the goals section of S. 3392 and H.R. 12874, places primary emphasis on achieving specific cost objectives during each phase of the program and stimulating demand for photovoltaic systems through a series of highly visible private sector applications.

I agree with many elements of this plan. However, it is premised on certain assumptions about the future cost of other sources of energy, the size of potential markets for photovoltaic energy systems, and the willingness of the public to substitute these systems for other sources of energy at specific price levels. This is, at best, a speculative undertaking and the subject of considerable debate.

For example, a recent "venture analysis" of the National Photovoltaic Program Plan conducted by the National Solar Energy Research Institute concluded that near-term and intermediate markets would not develop quickly enough to support the capital formation needed to make advanced photovoltaic technologies competitive with electricity derived from non-renewable sources of energy.

It is unfortunate that this study has been misrepresented by some as a legitimation for keeping photovoltaics in the laboratory until "major breakthroughs" occur. It does indicate, however, that there is no unanimity of opinion within the Department of Energy on the best way to achieve our goals for photovoltaics. In this light, I believe it would be a serious mistake for Congress to "lock in" specific cost objectives, timing requirements and annual production goals.

Our ultimate goal, of course, if to develop photovoltaics to the point where this technology is capable of making a significant contribution to the nation's energy supply picture—before we begin running out of oil and gas. It is generally conceded that, to accomplish this goal, photovoltaics must be able to compete with ultility-generated electricity. Only then will this technology make sense as an energy alternative for the average homeowner or businessman.

The bill I will introduce shortly would establish a 20-year Federal commitment to develop photovoltaic energy. As in the McCormack-Matsunaga bill, the first ten years would be devoted to defining and developing the photovoltaic technologies which are likely to be competitive with utility-generated electricity by the end of the next decade, as well as attempting to make inroads into the potential markets for these systems. But my proposal would afford DOE greater flexibility in achieving this goal once the uncertainties surrounding the development of photovoltaics are resolved. This will insure that the Department does not wed itself to "dead end" technologies designed to meet the interim goals established by Congress, but which have no chance for achieving our long-term objectives. To require that DOE pursue such a course would, in my judgment, be an inefficient allocation of the limited Federal resources which are devoted to the development of photovoltaics.

Additionally, my bill would commit the Federal government to the goal of maximizing the use of this energy resource between 1990 and the year 2000, when photovoltaics can reasonably be expected to provide a substantial contribution to our electricity needs. It has become apparent in our experience with

solar heating and cooling that supporting the technical development and demonstration of a new energy source, while necessary, is not sufficient to bring it on line. We must also be willing to make a long-term commitment to creating a favorable economic and institutional climate for photovoltaics, one which will permit this technology to compete on an equal footing with the heavily subsidized conventional sources of energy. My bill singals to the industry and to the public that the Federal government is prepared to make this commitment over the long term, as well as to support near-term development of this technology.

One of the best features of the McCormack-Matsunaga bill, and one which I have incorporated in my bill, is the creation of a Photovoltaic Advisory Committee comprised of experts in the research, manufacture and marketing of photovoltaic systems. Its main purpose is to give the Federal Photovoltaic Program ongoing direction. Its responsibilities should be enhanced, however, by requiring that it conduct systematic annual reviews and establish funding priorities and the development timetables for the various photovoltaics technologies. The Committee would also assist the Secretary in "weeding out" those photovoltaic technologies which, after initial development, appear unlikely to achieve the goals of this legislation.

One area where I believe we can be doing much more is in Federal procurements of photovoltaic systems. I am a firm believer in using the tremendous buying power of the Federal government to promote solar development. A provision I authored in the Military Construction Authorization bill earlier this year requires that all new military housing and 25 percent of other new base facilities use solar systems. This initiative is expected to generate more than $50 million in additional revenues for the solar thermal industry next year alone, and $100 million each year thereafter. By way of comparison, total sales of solar collectors last year were $150 million.

Numerous Federal photovoltaics applications have already been identified, and it is clear that purchases of these systems by the Federal government would have a similar effect on the photovoltaics industry—with corresponding reductions in the cost of these systems for consumers.

Besides saving the taxpayers money in the long-term and giving agencies hands-on experience with these systems, a Federal procurement program would also afford an opportunity to infuse an element of competition into photovoltaics development.

This bill, therefore, would require that the Federal government systematically identify all potential applications of photovoltaic systems for its own uses, discriminating between those that are cost-effective or "marginally" cost-effective with currently available technologies.

On the basis of this government-wide survey, and with an eye on the developmental needs of the various photovoltaics technologies, the Congress would authorize the amount of money available each year for the purchase of these systems. The Secretary of Energy would assign a priority to each potential application, and photovoltaics firms would summit bids for each project. These bids would be required to reflect actual costs plus a reasonable profit. Contracts would be awarded to the firm or consortium of firms submitting the lowest bid for each project. The total number of projects funded each year would be contingent upon the size of the bids selected for each of the "priority" projects. If efforts to reduce the cost of these systems are successful, many of those applications which have been identified as "marginally" cost effective could be funded.

Annual reviews of the Federal Photovoltaic Utilization Program would take note of state-of-the-art improvements in photovoltaic systems and, on this basis, identify new cost-effective Federal applications of these systems.

This program would supplement both the $100 million provided for Federal demonstration of photovoltaic energy systems which is included in the National Energy Act.

The advantages of introducing an element of competition into the development of photovoltaics are manifold. While the demonstration program would sustain all promising photovoltaic technologies, manufacturers that develop low-cost technologies, systems and manufacturing techniques will be rewarded for their efforts. Principal decisions on the types of technologies to be developed for the Federal procurement program, the most advantageous "mix" of components to reduce the cost of these systems and the timing of putting these technologies into commercial-scale production would remain in the private sector.

The Department of Energy does not have an identifiable international photo-

voltaic program at the present time. This is unfortunate, for it is clear that a comprehensive international program must be an integral part of any strategy to accelerate the development of this technology. My bill will attempt to lay the groundwork for such a program by requiring DOE, in conjunction with the State Department, the Agency for International Development, the Peace Corps and other agencies, to identify possible applications for American photovoltaics systems overseas. These agencies would be required to make recommendations to the Congress for policies and actions, consistent with our foreign policy goals, to facilitate the timely transfer of these technologies to other nations. Additionally DOE would be required to work with the Department of Commerce, the Export-Import Bank and others to assist American firms in developing the international market.

Another vital—but, as yet, unexplored—area is the appropriate role of utilities in the development of photovoltaic systems. Storage of photovoltaic-generated electricity comprises a very large part of the cost of these systems.

The existing National Grid System, which serves 98 percent of this country, could be utilized to reduce the storage requirements for photovoltaic-generated electricity and, thereby, the cost of photovoltaic systems. In many parts of the nation, the time of peak efficiency of the solar cells—the period of greatest sunlight—is also the time when demand for electricity is greatest for space conditioning. Obviously, photovoltaics could do a great deal to reduce the need for additional utility-generating capacity. The Department of Energy believes that photovoltaic systems used to meet these "peak-load" needs in the Southwest could become commercially competitive as early as 1983. Additionally, many private utilities, which are capital intensive by nature, would be in a good position to make the investments necessary to adopt photovoltaic electricity for grid use.

There are important questions regarding the load management implications and reliability of photovoltaic systems used by utilities, how the use of photovoltaic electricity should affect rate structures, the implications of utility ownership of these systems and a host of other concerns. My bill requires that the TVA, the Corp of Engineers and other Federally-owned public power administrations serve as a test bed to resolve these issues. Additionally, municipal and private utilities are encouraged to participate in this area through a systems of competitive grants.

We must also begin to pave the way for widespread commercialization of photovoltaic systems in the latter part of the next decade and into the 1990's. By way of comparison, the Federal government has subsidized conventional sources of energy to the tune of $133 billion between 1918 and 1976. This gives us some idea of the tremendous national investment necessary to develop a new energy resource. Perhaps the greatest shortcoming of the Solar Heating and Cooling Demonstration Act has been the failure of Congress to follow up a successful demonstration program with a system of incentives which would permit this energy resource to compete on an equal footing with conventional sources of energy.

The legislation I am introducing today requires the Department of Energy to work with the Treasury Department, the Commerce Department and others to develop policy recommendaions for Congressional action to break down the institutional and economic barriers to photovoltaics. Only in this way will photovoltaics achieve the aggressive goals we are establishing for this technology.

Finally, DOE is required to study and make recommendations to Congress on such issues as competition in the industry, solar access, the need for industry-wide warranties and standards of reliability, and other barriers to the realization of this technology.

Mr. Chairman, it is not possible to overemphasize the importance of a strong federal commitment to the early development of photovoltaics. I applaud your efforts, and those of Congressmen McCormack and Goldwater. My testimony today is in strong support of that effort, but I am also urging you to go even further to ensure that we establish a truly comprehensive photovoltaics program which will achieve our shared goals for this technology. I hope you will consider these suggestions, and I look forward to working together with you to bring this important legislation to fruition.

Senator MATSUNAGA. The next witness is an old buddy of mine from the House, one who has truly shown great leadership in the area of photovoltaic research, as well as in other areas of energy, such as in

nuclear energy research and development. I am pleased to have with us Congressman Mike McCormack.

STATEMENT OF HON. MIKE McCORMACK, A U.S. REPRESENTATIVE FROM THE STATE OF WASHINGTON

Mr. McCormack. Thank you, Mr. Chairman. I am pleased to be invited to testify before the committee this morning, and join you in discussing the solar photovoltaic energy research development and demonstration legislation that you have sponsored here in the Senate, and that I have sponsored in the House, along with Congressman Goldwater and Congressman Teague and about 100 other Members of the House.

I appreciate this opportunity to come and testify. I have with me this morning on my left Dr. John Andelin, who is chief of staff for our subcommittee, and Mr. Henry Eaton on my right, who is a specialist in photovoltaic energy. Between us we hope to answer any questions you have.

Several developments relating to photovoltaic energy during the past 1½ years are, I believe, relevant, and should be reviewed. Then, I shall discuss some of the most significant points of this proposed legislation. And as I say, attempt to answer your questions.

Photovoltaic energy systems offer a potential for producing significant quantities of electrical energy directly from solar radiation. This direct conversion of sunlight to electricity in photovoltaic systems is clean and silent, involving no heat cycle, and no moving parts. Photovoltaic systems are intrinsically modular, thus permitting a wide range of applications, sizes and types and with essentially the same technology.

A small-scale photovoltaic industry exists in the United States today. There are 10 manufacturers of single-crystal silicon photovoltaic cells and two pilot production lines for cadmium sulfide, CDS systems. There is no large automated manufacturing facility in this country. Indeed, there is none in the world.

The production of photovoltaic systems is slow and expensive. It does not, at present, lend itself to mass production. Careful individual handling of each component is required. Yet, photovoltaics is a high technology and is expected to be a high technology for the foreseeable future, possibly forever.

Before 1977, the cost of photovoltaic systems were even higher than it is today, but in the spring of 1977, this picture of high costs showed signs of change. At that time, the photovoltaic industry indicated to the administration that it was substantially ahead of schedule in meeting the planned cost reduction goals of the Energy Research and Development Administration's photovoltaic program.

ERDA then undertook an extensive program review that resulted in a draft revision of the program plans for photovoltaic development.

In September 1977, the Subcommittee on Advanced Energy Technologies and Energy Conservation Research, Development, and Demonstration, which I chair, and of which Congressman Barry Goldwater, Jr., is ranking minority member, held oversight hearings on the draft photovoltaic plan. The picture of the photovoltaic industry pre-

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sented at that hearing was a confusing one, with conflicting estimates with respect to costs, capabilities, and production potential. However, one thing was evident, the industry was moving ahead faster than had been previously assumed.

I felt we needed to get a clearer picture of what was happening, so we set up an informal day-long discussion in December with representatives of the Department of Energy, the Senate Energy and Natural Resources Committee, and the various groups that make up the photovoltaic industry.

The information so obtained and clarified in a series of followup meetings with industry representatives, clearly indicated that there was much to be gained by Federal involvement in the development of the photovoltaic industry during the next decade. H.R. 10830, which Chairman Teague, Congressman Goldwater, and I first introduced on February 8, 1978, establishes such a Federal involvement. The bill had about 100 cosponsors. Mr. Chairman, I might parenthetically insert this is our third major solar energy bill that we have sponsored in our subcommittee, and I am very proud to have been a sponsor or cosponsor of all of those. And I am proud of the progress we are making in this field.

We had a series of unusually constructive hearings on the bill, and we unanimously reported a clean bill out of the committee on June 9. This was passed by the House without amendment on June 28 by a vote of 385 to 14. Those 14 votes did not oppose the bill, they were just opposed to any spending at all.

H.R. 12874 is identical to S. 3392, which you have sponsored along with Senators Durkin, Hatfield, Domenici, Anderson, and Mathias. Of course, Congressman Goldwater and I are flattered that you have sponsored this bill and pleased with this morning's hearing.

Mr. Chairman, the basic philosophy undergirding this bill is that the time has come to develop a focused, goal-oriented, rationalized solar photovoltaic research, development and demonstration program that is based on a cooperative effort between the Federal Government and private industry. Such a program must assure a realistic attempt, to make solar photovoltaics a viable, practical, cost-effective energy technology having wide applications and possibilities before the end of this century, S. 3392 sets forth such a program.

The bill dedicates the Nation to a 10-year research, development, and demonstration program in solar photovoltaic energy technologies. It sets clear goals for the program to meet. This is very important, again, parenthetically from my prepared statement. We have been operating in recent years in a totally irrational atmosphere on photovoltaics. Irrational in the sense of those saying it was far too expensive to touch and others saying we should spend a quarter of a billion dollars a year just because it was fun to spend a quarter of a billion dollars a year on solar energy.

We had to establish a rationalized program, and this is what this bill attempts to do. These goals relate to advances in the technology and to reduction in the cost per unit of energy produced to $1 per peak watt. The bill establishes a plan to double the total U.S. production of photovoltaic systems each year for 10 years, starting in 1979.

Doubling each year is a very aggressive approach, but by 1988, photovoltaic production, if we follow this plan, will be 1,000 times

what it is today. Thus, the production in the year 1988 will be 2 million peak kilowatts of photovoltaic capacity, with a cumulative total of 4 million peak kilowatts of photovoltaic capacity produced during that 10-year period.

The bill declares that the Federal Government is serious about this technology, and is dedicated to facilitating its adoption by the private sector. Demonstrations are planned for a variety of uses in each region of the country. The bill provides necessary and initially aggressive Federal funding assistance for this national effort.

This funding will amount to $1.5 billion during the next 10 years with an anticipated investment of $2½ billion by private industry. The bill establishes a target for Federal purchases, starting with a high percentage of Government support in the beginning but declining to an estimated 10 percent by 1988.

Overall, the bill contemplates a research and development program of about $600 million over these 10 years, and a demonstration program, that is by product, of about $900 million, totally about $1.5 billion over the next 10 years. There are those who have expressed some fear, some apprehensions about our using the figure of $1.5 billion over the next 10 years.

Yet in reality that is a lower estimate than one would get if one took an irrational program and let it run wild, without any particular goals or organization. I am very pleased with the fact that the House and the Senate both have supported the magnitude of this program for fiscal 1979. We requested, $125 million for outlay for this program for fiscal 1979 in the bill, and authorized $125 million in the authorization bill. That has been reported out of the House, and which this committee and the Senate has also reported.

In addition, the appropriations conference for the public works subcommittee appropriated $118.5 million for photovoltaics, in addition to a small amount for capital construction for photovoltaics. Thus we have an appropriation of almost exactly what we have requested in scope for this bill for fiscal 1979. The bill is rationalized and on track.

There are two final comments I would like to make with respect to the bill, Mr. Chairman. They fundamentally relate to what we can expect to do. Our goal is to bring up the production level and bring down the cost level to the point where photovoltaic systems will be competitive, at least in some areas of this country, where electricity is otherwise unavailable or extremely expensive, and also in other countries in the world where there are no electrical energy systems at all.

But to be realistic, we should not consider photovoltaics even by the end of this program, or perhaps even by the end of this century, to be competitive with conventional electricity produced, for instance, by coal and nuclear powerplants.

It is not likely that it will be economically competitive. There may be instances where the application of photovoltaics will be appropriate for peaking power, especially in areas such as the southwest where you have high solar insolation at the same time you have high energy demand for air-conditioning and irrigation systems, for instance. But even at the cost of $1 per peak watt for photovoltaic system, the electricity produced would really be very expensive. It would be a remarkable accomplishment to bring the cost down to that level, but

this would still be equivalent to 10 or 12 cents per kilowatt-hour for electricity.

Our most ambitious goal for photovoltaics is still the highest price we find in this country for electricity today. I think we should keep this in perspective, and not require the program to compete with electricity produced by conventional systems such as coal and nuclear energy. It is not necessary for the program to do that to be successful and to make that requirement, I believe, would be counterproductive.

The next point I would like to make is that the bill will create a photovoltaic industry. As the bill is written, it will bring about the creation of the photovoltaic industry. There is no doubt about the fact that the purchase of 900 million dollars' worth of photovoltaic systems during the next 10 years will create the industry. The movement is already quite visible.

Major industries, such as General Electric and Eastman and other big industries are already moving aggressively and we now have information that in France and Germany there also is aggressive movement in this area. We expect that there will be several innovations in photovoltaic systems which may lend themselves to mass production, and much cheaper systems.

There is the probability of world markets. In all likelihood we will have greater markets for photovoltaic systems in underdeveloped countries than elsewhere, and we are working on a later bill which we will be happy to sponsor with you and other members of this committee or any other Members of the House and Senate, who wish to. This additional bill would provide foreign assistance programs for less developed programs which will also support the development of world markets for photovoltaics.

To me the important thing is that what we have written in this bill, what we have prepared is a program for a rational beginning. It will not make photovoltaic energy competitive with conventional electricity during this 10-year period, and it may not even at a later date. But it will start in the direction of a rationale manner, and that is the purpose of the legislation.

Mr. Chairman, I thank you for the opportunity to testify and I will try to answer any questions you might have.

Senator MATSUNAGA. Thank you very much, Congressman McCormack. You are to be congratulated and commended for the leadership which you have played in this area. You speak of setting up a goal to reduce the cost per unit of energy produced by photovoltaic cells to $1 per peak watt. How does this compare to what is now being produced by coal, and nuclear energy, and petroleum?

Mr. MCCORMACK. A dollar per peak watt today would be equivalent to electricity on the line at 10 cents a kilowatt-hour, approximately. About the only place that electricity costs 10 cents per kilowatt-hour in this country today is in New York City, and isolated areas where there is no grid and where you have to have diesel or turbines—diesel systems or turbines using petroleum trucked in from long distances.

Conventional electricity sold across this country would be 3 or 4 cents per kilowatt-hour. I think it's closer to 3 in Washington, D.C. In the west coast, the Northwest, the Bonneville grid, it comes in about

1¼ cents per kilowatt-hour. If we brought the cost of photovoltaic systems down to $1, which is an extremely ambitious goal, and the photovoltaic industry says we can't get it down that far by the end of the program, it may never be that low, it would still be about twice or three times as expensive as conventional electricity today.

Senator MATSUNAGA. That is the biggest argument raised against photovoltaic energy, isn't it?

Mr. MCCORMACK. Yes, it is. This has always been the biggest argument against it, Mr. Chairman, and that is why we were very cautious about moving into the program. But we believe there are a large number of applications, remote systems, particularly for irrigation pumping where you don't have utility grids and all kinds of isolated systems, where there is no other power available.

Peaking power in certain parts of the country, as I mentioned, where you have a high degree of sunshine and the peaking power requirements, peaking power requirements frequently come in at 10 or 15 cents per kilowatt-hour just for peaking. So this would be cheaper than some peaking systems. The less developed countries and underdeveloped countries of the world, photovoltaic systems would serve a remarkable purpose in providing a small amount of electricity.

For instance, let us say in some totally isolated area of an underdeveloped country for electricity for a hospital, adequate refrigeration for medicine, and enough electricity to operate hospital equipment, to provide lights, to provide a minimum amount of communication system. This is affordable, this is cheaper than trying to move in a turbine generator or diesel generator, and then move the fuel in.

Of course we're using sunlight rather than petroleum. So there are a lot of arguments in favor of it. But, Mr. Chairman, if I might just summarize, I don't think we should try now to define what the uses will be exactly. I think what we need to do is bring the technology to a point where it is at least marginally competitive for some uses, and then see what results beyond that.

We have learned it is very difficult to project even 10 years into the future. I might say one other point, Mr. Chairman. We have dreamed of the idea of literally mass-producing photovoltaic systems. One could imagine printing them like newspaper, for instance. Some of the original photovoltaic systems use a system of copper oxide. If one could imagine thin films of copper impregnated on plastic, and run through some sort of machine such as a newspaper printing press that oxidized the surface and created a photovoltaic system, it could indeed be much cheaper.

We don't see that happening in the next 10 years, but it may be out there, and the more we learn about it in our research programs, the better chance we have.

Senator MATSUNAGA. Would a better comparison be per peak watt compared to per peak watt of conventional type of electricity?

Mr. MCCORMACK. Yes, Mr. Chairman, I think that's the best way to make the comparison or to compare it to electric costs where there is no grid at all in this country. There are people living in areas where there is no electric grid today. It's possible for irrigation systems, for instance: in Alaska and the Indian country in the Southwest, there are people living without electricity, and this would bring electricity

to them much more cheaply than trying to run hundreds of miles of lines and maintain them.

Mr. MATSUNAGA. Well, thank you very much, Congressman McCormack. Any questions?

Senator DOMENICI. I have no questions, Mr. Chairman.

Mr. MATSUNAGA. Thank you again.

Mr. MCCORMACK. Thank you, Mr. Chairman; I appreciate being here.

Senator MATSUNAGA. Our next witness is Congressman Goldwater.

Mr. GOLDWATER. Mr. Chairman, thank you.

Senator MATSUNAGA. Congressman Goldwater, we are happy to have you, and we would congratulate you also, along with Congressman McCormack, for the great leadership you have shown in the area of photovoltaic energy. We are happy to have you testify.

STATEMENT OF HON. BARRY M. GOLDWATER, JR., A U.S. REPRESENTATIVE FROM THE STATE OF CALIFORNIA

Mr. GOLDWATER. Thank you very much, Mr. Chairman. I have enjoyed working with Members on this side of the Capitol as well as their staff. I am happy to be here today to testify in behalf of the Photovoltaic Energy Research Development Act of 1978.

When Congressman McCormack and I introduced a similar piece of legislation in the House, I mentioned in my statement that it was time to develop a focused goal-oriented approach to the development of photovoltaics, based on a cooperative long-term effort between the Federal Government and private industry.

We have done this in the past on several pieces of legislation, which now, in my opinion, form the backbone of our Nation's energy research, development, and demonstration program. In particular, I am thinking of the Solar Heating and Cooling Demonstration Act of 1974, the Geothermal Research, Development, and Demonstration Act of 1974, the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976, the National Energy Extension Service Act, the Automotive Propulsion Research and Development Act of 1977, and so forth, all of which have made significant, cooperative, and coordinated approaches to solving a particular energy need.

One thing that each of these bills had in common was that they recognized that additional coordination, visibility, focus, and impetus, as well as funding, was needed to optimize the prospects for bringing their respective energy forms into commercial utilization. In each case, it was realized that a separate legislative framework, rather than simple inclusion as sub-subtopics in the overall energy research and development budget, would be the best means to accomplish this goal.

It was against this background that we introduced the photovoltaic bill, which I hope your committee will treat as favorably as the earlier pieces of legislation I have referred to. Photovoltaics is among the most promising solar options, in terms of the technology being proved, markets having been identified, and cost reduction goals having been firmly established.

There is little doubt that photovoltaics will meet the cost goals under which a variety of market applications will become attractive. If we

move now—if we establish the focused, goal-oriented approach that the legislation presently before this committee entails, then we stand a good chance of achieving the maximum practical contribution of 1 quad of energy from photovoltaics by the year 2000, as defined in the recently released domestic policy review of solar energy. Without this bill, the photovoltaic contribution by that date may not surpass the base case prediction of one-tenth of a quad.

Mr. Chairman, I do not wish to describe all the features of this bill, as that has been ably done by the distinguished preceding witnesses. Let me just point out that this bill does dedicate the Nation to a 10-year research program in solar photovoltaics, to advance the state of the art and to reduce the cost per unit of energy produced. In so doing, the bill provides needed permanency to the photovoltaics program and partly divorces it from the whims of the administration regarding whether the program should proceed, and at what pace.

Second, although the bill permits the Federal Government to pay up to 75 percent of the costs of photovoltaic systems used in grant projects, it also stimulates private buyers to purchase at least 90 percent of U.S-produced photovoltaic systems by fiscal year 1988. In this manner, the bill fully recognizes the need to develop an industry, but also the need to get that industry to stand on its own feet by the time Government supports are phased out.

I would like to conclude by saying that this bill maximizes the prospects for moving into the marketplace a proven energy technology, one that can be used in both centralized and dispersed applications, and which can make a real contribution in the future toward reducing our dependence on foreign oil. By accelerating the development of our photovoltaics industry, we also improve our chances for obtaining a significant share of the large international market that is sure to develop for these devices.

Mr. Chairman, as we look at the several other energy bills I mentioned earlier, we can see the major process that has been made in those areas, and how that progress can be traced to the existence of that legislation. I am convinced that if the Congress passes this photovoltaics bill, we will be able to look back in a few years and see similar, or perhaps even more outstanding, progress. That is why I urge passage of S. 3392.

Thank you, Mr. Chairman and member of the committee, for this opportunity to present my views. If you have any questions, I will be pleased to answer them.

[The prepared statement of Mr. Goldwater follows:]

STATEMENT OF HON. BARRY M. GOLDWATER, JR., A U.S. REPRESENTATIVE FROM THE STATE OF CALIFORNIA

Mr. Chairman and distinguished members of the Subcommittee, I am pleased to come before you today to testify in support of the Solar Photovoltaic Energy Research, Development and Demonstration Act of 1978. By providing a forum for discussion of this subject, your Subcommittee has shown once again that it is in the forefront of recognizing and encouraging utilization of the most promising energy technologies.

When Congressman McCormack and I introduced this bill in the House earlier this year, I said that the time has come to develop a focused, goal-oriented approach to the development of photovoltaics, based on a cooperative long-term effort between the Federal Government and private industry. This approach is in several ways similar to that which has been taken by the Congress over the

last few years in several other pieces of energy legislation which now, in my opinion, form the backbone of our nation's energy research, development and demonstration efforts. The particular legislation I am referring to is as follows: the Solar Heating and Cooling Demonstration Act of 1974 (Public Law 93–409), which initiated the Federal Solar Heating and Cooling Demonstration Program; the Geothermal Energy Research, Development and Demonstration Act of 1974 (Public Law 93–410), which consolidated the Federal effort in geothermal energy technology development; the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976 (Public Law 94–413), which established an R&D program for electric and hybrid vehicles and set out a program of demonstrating their technical and economical feasibility; the National Energy Extension Service Act, which established an energy information outreach program in the Department of Energy modeled after the cooperative extension service in the Department of Agriculture; and the Automotive Propulsion Research and Development Act of 1977, which established a program in the Department of Energy which will lead to the development of new automobile engines, such as turbines, which will be both compatible with the fuels to be used in the future and also far superior to to present engines in fuel economy.

The one thing that each of these bills had in common was that they recognized that additional coordination, visibility, focus and impetus, as well as funding, was needed to optimize the prospects for bringing their respective energy forms into commercial utilization. In each case, it was realized that a separate legislative framework, rather than simple inclusion as sub-subtopics in the overall energy research and development budget, would be the best means to accomplish this goal. When we look back now at the progress that has been made in each of these areas, with, for example, solar heating or cooling now being employed on about 60,000 homes nationwide, and plans for the construction of perhaps a dozen new geothermal energy plants starting to take firm shape, it appears more and more that our legislative approach in this regard has been successful.

It was against this background that we introduced the Photovoltaic Energy Research, Development and Demonstration Act, which I hope your Committee will treat favorably as the earlier pieces of energy legislation I have referred to. Photovoltaics is among the most promising solar options, in terms of the technology being proved, markets having been identified, and cost reduction goals having been firmly established. There is little doubt that photovoltaics will meet the cost goals under which a variety of market applications will become attractive. The main question is when that event will occur. If we move now—if we establish the focused, goal oriented approach that the legislation presently before this Committee entails—then we stand a good chance of achieving the "Maximum Practical" contribution of one quad of energy from photovoltaics by the year 2000, as defined in the recently released Domestic Policy Review of solar energy. Without this bill, the photovoltaic contribution by that date may not surpass the base case prediction of one-tenth of a quad.

Mr. Chairman, I do not wish to describe all the features of this bill, as that has been ably done by the distinguished preceeding witnesses. I would like to make a few points, however, about what the bill does and does not do, to assist this Subcommittee in assessing its merits. First and foremost, it dedicates the nation to a ten year research, development and demonstration program in solar photovoltaics, to advance the state-of-the-art and to reduce the cost per unit of energy produced. In so doing, the bill provides needed permanency to the photovoltaics program and partly divorces it from the whims of the Administration regarding whether the program should proceed, and at what pace. It was failure of the Administration to provide adequate funding for photovoltaics in fiscal year 1979 that led, in part, to the impetus for introduction of this bill.

Second, although the bill permits the Federal government to pay up to 75 percent of the costs for photovoltaic systems used in grant projects, it also stimulates private buyers to purchase at least 90 percent of U.S.-produced photovoltaic systems by fiscal year 1988. In this manner, the bill fully recognizes the need to develop an industry, but also the need to get that industry to stand on its own feet by the time government supports are phased out.

With regard to the funding levels specified in the bill, not only for the coming year but for the full ten year period, this is an area we carefully examined. Although one could make a case for spending either slightly more or less than the bill presently foresees, I believe that the funding presently included is consistent

with that required for the development of other advanced technologies of similar promise, and that it properly reflects the degree of commitment we need to photovoltaics at this stage. The requirement in the bill for annual authorization of appropriations will permit modification of presently planned funding levels, should that be appropriate.

I would like to conclude by saying that this bill maximizes the prospects for moving into the market place a proven energy technology, one that can be used in both centralized and dispersed applications, and which can make a real contribution in the future towards reducing our dependence on foreign oil. By accelerating the development of our photovoltaics industry, we also improve our chances for obtaining a significant share of the large international market that is sure to develop for these devices.

Mr. Chairman, as we look at the several other energy bills I mentioned earlier, we can see the major progress that has been made in those areas, and how that progress can be traced to the existence of that legislation. I am convinced that if the Congress passes this photovoltaics bill, we will be able to look back in a few years and see similar, or perhaps even more outstanding progress. That is why I urge passage of S. 3392.

Thank you, Mr. Chairman and Members of the Committee, for this opportunity to present my views. If you have any questions, I will be pleased to answer them.

Senator MATSUNAGA. Thank you again, Congressman Goldwater, for your testimony and the leadership you have demonstrated in this area. One of the real objections raised against both the House bill and the Senate bill is that solar photovoltaic cells will never be able to compete economically. Do you agree with that?

Mr. GOLDWATER. I would never make that statement. In any technology effort where we are working with unknowns, anything is possible if we put our minds to it in an organized way, and fully apply the resources that are available. I don't think anybody can make that kind of statement about a technological effort, that is, say that it will never be economical. I don't know for a fact whether we can or cannot make photovoltaics economically competitive with other energy sources, but I don't think we have really explored all the possibilities, and the only way we are going to do that is if we approach in an orderly kind of way, as this bill provides.

If we don't do it, we will never know the answer. That is a point that has to be made. The potential looks good to reduce the cost of photovoltaics, and I think we should at least make the effort this bill entails to explore the subject and find the answers to questions on technology, economics, and so on.

Senator MATSUNAGA. Thank you very much, Mr. Goldwater. Senator Domenici.

Senator DOMENICI. I have no questions.

Senator MATSUNAGA. Thank you again.

Senator DOMENICI. Mr. Chairman, I wonder if I might—I won't take the witness stand, but may I share my statement in support of the measure at this point.

Senator MATSUNAGA. Without objection, the statement of the Senator from New Mexico will be inserted into the record.

[The prepared statement of Senator Domenici follows:]

STATEMENT OF HON. PETE V. DOMENICI, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Good morning, Mr. Chairman, I appreciate the opportunity to testify before this distinguished subcommittee in support of S. 3392, the Solar Photovoltaic Energy Research, Development and Demonstration Act of 1978. I would like to note at the outset that the introduction of S. 3392 and its active consideration by the

subcommittee in this hearing are a direct result of the fine and continued leadership of the Senator from Hawaii, my good friend and distinguished colleague, Mr. Matsunaga, in this critical area of our Nation's long-range energy future. I commend him now for his leadership and I am proud to be a cosponsor with him of this important legislation for our national solar energy program.

Mr. Chairman, in reviewing the recent status report on the solar energy domestic policy review, I noted with great interest that the total Federal funding for all solar energy research and development in fiscal year 1974, including calendar year 1973 and my first year here in the Senate, was only $14.8 million. At that time, there also had been no specific statutory programs established to support solar energy development. The federal program then was a basic research effort principally contained in the National Science Foundation.

Since then, we have experienced the Arab oil embargo, the fivefold run-up in world oil prices, and a series of new solar legislation and statutorily mandated solar research and development programs. Total cumulative Federal funding for solar energy research and development for the following five years, including fiscal year 1979, will total almost one hundred times that fiscal year 1974 level, or almost 1.5 billion dollars, and solar funding fiscal year 1979 alone will be approximately one-half billion dollars. These dollars support the solar heating and cooling demonstration act programs, the solar thermal demonstration projects, wind energy demonstration projects, ocean thermal energy conversion (OTEC) research and development, as well as solar photovoltaic research and development, among other activities. So, I think it is fair and important to note that we have come a long way in supporting solar energy in the last five years, since that 14.8 million dollar total solar budget in fiscal year 1974, my first year here.

At the same time, Mr. Chairman, we have a long and challenging way to go in fully realizing the enormous potential of solar energy in this country and, with our leadership, the rest of the world. For instance, the domestic policy review status report indicates that solar energy, other than biomass and hydro, could provide anywhere from about three percent to almost ten percent in a maximum practical case of United States energy supply by the end of the century. CEQ and other have championed analyses showing an additional ten percent could be supplied by solar energy in the year 2000, and the status report indicates that may be the case under a "technical limit" involving a Manhattan project or Apollo program-type Federal commitment and large-scale Federal intervention in our domestic energy markets. I want to make it clear that I do not endorse necessarily any of these analyses or long-range projections, but rather I offer them as documented indications that solar energy has a great potential which the United States must pursue systematically.

One key element, Mr. Chairman, of any such systematic pursuit of solar energy development in the United States, is our solar photovoltaic program. For example, the domestic policy review status report concludes that about one quad of total United States energy supply (a little less than one percent) in a maximum practical case could be photovoltaic, and as much as two and one-half quads of photovoltaic supply could be available under a technical limitation case. Again, I recognize the many considerations that go into this analysis and I do not necessarily endorse these specific projections. The projections, however, do give us a qualitative sense of the potential and importance of photovoltaics in our domestic energy supply future.

Many of us have become well acquainted with the technical potential of photovoltaic energy over the years as a result of the NASA space program. As a member of the former Senate space committee, I saw firsthand the impressive performance of the photovoltaic energy systems which electrically powered our satellites and space vehicles. The phenomenally simple principle of solar energy in and electric energy out provided the space program with the direct conversion mechanism for reliable electric power for the space program. That same principle can be applied terrestially to achieve a renewable, non-depleting and reliable source of electric energy for a multitude of conventional and unconventional applications here on earth.

Of course, our energy research and development program has clearly recognized that solar photovoltaics is a worthy candidate for domestic energy supply applications and supporting research and development. $118.5 million for photovoltaic research and development, or almost twenty-five percent of all solar research and development funding, is included in the pending public works appropriations bill for fiscal year 1979. That appropriation would fund the au-

thorizations contained in both the pending Department of Energy authorization bill and the pending National Energy Act Conference Report. The conference report contains 98 million dollars over the next three fiscal years, fiscal year 1979 through fiscal year 1981, for federal purchases of photovoltaic cells and systems, a provision I was pleased to propose and support with others in the national energy act. Also, funding for the program has increased from a small effort five years ago to 51 million dollars in fiscal year 1977 and 76 million dollars in fiscal year 1978. So, we have already provided a steadily increasing and substantial level of direct Federal funding for this program over the past several years.

What, then, is the status of our domestic photovoltaic industry? The industry includes about ten manufacturers of photovoltaic systems, with total delivery of 700 peak kilowatts in 1977. Photovoltaic arrays are produced in handcrafted processes, without advanced production techniques or automated manufacturing facilities. The prices for these products are admittedly high, twelve to thirty dollars per peak watt and applications consequently are limited to very small scale sizes and remote locations, where such prices are cost effective. Primary uses for these photovoltaic products are in communications equipment, with other applications in navigational aids and monitoring and sensing devices.

The current industry status is a marked contrast to the potential of solar photovoltaic energy projected by the various current analyses, such as the domestic policy review status report. The status report and the recently released preliminary report on photovoltaic incentives options, as well as other analyses, have considered in detail impediments to development of photovoltaic and the resulting actions necessary to transform the current industry and existing photovoltaics energy supply into the positive potential projected for the end of the century. Perhaps foremost among all of the factors constraining industry development and growth today is uncertainty in the future government role and support, the results of research and development, and the relative economics of photovoltaics in the energy markets of the future. Industry understandably is unwilling to commit the vast technological capabilities of this nation to the required engineering and product development in the absence of a clear and reasonably predictable, longer term commitment of the Federal government to our photovoltaic program. Industry also is understandably reluctant to make the required financial commitments to its own long-range development program without a clear statement of our Federal goals for this new civilian energy supply technology and our Federal plans to pursue these goals. Those uncertainties, perhaps more than any other factor, now stand in the way of long-range progress in photovoltaic development, even with the current level of funding exceeding 100 million dollars this year. In fact, my strong support for the three-year 98 million dollar purchase program in the pending national energy act conference report was a direct effort to deal with this Federal government and market uncertainty factor in the near term.

Certainly, Mr. Chairman, E.R.D.A. and D.O.E. have had their various photovoltaic program plans within those agencies. But, we never have had a truly national statement of photovoltaic goals or plans. Also, all of the agency goals and planning were subject necessarily to the continual review and modification which occasions much of our Federal research and development effort. Today's goals and plan often become, and in photovoltaics have become, tomorrow's "inoperative" policies, as the program suffers continuing currents of policy and budget priority change.

Mr. Chairman, S. 3392 would give just the exact statement of Federal goals and the required plans and policy needed to resolve the current uncertainties in the photovoltaic industry. The bill would establish for the first time a set of truly national goals for this energy and technology and provide a coherent Federal policy and plan for supporting with industry those goals. Nationally, the bill establishes objectives including doubling photovoltaic production each year for the next ten years, leading to an annual production of two million peak kilowatts by 1988, and to reduce the average costs to one dollar per peak watt of installed capacity in 1988. Importantly, the bill also establishes an affirmative goal of a ninety percent commercial/ten percent government market for photovoltaics in 1988.

S. 3392 also establishes the statutory planning and procedures to meet these goals over the next ten years, including an accelerated demonstration program for Federally-assisted demonstrations of photovoltaic applications in commercial

markets. The bill also mandates Federal demonstrations of photovoltaic applications in Federal buildings and facilities. All of these activities under the bill will be coordinated closely with representatives of all interested government and private sectors, and an advisory committee is established to provide formal review and comment on the program. Special provisions ensure protection of small business participants in the industry and the Federal program. All of these requirements shall be the subject within one year of a plan submitted to the Congress to implement the Federal program and achieve the stated national goals.

Importantly, while the bill expressly contemplates a substantial level of funding (an averaged of 150 million dollars per year) over the next ten years, no new authorization of funding, beyond those in the Department of Energy authorization bill and the pending national energy act conference report, would be made by the bill. Consequently, the bill makes a significant step forward in photovoltaic development within the current congressional budget for fiscal year 1979. While the House Committee Report on the Companion House-passed bill suggested that peak funding in later years might approach the two hundred to two hundred fifty million dollar level to implement this program, there is no commitment now to obligate any specific level of funds in later years. Congress, therefore, can retain control of the specific program budgets on a year-by-year basis.

Mr. Chairman, I am pleased to note that this bill also would place priority, as stated in the House Report, on the research and development for components and systems which are required for expanded application of photovoltaic energy, such as variable speed D.C. pumps for use in photovoltaic-powered irrigation. My home State of New Mexico has pioneered the use of solar energy for irrigation as an alternative for natural gas-fueled irrigation. Continued emphasis on solar-powered irrigation, now with photovoltaic energy, will provide additional applications in New Mexico and other agricultural states to substiute his new energy technology for conventionally-fueled technology. To me, Mr. Chairman, such important applications are the essence of how we can introduce photovoltaics into our domestic energy economy of the future.

Mr. Chairman, S. 3392 is a rational, reasonable, and responsible approach to the long-term development of the solar photovoltaic potential for the United States. It provides the needed policy and planning reference frame for that development over the next ten years and places this nation on a direct path to full realization of our national photovoltaic potential by the end of the century. It, however, is not, as some have suggested, the equivalent of President Kennedy's commitment to reach the moon in the 1960s, nor is it a Manhattan project or Apollo program-type federal crash program. Rather, S. 3392 is a balanced approach which will give our photovoltaic industry, current and future, the certainty to proceed with maximum speed and necessary federal support to meet our national goals. I urge this subcommitee and committee to give S. 3392 full consideration and report it at the earliest possible date.

Thank you, Mr. Chairman.

Senator MATSUNAGA. Our next witness is Dr. Eric H. Willis, Deputy Assistant Secretary of the Department of Energy, representing the views of the administration. Dr. Willis, we will be happy to hear from you.

STATEMENT OF DR. ERIC H. WILLIS, DEPUTY ASSISTANT SECRETARY, ENERGY TECHNOLOGY, DEPARTMENT OF ENERGY; ACCOMPANIED BY DENNIS COSTELLO, SOLAR ENERGY RESEARCH INSTITUTE, GOLDEN, COLO.; AND DR. HENRY MARVIN, DEPUTY PROGRAM DIRECTOR, SOLAR AND GEOTHERMAL, DEPARTMENT OF ENERGY

Dr. WILLIS. Good morning, Senator. I would like to introduce my two colleagues who are accompanying me today. They are Mr. Dennis Costello of the Solar Energy Research Institute of Golden, Colo. He is here because he was the principal investigator into our venture analysis performed by that institute.

I am also accompanied by Dr. Henry Marvin, who is no stranger to you in solar energy. He is Deputy Program Director of the Solar and Geothermal Area, Department of Energy. Mr. Chairman, I am glad to have this opportunity to review for you the photovoltaics program of the Department of Energy. As requested in your letter dated September 5, 1978, I will place special emphasis on those program elements aimed at commercialization, and in particular, on our views on Senate bill 3392, "Solar Photovoltaic Energy Research, evelopment, and Demonstration Act of 1978." In that context I think it would be sensible to review the background of the bill, at least as seen from the perspective of the Department of Energy.

As you know, this bill would enact into law many elements of a plan originated in our photovoltaics program early in 1977, and which was published in February of this year. It was first reviewed by our management last summer. Initially it appeared to have some considerable appeal because it seemed to promote the kind of cost reduction and user participation that I know we all feel is the key to the penetration of photovoltaics into the energy supply system. It had the excellent intent of an initiative to do something.

That, we are all keen to bring about. On the other hand it was not a plan that had been examined in sufficient analytical detail. In fact, we felt a little bit uneasy about the costs and benefits of the market pull portion of the plan and thus were somewhat reluctant about its being translated into a legislative mandate. Therefore, we raised the question of the advisability of this initiative with the Under Secretary and he requested that a venture analysis be performed by the Solar Energy Research Institute, SERI. That is the analysis that Mr. Costello was responsible for performing for us. The analysis had the objective of evaluating this specific approach to commercialization at this time, not necessarily now, but in the future. Mr. Chairman, I want to be sure at this point that we are not misunderstood. Both we and the proponents of this approach, particularly the eminent Congressman who preceded me in testimony, are agreed on the need to press forward with commercializing photovoltaics. We are not backing away from a strong commitment to the technology or its rapid commercialization. We feel that it has a significant role to play in the family of solar technologies.

The analysis that we commissioned to answer this question investigated the costs, benefits and risks of adding an 8-year Federal market-pull program to our base program of research and development, technology development and systems engineering and program support. In this initiative, it was postulated that the Federal Government would subsidize the difference between the price charged by photovoltaics producers and the maximum price the consumer would pay.

The conclusions of the analysis conducted by SERI covered three major points: The first was that the technology breakthrough to photovoltaic array prices of 10 to 30 cents per peak watt could outweigh the benefits to the Nation from the proposed market-pull program. This conclusion came as somewhat of a surprise to me.

The second conclusion was that the intermediate market, which lies between today's cost and array prices of about 50 cents a peak watt, is probably not large enough to support the price reductions anticipated by the market-pull strategy.

And third, it concluded that there is a necessity for a series of field tests and experiments explicitly directed toward ascertaining performance and market information. I think the latter conclusion is an important one and often a neglected one.

We have taken aggressive action to meet the need for technology breakthroughs. This is reflected in the budgets applied to research and development over the past few years.

As a result of the initiatives announced by the President on May 3, 1978, this reseach development and demonstration effort is growing from $6 million in fiscal year 1977 to $9 million in fiscal year 1978 to almost $35 million in fiscal year 1979, and we expect further expansion in fiscal year 1980. Recently, we have selected 49 additional R. & D. contractors who submitted proposals in response to four program research and development announcements. These include efforts on amorphous silicon materials, several on new thin film materials and research aimed at exploiting basic physical mechanisms that can lead to breakthroughs in increased performance or reduced cost. Congressman McCormack alluded to some of these in his testimony a short while ago. We are pleased with the quality of these proposals and feel certain that this expanded program will increase the probability of achieving our cost goals. As you know, the Jet Propulsion Laboratory, in coordination with the Solar Energy Research Institute, is managing the system integration and technology development portions of the program. We feel we have a purposeful program, with very good management.

In addition, work is now underway on the development and initial implementation of the photovoltaics commercialization program. The Assistant Secretary for Conservation and Solar Applications will utilize supplemental fiscal year 1978 funding to design, procure, and install Federal applications, and to perform studies of how best to penetrate the domestic and foreign private-sector markets. Part of this fiscal year 1978 funding is also being used to support improved manufacturing processes, which are of the essence in these cost reduction efforts.

The findings of the SERI analysis and other information that we have received in recent months underline the uncertainty in reaching specific cost goals; not to mention the estimates of the resources required to meet those goals. We have concluded that the photovoltaic program provided by this bill is probably not the best that can be devised at this time. We are convinced, however, that some sort of market-oriented initiative is important. Therefore, we are examining options that would be less costly with the anticipation that they will also prove more effective. I might add, they would be subjected to equally stringent venture analyses like that which we had performed on the current analysis.

Now let me turn to the status of photovoltaics. At present about 1 megawatt of photovoltaic generating capacity is sold annually; these sales are almost exclusively for uses off the grid. Except for these limited applications, mostly in remote locations, the cost of photovoltaic power militates against its wide use, as you rightly observed a little while ago. Furthermore, I know you realize that reducing the cost of the photovoltaic cell alone will not be sufficient to make the system economically competitive. Cost reductions will be needed in all compo-

nents of the system. By "system" I mean the photovoltaic array, the power conditioning, storage and installation technology. (We often refer to so many dollars of peak watt of array without referring to the system.)

In connection with installation technology, Mr. Chairman, I think we ought to take note of the fact that this factor today is causing us considerable concern, the cost of the labor installing photovoltaic and other solar arrays. At present, a price of 4 to 6 cents per kilowatt-hour of electricity is about the utility industry norm and photovoltaics at this cost would be competitive.

Today's cost of photovoltaic electricity ranges from 50 cents for the most basic DC system to $2 per kilowatt-hour for an on the grid residential design. If present trends continue we expect this will drop to the range of 10 to 50 cents by 1982. This 1982 price depends on array costs of about $2 per peak watt. We have designed our program with the goal of bringing the cost per kilowatt-hour down by as early as 1986 to the range of 6 to 12 cents in 1978 dollars for power generated on site and used by consumers without on site storage. (Since it is grid connected, the utility standby generators serve as storage.) Exactly when this goal will be achieved, of course, depends on the Government resources committed to photovoltaics as well as on the size of the markets, which the venture analysis shows to be highly uncertain at present.

We are optimistic that the central utility application of photovoltaic power will be practical in the 1990's. The program plan is aimed at achieving a cost level of 4 to 6 cents per kilowatt-hour in today's dollars for utilities as early as 1990.

Achievement of the intermediate goal requires reducing the cost of solar arrays to 50 cents per peak watt, whereas the longer range will require arrays at 10 to 30 cents per peak watt. In addition, efforts to overcome institutional and other noncost barriers will be required. It is not enough to simply provide a user with a photovoltaic array that provides DC electricity. It must be part of an overall system that as far as the user is concerned is essentially equivalent to the electricity he or she gets now from the plug in the wall. This means that we must understand the integration of distributed and intermittent electric generators into the electrical grid system. Unless we understand all aspects of that problem, it will be difficult, perhaps even impossible, to effect a major contribution of photovoltaics to our energy supply network. We are working hard on this problem and I firmly believe that we will solve it. But, in fact, it is a problem that often gets ignored because it is less exciting than the development of new materials and new methods of packaging them into modules and arrays.

In summary, Mr. Chairman, the SERI venture analysis has led us to focus more attention on research and development aimed at technology breakthroughs and on efforts to prepare for the grid connected market, the largest and most important for photovoltaics. We have concluded that the photovoltaics program provided by this legislation is probably at the present time not the best that can be devised at this time. Both we and the proponents of this measure are agreed on the need for a strong commitment to pressing forward with commercialization of photovoltaics.

Mr. Chairman, I want to thank you for the opportunity to comment on this legislation.

Senator MATSUNAGA. Thank you very much, Dr. Willis, for your testimony. We certainly appreciate your taking the time to appear before the subcommittee. You recall that in your preliminary report, in the Department of Energy report, "photovoltaic incentives options". You are familiar with this.

On page B–6 of this report in the statement, industry's comments with relation to the array price to the market growth, it makes the following statements. "One, the market will enter an explosive, self sustaining growth phase at array prices of $1 to $2 per watt. That is the peak watt, as long as arrays are of low profile and can operate unattended. Lower certainty if there are higher concentration arrays.

"Two—this comment goes on—there are many markets for photovoltaic products at prices considerably greater than $2 per peak watt. Particularly in LDC's, LDC applications, $10 to $5 peak watt range also likely to be cost effective.

The goal, as you know, of the bill before us, is $1 per peak hour—per peak watt, rather, and as you say, we may be able to bring it down as low as 50 cents per peak watt. Now, it would appear to me that if we do succeed in our objectives by this bill, we would be far below what is considered cost effective by industry today.

I would appreciate your comment on this, inasmuch as one of your objections, as I see it, from your testimony, is that it would not be cost effective as compared to other forms of energy.

Dr. WILLIS. I think you have hit on one of the critical points, namely the size of that intermediate market, to circumscribe the figures you have just given. Since Mr. Costello is the author of that report from which I reported, may I ask your permission for him to give you his views on that?

Senator MATSUNAGA. Mr. Costello, will you state your full name for the record.

Mr. COSTELLO. It is Dennis R. Costello.

Senator MATSUNAGA. And your capacity?

Mr. COSTELLO. I am the project leader for the SERI photovoltaic venture analysis.

Senator MATSUNAGA. Thank you, we will be happy to hear from you.

Mr. COSTELLO. We looked into the study you quoted and in fact the authors of that study were also subcontractors in our photovoltaic venture analysis. We do agree that there are a number of intermediate markets. The basic question we addressed was whether those markets are large enough to sustain an industry. In other words, are the markets large enough to allow the industry to make the necessary capital investments in order to get the cost reductions that are necessary.

We could not find sufficient evidence to prove that these markets are large enough to sustain an industry comprised of a number of producers at the multimegawatt stage.

After looking into the markets we also found that the estimates of the size of those markets differed tremendously between different contractors who worked on analyzing those markets. So the range of the size of those markets is highly uncertain.

We looked behind what caused those uncertainties, and it is basically that there has not been enough investigation to date to give any

validity to either the existence or nonexistence of those markets. The information we do have does agree that those markets would be international rather than domestic. Domestic intermediate markets would probably be relatively small, and the large markets would be international until the U.S. grid can be penetrated.

Senator MATSUNAGA. You did consider the LDC markets.

Mr. COSTELLO. Yes; we did.

Senator MATSUNAGA. What was your finding, to what extent will this stimulate the market at all, or the production? Will the demand be sufficient in the LDC markets to call for greater production?

Mr. COSTELLO. To preface that, I would like to say that our analysis looked only at a single market pull strategy lasting 8 years, and totaling $380 million, as Dr. Willis said.

The focus of our study was to see how that market pull strategy would affect those markets. We found it would not have a major impact on those markets. It would have a small impact on reducing the price to the end user in those markets and increasing the demand for those markets. However, the increased demand would not be large enough to justify the cost of the program.

Another conclusion we reached was that there is very little available information on international markets, we have hardly any information, so the size of those is highly uncertain. We have to first decide or find out how large those markets are, and then how can U.S. companies penetrate them. There will be competition from foreign suppliers in those markets.

Senator MATSUNAGA. Has there not been a change in recent months, even since the report was issued, among the bigger producers of photovoltaic sells? At one time they saw no economic marketing, but today they see a future in it. They are beginning to take active interest in greater production.

Mr. COSTELLO. Yes; that's true. I think the market that looks most exciting at this point, internationally, is agricultural pumping, medium and low lift pumping. All our study can say about that is we don't have any definitive information.

Senator MATSUNAGA. Your analysis did not in any way conclude that the approach taken by the bill, S. 3392, is the wrong approach.

Mr. COSTELLO. That is correct. Our analysis looked at a single market pull strategy listing 8 years. As such, looking at that, we cannot conclude that the bill is either supported or not supported by our analysis. It is important to keep a few things in mind.

Senator MATSUNAGA. So you are not in any way opposing the bill on the basis of the analysis of your study.

Mr. COSTELLO. That's right. There are certain aspects that both oppose it and are in support of it.

The study cannot be used to support any specific photovoltaics spending level for the government. Second, the uncertainty of the intermediate markets adds uncertainty to the achievement of the bill's price and quantity goals. In support of the bill, the study concluded that the industry is looking for a long term Federal commitment to photovoltaics, the international markets are very important to the future of the industry, and research and development is important, but some field tests to gain information are also needed.

Senator MATSUNAGA. Thank you, very much.

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Dr. WILLIS. In fact, Mr. Chairman, I think it is inconclusive, and I would like it to be far more definitive.

Senator MATSUNAGA. Dr. Willis, on page 3 of your prepared statement, you spoke of further expansion in fiscal year 1980. But you failed to state any specific amount whereas in previous years you stated specific amounts of $6 million, $9 million, $35 million, ending in fiscal 1979. What is your projection for expansion in fiscal year 1980?

Dr. WILLIS. The omission of any number is intentional, Mr. Chairman, simply because that will be part of the President's budget for fiscal 1980 program. And I would not like to anticipate that at this time. As you know, we have a long way to go before it is finally promulgated in January, and I would not like to venture a number.

Senator MATSUNAGA. Inasmuch as in fiscal 1979 you proposed to increase from $9 million to $35 million, I suppose we can expect a greater amount if you intend to expand the program in fiscal year 1980.

Dr. WILLIS. It was the intent in including that to make the point that we would not be falling off a cliff in 1979 in fiscal terms, that we would be continuing to support it, aggressively. Including that phrase to support the contention I made that we are taking and are continuing aggressive action.

Senator MATSUNAGA. I am inclined to think that if we pass this bill, that it might help you in your aggressive approach to further development of photovoltaic cell.

Dr. WILLIS. Well, Mr. Chairman, should the bill pass, let me assure you we will make every effort to make a virtue out of the requirement to implement it.

Senator MATSUNAGA. You do not oppose the passage of this bill.

Dr. WILLIS. We cannot support a bill in which we feel that a portion, not the whole bill, the portion which has the market pull program or the market pull initiative behind it, is a nonproven method of market stimulation.

Senator MATSUNAGA. Of course you do state that you will be studying other alternatives.

Dr. WILLIS. That is true.

Senator MATSUNAGA. How long will that study take?

Dr. WILLIS. We would hope to have these completed before the fiscal year 1980 budget is announced.

Senator MATSUNAGA. By the end of when?

Dr. WILLIS. Before the fiscal year 1980 budget comes to fruition.

Senator MATSUNAGA. Senator Domenici.

Senator DOMENICI. I have a few questions. Dr. Willis, I had some information that before ERDA's demise, a general advisory committee, pretty high powered, and Hirsch was still there, did an in-depth analysis of this very subject. Are you familiar with that, is it around? I understand it was a very in-depth study, and took a lot of high-powered people.

Dr. WILLIS. Dr. Marvin is more familiar with that study than I am.

Dr. MARVIN. I think you referred to the committee they set to look at solar as a whole, is that correct, Senator?

Senator DOMENICI. Within which photovoltaics were also studied, yes. What happened to that study, where is it?

Dr. MARVIN. It has been published. That committee was carried over as DOE began under a different heading, just to allow it to put its report together.

Senator DOMENICI. Is it available?

Dr. WILLIS. Senator, it is available, and we will make sure that it is available to you.

Senator DOMENICI. We would like to have it. I'm not questioning anything you are saying here, and I understand perfectly well what you are saying. Dr. Willis. If I understand correctly, your concern is that we might be in this bill freezing in the criteria for the private sector at a point in time when you are worried about two things, that we might be providing the kind of photovoltaic that does not have a broad enough use, and that additional array research may indeed find two things, a larger market and a lower price. Is that correct?

Dr. WILLIS. The larger market would flow from the lower price. At the present time, the market is going to be very, very inhibited until you get down to that lower range, below that intermediate market. It was the size of the intermediate market that I referred to in my testimony, which is both uncertain and probably too small to stimulate the effect of the buy that was contemplated.

Senator DOMENICI. What prevents the private sector in the United States involving itself even more so in the research than they are, instead of going to the next point of manufacturing and buying?

Dr. WILLIS. I think in truth they are being involved. As I mentioned in my testimony, we had 49 R. & D. contractors in the photovoltaic research area. That must, in all conscience, represent the bulk of the more purposeful firms and businesses.

Senator DOMENICI. I understand that, but what generally has happened in American enterprise, when you have generations of technology, you usually find the marketplace going itself through its own internal R. & D. and market analysis, going from one technology to an improvement there, into an even more refinement thereof. And they are involved themselves.

Basically what we have committed ourselves to is for the Government to be involved, which I have supported in the basic research. We have one mandated cost buy, as you know, $98 million over 3 years. But I don't understand, if this is something that is going to work and has great potential, why isn't the normal sequence of technology updating happening in the marketplace?

Dr. WILLIS. Because the producers cannot see the market and their return on investment, and they are rather reluctant, not only to put dollars down but most certainly R. & D. dollars. That's why the Government has to step in and take the high pay off activity in the R. & D. area, particularly with new materials.

I mentioned an amorphous silicon concept, such as sprayed-on nylon, that Congressman McCormack alluded to. If we were to derive the technology to the point where we could make a cheap product, then the market would become an attractive one. You have something to expand into. At the moment you have a limited market to expand into, and that is not conducive to the investment in the private sector.

One company, an eminent one, made the point that normal business requires that it show something like a 15 percent return on investment.

This company has analyzed the situation and has not found it in this particular circumstance.

Senator DOMENICI. Let me just ask my last question. What you are really concerned about is the rigidity in the bill, not in its goals, not in its objectives.

Dr. WILLIS. Not in its objectives, no.

Senator DOMENICI. You might change the relationship of R. & D. money to purchase money, and you might create more flexibility in the establishment of the standards and the like that are provided in this bill. Do I understand you correctly?

Dr. WILLIS. I would like to subject any initiative in cost reduction to the same kind of analysis that we did in the venture analysis with SERI.

Senator DOMENICI. Let me just tell you my own personal views as to why this kind of bill finds support. We find ourselves here, especially on the Energy Committee, constantly funding almost in a shotgun manner huge research projects and alternative sources of energy.

It appears that there is no end to that, and little comes out on the market shelf, all for use by the American consumer. The frustration that comes from that leads to us saying, well, we will just say "do it." If I understand you correctly, you are saying you are concerned that we are going to tell you to do something that is not going to end up proving marketwise feasible after you've done it.

Dr. WILLIS. I think that is a very correct statement, and I think that is precisely what this venture analysis showed, that the return on investment for the taxpayer's dollar is not there.

Senator MATSUNAGA. Thank you very much, Senator Domenici, and thank you, Dr. Willis. Thank you all for taking time out to help us out.

Dr. WILLIS. Thank you for your courtesy.

Senator MATSUNAGA. Our next witness is Mr. William C. Hittinger, executive vice president, research and engineering, RCA Corp., Princeton, N.J. Mr. Hittinger.

STATEMENT OF WILLIAM C. HITTINGER, EXECUTIVE VICE PRESIDENT, RESEARCH AND ENGINEERING, RCA CORP., PRINCETON, N.J.; ACCOMPANIED BY DR. ROBERT WEINBERG, DIRECTOR, SOLAR ELECTRIC BUSINESS DEVELOPMENT; AND DR. BROWN WILLIAMS, DIRECTOR, ENERGY RESEARCH LABORATORY

Mr. HITTINGER. Thank you very much, Mr. Chairman, members of the committee. We at RCA welcome the invitation to testify on S. 3392, and we sincerely hope that our participation will be useful to you. I would like to introduce also two other members of our staff. On my left, Mr. Robert Weinberg, who is director of solar electric business development for RCA. On my right, Dr. Brown Williams, who is director of energy research laboratory of our central research organization.

I might mention that Dr. Williams did testify in May in connection with the House bill on the same subject. I would like to begin by making the following very broad points.

First, we believe there is a real need to develop alternative methods beyond those already in use for generating energy.

Second, we believe that photovoltaic technology offers the potential of providing one such alternative.

Third, we believe it is not yet clear which of the competing photovoltaic technologies will prove to be most cost effective, and we therefore recommend that research and technology development spending aimed at identifying the optimum technology predominate during the first 5 years covering this act or until such time as low-cost technologies are identified.

Fourth, we believe that the risks of successful, widespread, commercialization of photovoltaic technologies are sufficiently high that it is necessary for the Government to commit substantial, long-range support, to bring the business risk within reasonable limits. For this reason we support the enactment of this proposed legislation.

Fifth, once the optimum technology or technologies have been identified we believe that funding should emphasize demonstration programs which will assist industry to put the required facilitation in place so that volume and cost objectives may be met. Beyond these general comments, it should be recognized that the path to large-scale commercilization of photovoltaic energy devices will not be easy and will require dealing with a number of impediments currently lying in that path.

Among these I would begin by mentioning the uncertainty of technologies. There are currently two major technological options for photovoltaics: flat panel devices and concentrators. Further, there are numerous material candidates within each major technological option. Examples are single crystal silicon and GaAs, which have been known and used for recent years.

More recently, polycrystalline silicon and GaAs thin flms, ribbon and cast sheet silicon, amorphous Si thin films and thin films of Cds-CU_2S. RCA is investigating both major options and several of the material candidates. We believe it is not yet clear which technology will achieve the objectives of this act, and may not be clear until the 1983–84 time frame. The risk is in selecting one in which to invest major production facilities.

A second uncertainty has to do with markets. While it is clear that alternate sources of energy are required, it is not clear which applications are most amenable to photovoltaic systems use, where those markets are, how those markets might best be approached and what costs may be acceptable for specialized application. A great deal more must be known about the commerical market.

Three, there are institutional impediments. The time required to surmount institutional barriers for photovoltaic applications is likely to be long. It is likely, for example, that utilities will require extensive time-consuming qualification test programs before adopting any specific technology.

Fourth, there will be a need for auxiliary equipment. For large scale use it will be necessary to develop economic auxiliary equipment required to convert the low voltage nonconstant direct current energy provided by photovoltaic cells to the form required by the application. Examples of actions needed may be the development of a more complete complement of equipment powered by direct current and/or the development of cost effective inverters of direct current to the more widely used alternating current.

Five, there is a risk of premature standards. If product certification requirements or performance criteria are applied prematurely we may encourage the development of technologies which, while more fully develped at that time, may not bear the longer term potential of lesser developed technologies. In so doing we may seriously jeopardize the long-term position of the less mature but potentially better long-term solution.

Six, there is the issue of uncertain return. All of the above uncertainties present a degree of risk which represents more than is usual for private investment.

We do believe there are government actions which can help minimize these impediments.

Regarding uncertain technologies, we urge that the Senate recommend that research and technology development spending predominate in the first 5 years in order to allow time for the optimum technologies to be identified and developed.

Regarding uncertain markets, the Secretary of Energy should be asked to generate and disseminate detailed industry marketing information. Since a major portion of the interim photovoltaic market may be exports to lesser developed countries, the Secretary should be asked to include both domestic and non-U.S. marketing information.

On the risk of premature standards, the Secretary of Energy should be given the option to defer setting standards if he believes it is in the best interest of the act. Funding and its allocation should relate to the performance achieved and not be tied to the calendar.

Concerning other impediments, demonstration projects will be necessary and useful to achieving the objectives of the act. During the first 5 years while the emphasis is on identifying and developing the optimum technologies, demonstrations will provide for these advantages:

They will help to make the public aware of the need for and of the potential of photovoltaic devices. They will provide a vehicle to evaluate the performance of devices under real application conditions. They will provide support for the development of the auxiliary equipment which will be required regardless of the photovoltaic technology chosen. They will provide valuable marketing and application experience.

On the matter of uncertain return, the Secretary should be encouraged to explore the effect that incentives may be likely to have in the development of the industry. An understanding of the quantitative effects of investment tax credits for manufacturers and of tax rebates for users should be developed.

Once the optimum technologies have been identified, demonstration projects will be essential in helping to provide an assured market. This will reduce the risk of facilitating for the large production capacity aimed for in this act and help stimulate private investment. Without this long-term commitment of Government assistance a significant photovoltaic industry may not develop before the year 2000.

In this regard I am struck by the similarity of this issue with the issue of promoting silicon transistors back in the early and middle 1950's when there was an interest in the technology, but a great puzzlement over how to achieve results. The Department of Defense in particular played a very important role in stimulating that industry

in helping to create a market that led to the takeoff in transistor technology in the late 1950's and beyond.

In summary, we recommend that the bill be passed and we suggest emphasis that would further encourage the development of a commercial photovoltaic capability.

In the category of technology risk, initially emphasize research and technology development with the emphasis shifting to demonstration projects when low-cost technologies are developed.

Provide flexibility in the adoption of standards or the enforcement of product certification requirements. Give the secretary the option of deferring implementation of such standards if it becomes obvious that a rigid time schedule would stifle developments.

To reduce marketing risks, generate and disseminate domestic and foreign marketing information.

Recognize institutional barriers in setting demonstration priorities.

Last, recognize investment risk by considering tax credits applicable to both producers and buyers.

We thank you very much for your consideration.

Senator MATSUNAGA. Thank you very much, Mr. Hittinger. I appreciate your support of this measure. I think one of the best ways, if not the best way, of making rapid and real progress is through cooperation between development—between the Government and private enterprise. We do hope that development and marketing of solar photovoltaic cells will prove in time a prime example of the proof of the pudding. Thank you very much.

Mr. HITTINGER. You are welcome.

Senator MATSUNAGA. Our next witness is Mr. Peter Zambas, general manager of Arco Solar, Inc., from Chatsworth, Calif., a neighbor. We would be happy to hear from you, Mr. Zambas.

STATEMENT OF PETER ZAMBAS, VICE PRESIDENT AND GENERAL MANAGER, ARCO SOLAR, INC., CHATSWORTH, CALIF.

Mr. ZAMBAS. Mr. Chairman, I am Peter Zambas, vice president and general manager for ARCO Solar, Inc. I would like to thank the committee for this opportunity to speak in favor of the Solar Photovoltaic Energy Research, Development and Demonstration Act of 1978. We feel the proposed expenditures of $1.5 billion will result in a more rapid achievement of the national photovoltaic program goal of 50 cents per peak watt by opening up new markets for photovoltaic utilization and by fostering rapid commercial expansion.

I have submitted a statement for the record and I will read a summary of it now. Then I will be happy to answer any questions about the background or current activities of our company. My statement will focus on how we feel the U.S. Government, through this legislation, might stimulate the worldwide use of photovoltaics and, thereby, aid the industry.

We at ARCO Solar feel it is technically possible to reduce the panel price per peak watt to $1. We also feel that by the time we reach that $1/watt price, we will see our way clear to further reduction of the price to 50 cents per peak watt. What we and the industry need to accomplish this are firm purchase orders.

Over the past several years the U.S. Government through its large-scale procurement program, has spurred the industry to reduce the price of photovoltaics from $50 a peak watt to $10 per peak watt. We feel that a continuation of these large scale purchases can further reduce the price of photovoltaics.

The international market is one place where these purchased systems can be put to beneficial use. It is difficult to sell photovoltaics in the foreign market, and especially to the developing countries because they often do not recognize the need or know the alternatives available to raise their standards of living through electricity.

The U.S. Government could act as a broker between the photovoltaic industry and the foreign market by buying and placing in service demonstration projects. Such projects would prove that photovoltaics are a viable energy source for the developing countries.

The use of energy in foreign policy is not new. Photovoltaics could be the alternative that provides developing countries with power. At the same time it would not orient those developing countries toward the fossil fuels on which we currently depend so heavily. Therefore, photovoltaics may become a tactical as well as a strategic device in foreign policy.

I will give you one example of what photovoltaics can do in the foreign marketplace, particularly the less developed countries who are also the recipients of a major portion of our foreign aid. Our predecessor company, Solar Technology International, in conjunction with HEW's public health service, developed a modular unit system which contained one 20-watt panel, a battery, a light and a water pump.

One of these units was given to an Indian family, and it worked beautifully. The family took pride in their source of power. It was safe, easy to install, and, more importantly, easy to maintain. Maintenance was a problem when a centralized power system was installed for a similar community, because no one person took the responsibility to oversee and maintain the system.

The village market is one promising component of the larger international market. Through the development of the large international market, we can increase our sales and, thereby, streamline our processes, and bring the cost of photovoltaics down to where we can make a significant impact on the long-term energy picture in the United States and the world.

We feel that the international market as the key market is helping the industry bridge the gap between the current selling prices and the target selling prices of 50 cents per peak watt. We believe that the applications of photovoltaics in the international market as a form of foreign aid will positively impact the balance of payments in the long term, will help other countries achieve energy independence, while at the same time it will relieve the pressure on the fossil fuels we rely on.

Returning to the question of price, we know that, at present pricing levels, the current market for photovoltaic devices is primarily in remote applications. When the price is reduced to the $2 to $5 per peak watt level, photovoltaics can be competitive with diesel generation. Eventually, the price must come down to the 50 cents per peak watt level so that photovoltaics can compete with and replace central station electric generation.

We believe that these goals can be achieved through the automation of our production processes and the reduction of the cost of raw materials. We feel that automation is a technical development which will evolve as the need for greater production capacity becomes necessary. Such need will only develop as more orders are placed for the delivery of photovoltaic products.

Reducing the cost of materials is another matter. Many of our production processes today are a spinoff from other industries. We are now attempting to modify them to better fit our requirements. The use of highly purified silicon as a raw material is an example of the current difficulties arising from the spinoff nature of our industry.

We do not need such a high grade silicon. But none other is available. The Federal Government has funded research, development, and pilot activity for the production of low cost silicon. We believe that further and more concentrated activity in this area will not only be beneficial but will be crucial to the price reduction efforts of the Government and the industry.

Senate bill 3392 can be instrumental in furthering the national effort for increasing the use and decreasing the price of photovoltaic devices in many ways. This bill can be a vehicle for the initiation of a joint industry-Government effort to make the United States the leader in exporting solar photovoltaic products to the world.

Specifically, the bill can help in three ways: One, by making large-scale purchases of photovoltaic power modules, and systems for use in foreign aid as an adjunct to foreign policy. Two, by creating the proper incentives for the use of photovoltaics in developing countries. Three, by establishing a mechanism for the coordination of the activities of different departments within the Government.

The advantages of this approach for stimulating the use of photovoltaics worldwide will be threefold: One, we will be exporting a valuable commodity which will ultimately have a significant positive impact on the balance of payments. Two, we will be aiding developing countries by providing them energy from a renewable source. Three, we will be creating a strong photovoltaic industry with a significant domestic energy supply capacity which will have very positive strategic impact on the Nation's economy, self-sufficiency, and general well-being.

Incentives have been mentioned as an area in which this bill could assist. We feel that the proper incentives should be in the place for both the foreign and the domestic users to purchase photovoltaics.

Another key consideration to this legislation is to make sure that there is coordination between the efforts of all Government departments so that funds allocated for photovoltaics are put to optimum use for purchases and some research and development.

This bill could assist by establishing demonstration projects in different parts of the United States where the industry can monitor the power requirements and application problems in running a residential home, for example. This type of demonstration would set an example for the rest of the world on the use of advanced technology.

Finally, this bill could provide crucial assistance to the industry by funding pilot plants for the production of low cost silicon.

In conclusion, Arco Solar is pleased to have presented its views in support of the Senate bill 3392 today. We believe that this bill will stimulate a more rapid expansion of the solar photovoltaic industry if its provisions are properly implemented.

We believe that large scale purchase commitments are an effective complement to the Government's support of research and development activities. We believe that this bill provides the general framework for the implementation of a number of the programs that we mentioned earlier. Proper allocation of the funds called for will result in significant furtherance of the national photovoltaic goals. We strongly urge passage of this bill.

Mr. Chairman, we have offered these suggestions in the hope that they will strengthen the bill and the photovoltaic program. This concludes my prepared remarks and now I will be happy to answer any questions from you or the members of your committee.

Senator DURKIN [presiding]. Mr. Zambas, I do not mean this to be a hostile question at all, but why should the Federal Government help a corporation the size of ARCO?

Mr. ZAMBAS. Senator Durkin in the first place I would like to make one thing clear. I am testifying today on the views of ARCO Solar, as they pertain to the industry, as a whole. We recognize that the industry is composed of a number of producers and other research organizations, some of which are large and some of which are small. We are really trying to put forth the best thoughts that will produce a viable industry.

In some cases individual support may be required for small businesses. Where it is not required it will not be sought by large entities. But going to the larger question of support by the Government to the industry, it is, I think, to be expected that the industry will develop. But the goals set by the Government and, of course, by extension by the industry could be met on an accelerated schedule through the use of the funds stipulated in this bill.

If I might explain for a minute, it was mentioned before that the current market for photovoltaics is in the order of 1 to 2 megawatts a year. This is at current pricing levels of $10 to $15 a watt, depending on quantity. It is our firm belief that if the price per watt can be brought down to the $4- to $6-a-watt level, then photovoltaics will be competitive in a vastly larger market, which is the replacement of diesel generation units.

That market, we view in the order of 200 megawatts a year. Of course when the price goes down to $1 per peak watt, then we are looking at a market in the thousands of megawatts per year for central power stations. What the industry needs now is stopgap help from the Government, which will help industry reduce its costs from the $10 to $5 range.

We see the international market as being the first market that can provide the stopgap assistance. Anyplace in the world, especially the United States where there is a national power grid, photovoltaics cannot compete. Power out of the outlet in the wall is extremely cheap.

But there are vast areas in this world where there are no grids and where people depend on kerosene and batteries which they have to manually take to a central facility to recharge every week for elemen-

tary facilities such as one light or one pump, or a radio to communicate with the outside world.

These are areas where we feel the present proposed bill can assist by way of providing photovoltaics to these peoples in the less developed countries, and thus creating a market.

Senator DURKIN. Well, as I said, I want to make sure that the question was not taken as a hostile question because I am a cosponsor of the legislation we are discussing this morning. It is my understanding that—we have had testimony here that photovoltaics could produce electricity as economically as 10 cents a watt. Do you think that is realistic?

Mr. ZAMBAS. I think it is realistic; yes. The 10 cents per watt corresponds to the dollar per peak watt installed cost.

Senator DURKIN. The Department of Energy authorization bill has two programs. One is to buy up silicon cells and photovoltaic units in an effort to bring down the cost. In another we are able to add $20 million to provide loan guarantees for funding for a couple of pilot plants for mass producing the cells. Which, in your estimation, is the preferable route to go, or should we continue to pursue both routes?

Mr. ZAMBAS. I think we should pursue both routes. I think either route can be more applicable, more desirable, depending on the circumstances. As I mentioned before in our own particular case, we would not seek a loan or support, we would seek fixed-price orders.

But I know there are other producers who might benefit from the use of Government loans.

Senator DURKIN. I gather you are looking more for certainty in the marketplace than certainly in well defined, governmental program or posture or position, rather than dollars per se.

Mr. ZAMBAS. That is correct.

Senator DURKIN. If the DOE authorization ever gets out from the maze it is in, in both Houses now, and we get the appropriation for the loan guarantees for two pilot plants, is ARCO interested in the pilot plant to mass produce the cells?

Mr. ZAMBAS. Let me answer this question in this fashion. We are in the process of developing layouts and budgets for new plants ourselves. We would probably do it regardless of the actions of DOE. I feel that a large corporation such as ours can probably stand on its own without having to obtain a loan.

What we would have to have, I think, is a much higher certainty in the existence of the market than we have today. May I expand for a moment?

Senator DURKIN. Sure, that is why we are here.

Mr. ZAMBAS. The way that I see it is that an embryonic business can grow in basically two fashions. One is by a push-pull type of approach, expanding gradually, slowly, year by year, as the market develops, adding additional plant capacity to meet the new market and a little bit more.

That would result in a slightly lower cost per unit. This can take many, many years.

On the other hand there is the approach of looking at the development of a not-so-instant but much more accelerated market so that a manufacturer or any member of industry can invest capital with a

certain certainty of sales. This is what we are looking at. We see that the goals of the Department of Energy can be met at a certain time frame, but with the use of this bill we can accelerate the meeting of these goals, we feel.

The emphasis should be placed more on the international market than the domestic market because it is the one that is closest to the present time.

Senator DURKIN. That is my next question. I understand the Japanese and Germans are subsidizing their photovoltaic industry. How can you compete in the world market without some governmental consideration when you are faced with that competition, subsidized competition?

Mr. ZAMBAS. Well, this is a very good point. You are absolutely correct, the Germans and Japanese are both subsidizing and I would venture to say that the French are also subsidizing, although not as prominently as the Germans and Japanese.

It was an interesting experience 6 months ago. There was an exhibit in the Arabian Gulf. There were 5 or 6 U.S. companies represented and 12 French companies represented. Each one of the American companies had, of course, paid their own way. All 12 of the French companies arrived there at the expense of the French Government. That is a form of subsidy also.

Senator DURKIN. Who were the six American companies, if you will?

Mr. ZAMBAS. I can't recollect them immediately, but there was Solar Power, we were there, Solarex. That's about it, there were three companies. To come back to your question, however, I feel that we in the United States have better technology and we have the capability of reducing the costs much faster than they can in Europe and Japan. If that is an example at all, we finished delivery of the first consignment on the biggest commercial order of photovoltaic units to the Government—not to the Government, to the Federal communications authority of Papua, New Guinea, and that was an international competition, of course.

We were able to deliver at a lower price than our European competitiors.

Senator DURKIN. At one time we had better technology in radios and TV's, too. We still have the technology but we do not have the market.

Mr. ZAMBAS. That is true.

Senator DURKIN. I was not here for Dr. Willis' testimony and I apologize.

I realize that he is with the Department of Energy and might be a little reluctant to testify. Would you be willing to comment on his testimony that the cost reduction of solar cells will not be enough to make them competitive by virtue of the program outlined in the bill.

Mr. ZAMBAS. Well, I was a little disappointed in Dr. Willis' testimony. I feel that the silicon cells, as we know them today, can be produced much cheaper than they are being produced today. As I mentioned in my testimony, there are primarily two ways that we can reduce the cost down to a certain level, maybe 75 cents per peak watt, maybe $1, maybe 50 cents, that I cannot be sure of, and that is by mechanization, automation, and reduction of the raw materials cost.

We are well into the process of going into that direction. The only way we can automate and mechanize the process is by selling more, producing more, increasing our capacity. This is where the bill can become very helpful.

Senator DURKIN. By increasing your capacity, you are also going to have to increase ability to mass produce those cells. The cost is in the structure of the cell, under today's conditions as opposed to an assembly line stamping process.

Mr. ZAMBAS. That is true, but the idea is to produce more because then we can afford to invest in more complicated, sophisticated pieces of equipment. At the present time it is impossible for me, for example, to go to my executive committee and say I am producing at the rate of—I will just pick a number, 10 watts a day. It is impossible for me to go to them and say, I want to build a factory that will produce 10,000 watts a day.

On the other hand, if I have a certain guarantee of the market, then I can prove——

Senator DURKIN. They are not going to let you build them and just store them. Is Mr. Hittinger still here? I understand that RCA testified that uncertainty in the marketplace was an impediment. But then I also understand that you recently made a business decision to market photovoltaic concentrating systems.

Given the uncertainties, why have you made that business decision to go ahead?

Mr. HITTINGER. Senator Durkin, the business decision we made was to create an exploratory business group, really, to explore, study, experiment, test products for the marketplace. This, for the moment, at least falls short of saying we are marketing product today. We have been a producer of solar cells, we have been working the technology for many years.

At one time we actually produced commercial cells, back in the 1950's, as I recall, but withdrew from the market when it really did not develop. Our belief now is that photovoltaic technology will come, it will be important, it will generate electricity in many applications throughout the world.

Senator DURKIN. How about New England? I am kind of partial to New England and we are hooked. When oil was $1.25 a barrel, they would not let us buy it. Now that it is $14 they sell us more than we can afford. What about New England?

Mr. HITTINGER. Oh, yes, we are an American producer and our markets are predominantly in the States. I expect our market for photocells will be primarily in the States. At the same time I expect the entry cost, entry pricing will be more favorable in areas of the world where a large grid has not been developed, where electricity is not available, and where prices that realistically affect cost will not rule out applications as they will at the moment.

For example, when you are competing against an installed grid and installed electric utility. But the questions can be brought down to two following ones for us. One is a question of timing and the second is a question of risk. There is no question in my mind that photovoltaic technology will come.

If it is not accelerated through many means, including Government support, industry support, and the like, I believe that the timing will

be lengthened, it will be a long time out. Against that I think we can accelerate that timing by doing what this bill proposes.

The other issue is one of risk, and we have addressed that through various sources this morning. Any company that is in business has many opportunities for investing its funds, and the issue, of course, is where can you get the best return. The photovoltaic situation today is one of high risk for a variety of uncertainties that have been elaborated. Again, this is where this bill will be a very great help, we believe, to industry at large in the United States.

Senator DURKIN. Do either of you think there is anything in this bill that would impede the acceleration of the development of the cells?

Mr. HITTINGER. Well, I listed certain concerns in a constructive way, things to be aware of, such as freezing specifications too early, or doing too much demonstrating before the technology has been chosen. But I think these are details. I think the thrust of this bill is highly constructive. I think it can help greatly to accelerate the timing and reduce the risk to a reasonable level.

Mr. ZAMBAS. I basically agree with Mr. Hittinger with one caveat. I believe that funds should be properly allocated between research, development, and demonstration. But also with actual purchases. I agree that the technology may not be the best, as yet. There will be improvements in the future. But we need to support and strengthen the industry and production now, so that we can get to the next base, so to speak, and that can be achieved through purchases.

Senator DURKIN. Senator Hart was able to include in the military construction bill a requirement for strong consideration of solar. I was able to get an amendment adopted in one of the HUD housing bills so that HUD would have to consider solar utilization, with respect to low cost housing. HUD is opposed to it, and they will have to report back to the Congress why they would not go that route.

Is there any market for this program with respect to military housing, military installation, HUD housing, HUD developments and units? Do you think that might present a demonstration market and might present also provide part of the market you need to stabilize the price and bring some certainty?

Mr. ZAMBAS. In some situations, yes. It has been said that today anything over a mile away from a grid point and less than 3,000 watts could be cost effective. Any installation that would fall in this category could become cost effective. Of course, it all depends on where it is. Obviously an installation in Minnesota would have less of a chance than an installation in Texas, from a climate point of view.

Senator DURKIN. In a lot of areas of the country we have semirural areas. They are on the grid, of course, but have you given any consideration to a combination of like low head hydro to provide some of the power plus photovoltaic assistance, photovoltaic backups so it can be packaged in some of the rural areas that have water and sunlight.

Mr. ZAMBAS. Yes. In fact, in the southern tier of the United States there are more than 20,000 dams of varying sizes, all of which are facing south. Now a very good approach would be, for example, to cover every southern exposed dam with photovoltaics.

Senator DURKIN. And retrofit them with a new efficient turbine.

Mr. ZAMBAS. Of course.

Senator DURKIN. Very good. We can use that testimony, thank you.
[The prepared statement of Mr. Zambas follows:]

STATEMENT OF PETER G. ZAMBAS, VICE PRESIDENT AND GENERAL MANAGER OF ARCO SOLAR, INC., CHATSWORTH, CALIF.

I am Peter Zambas, Vice President and General Manager of ARCO Solar, Inc., a wholly owned subsidiary of the Atlantic Richfield Company. I would like to thank the committee for its kind invitation to testify today and discuss some of the problems we, as a manufacturer and marketer of photovoltaic power systems, face and the opportunity that this bill represents to aid our developing industry.

We believe the Federal Government has a critical role to play in fostering the development of the solar photovoltaic industry by helping us to bridge the gap of the current selling price of $10 peak watt and the target selling price 50 cents peak watt. A Federal role is critical—not only because the industry is in its infancy today and the investment risks associated with the industry are extremely high, but also because of the important role that this industry will play in solving some of this country's future energy problems.

We are extremely pleased with the proposed legislation. The Solar Photovoltaic Energy Research, Development, and Demonstration Act (S. 3392), and we strongly support it. For the embryonic, high-risk photovoltaic industry, this legislation should reduce the risk of making the transition to maturity. I have no doubt that the proposed expenditures of $1.5 billion will result in a more rapid achievement of the National Photovoltaic Program goal of 50¢ per peak watt by opening up new markets for photovoltaic utilization and by fostering rapid commercial expansion.

In my testimony today I will touch upon the background of ARCO Solar and some of the underlying reasons why ARCO is involved in the photovoltaic industry. I will describe some of our basic products and installations, and finally I will express our views on this proposed legislation (S. 3392) and how we feel the U.S. Government might stimulate the worldwide use of photovoltaics, and thereby, aid the solar industry.

BACKGROUND

Because of a growing awareness of the depletion of its oil reserves, Atlantic Richfield wanted to diversify into other areas related to the production and distribution of energy. The Company began investigating the solar market in 1972, before the oil embargo, because it recognized the importance of solar energy as a nondepletable and renewable source of energy.

Our investigations culminated in the acquisition of a minority interest in a leading manufacturer of solar heating and cooling devices and in our acquiring the assets of Solar Technology International, a manufacturer of photovoltaic power modules. Our agreement with Solar Technology International was consummated on September 30, 1977, and the name of the Company became ARCO Solar, Inc.

Since last September ARCO Solar has grown dramatically. We are now in a new facility that is approximately six times as large as the initial one. This facility houses one of the industry's most highly automated, low-cost solar cell production lines. During this same period, our staff has grown by a factor of ten, from seven to over seventy.

ARCO SOLAR TODAY

Obviously, we are very excited about the future of the photovoltaic industry. It is evolving quickly and ARCO Solar's growth has been equally dynamic. ARCO Solar's primary production and development efforts are in flat plate solar photovoltaic collectors, nontracking devices which convert the sun's energy directly into electricity. Our standard products range in size and output from less than five watts to greater than 35 watts per panel.

Our basic panel produces 20 watts of electricity and is used in systems in conjunction with regulators, batteries, and other electronic equipment which provide control and storage. These power systems are used in the telecommunications, cathodic protection, navigational aids, and other applications used in remote areas. They are typical of what ARCO Solar sees as the current photovoltaics market—remote power systems comprised of expensive and valuable equipment that do not require large amounts of electrical power.

While our current emphasis is in flat plate photovoltaic collectors, we are de-

veloping concentrators and conducting research on other methods of converting sunlight into electricity.

Concentrator systems make use of lower cost materials to enhance the output of each expensive silicon cell by concentrating the sun's rays. One concept for the concentrator system is based on the utilization of a Fresnel concentrating lens. Such a system was proposed jointly by ARCO Solar, Northrup, and Kaman Sciences Corporation in response to a Sandia Laboratories Photovoltaic Concentrator Program Research and Development Announcement for the Department of Energy. Our proposal was one of those selected. We are also investigating more advanced concentrator components and systems in our test facility on the roof of our plant in Chatsworth, California. We intend to pursue research efforts in other promising areas leading to the development of low-cost solar energy systems.

I would like to give you some examples of ARCO Solar installations around the world.

We have just completed the initial installation of a system to power communication repeater stations in Papua, New Guinea. Each one of these 35 repeater stations will be powered by one kilowatt ARCO Solar array which will provide the sole source of power for this, the backbone of the Papua, New Guinea communications systems.

In Arizona, in the Navajo Nation, we have installed a two kw water pumping system which provides water to over fifty Navajo families. This system demonstrates how photovoltaics can enhance the quality of life in remote areas. We believe this system represents a prototype of what can be applied in villages in other remote areas throughout the United States and the developing world.

We are also a manufacturer of a highly durable military field panel for Southcom International. This panel is used to power field communication devices such as two-way radios. We have developed the next generation of this module. It is a 25 watt, four bay, folding module which also uses the high density cell packing arrangement. This module is currently being tested by the Jet Propolusion Laboratory. These examples are characteristic of the products and applications we see today in remote areas in the price range of $9 to $13 per peak watt, which are competitive with alternate forms of power for those locations. We term applications such as these in the current market as being in the first stage market.

Perhaps the next stage in the photovoltaic market will be to supply power for villages, communities, and residences in areas of the world that do not have a centralized power base. An example of an application appropriate for this market was developed by ARCO Solar's predecessor company, in conjunction with the Bureau of Indian Affairs. A small individual modular kit including one 20 watt solar panel, one battery, a water pump, and a light was given to each home in the community. We found that the individual units were easier to maintain, simpler to operate, and safer than a centralized system. One problem associated with a centralized power system in a developing area is that of maintenance of the system. By providing each individual home with its own power system, this problem was avoided. We are currently exploring the market for this application in other village situations throughout the world.

The final target market which all of our work is leading towards is, of course, the utility or centralized power market at a competitive cost range of 25 cents to 50 cents per peak watt. The question then is what intermediate term market will help us bridge the gap between the current and the target markets. It is our belief that the proposed legislation can assist the industry in bridging that gap.

PROSPECTS FOR THE FUTURE

Today ARCO Solar sees how it is technically possible to reduce the panel price per peak watt to $1. We feel that by the time we reach that $1 per watt price we will see how to reduce the price to 50 cents per peak watt. What we need and what we feel the industry needs are firm purchase orders. Orders so that we can develop our processes and orders so that photovoltaics are applied throughout the world. We need to find the right combination of buyers to bridge the gap and give us that vision to 50 cents per watt.

How do we see the way to reduce the price to $1 per watt? Mainly through automation and the reduction in material costs. Our research and development efforts are aimed at streamlining our production and increasing the efficiency of our products to reduce the cost per watt. We feel price reduction can be accomplished in an evolutionary way by automating our current silicon cell,

module, and array production processes and by developing low-cost materials and components. We believe this automation is a technical development item which will evolve with the need for greater capacity.

The Jet Propulsion Laboratory has been an important factor in the development of the industry. We will continue to work with JPL on their cost reduction and technology development programs for photovoltaics.

To fill the gap between the current selling price and the desired selling price level, we, as an industry, are looking for an intermediate market. I mentioned earlier that one possible candidate is the village market, which is a part of the international market. The international market is currently larger than the United States market, and through the development of this market we can increase our sales and, thereby, streamline our processes and bring the cost of photovoltaics down to where we can make a significant impact on the long-term energy picture in the United States and the world. This brings me to the main point of my testimony today.

There is a great potential that, as a result of this bill, a joint industry/government effort will be initiated to make the United States the leader in exporting solar photovoltaic products to the international market.

We feel that this bill and the United States Government can help the industry penetrate the international market by:

1. Making large-scale purchases of photovoltaic power modules and systems for use in foreign aid as an adjunct to foreign policy.
2. Creating the proper incentives for the use of photovoltaics in developing countries.
3. Establishing a mechanism to coordinate the activities of the different departments within the government.

The advantages of following this approach of stimulating the use of photovoltaics worldwide will be threefold:

1. We will be exporting a valuable commodity which will ultimately have a significant, positive impact on the balance of payments.
2. We will be aiding developing countries by providing to them energy from a renewable source.
3. The growth of the photovoltaic industry will result in a significant domestic energy supply capability with positive strategic implications.

Over the past several years, the United States Government, through the large-scale procurement program, has lead the industry to reduce the price of photovoltaics fom $50 per peak watt to $10 per peak watt. We feel that a continuation of these large-scale purchases can further reduce the price of photovoltaics. The international market is one place where these purchased systems can be put into beneficial use. It does neither the industry nor the Government any good to purchase modules to place in warehouses; they must be put to use.

It is difficult to sell photovoltaics to the developing countries because they often do not recognize the need or know the alternatives available to raise their standards of living through electricity.

The United States Government could act as a broker between the photovoltaics industry and the foreign market by buying and placing in service demonstration projects. Such projects would prove that photovoltaics are a viable energy source for the developing countries.

The use of energy as an adjunct in foreign policy is not new. Photovoltaics could be the alternative that provides developing countries with power, and it would not orient the developing countries toward the fossil fuels on which we depend so heavily. Therefore, photovoltaics may become a tactical as well as a strategic device in foreign policy.

Incentives have been mentioned as an area in which this bill could assist. We feel that the proper incentives should be in place for both the foreign and the domestic users to purchase photovoltaics. Incentives can take many forms and we feel that the alternatives should be investigated and proper incentives put in place.

The Department of Energy, Department of Commerce, Department of State, United Nations, Solar Energy Research Institute, World Bank, and AID are all entities that could become involved in the export of photovoltaics. Therefore, we feel it is a key consideration with respect to this legislation to make sure that there is coordination between the efforts of each of these departments so the funds allocated for photovoltaics are most effectively used.

This legislation can also provide assistance in several other key areas.

Silicon will continue to be an important factor in the price of photovoltaic

power. We do not require semiconductor quality silicon and are continually searching for a reliable supply of low-cost silicon of the appropriate quality. We recommend that this bill be more specific in this regard and help the industry develop low-cost silicon.

Many of the production processes used in the photovoltaic industry today are spin-off processes from other industries. The bill could provide some assistance to the industry to invent and develop machines and equipment which will help us fully automate our procedures and, thereby, reduce the cost per watt.

The target market of the photovoltaic industry in the United States includes residential and commercial construction as well as the utilities. Therefore, we must learn how to run a residential home on photovoltaic power. This bill could assist by establishing some demonstration projects in different parts of the country where the industry can monitor the power requirements and application problems in running a residential home. This type of demonstration would set an example for the rest of the world on the use of advanced technology in the United States.

In conclusion, ARCO Solar is pleased to have presented its views in support of S. 3392 today. We believe that this bill will stimulate a more rapid expansion in a solar photovoltaic industry if its provisions are properly implemented. We believe that large-scale purchase commitments are an effective complement to the Government's support of research and development activities. We feel that the international market is the key market in helping the industry bridge the gap between the current selling prices and the target selling price of 50 cents per peak watt. We believe that the applications of the international market in foreign aid are varied and realistic. We believe that the value of using photovoltaics in foreign aid will positively impact the balance of payments in the long term, will help others achieve energy independence, while relieving the pressure on fossil fuels on which we rely, and will help the solar industry.

Mr. Chairman, we have offered these suggestions in the hopes that they will strengthen the bill and the photovoltaic program in the National interest. This concludes my prepared remarks and now I will be happy to answer any questions.

Senator DURKIN. Is Mr. Willis still here? He left. Is anyone representing him still here? He must be lobbying on the natural gas bill. [Laughter.]

We will get another shot at him some other day. I am a little concerned that once again the Department of Energy seems to oppose anything that does not involve liquid metal breeder reactors. I would for the record though like to submit questions to Dr. Willis. Is that solely his testimony? Was it cleared, with anyone further up in the Department of Energy, such as Dr. Schlesinger?

I for one am a little concerned that everything that promises to produce energy as an alternative to oil, whether it be hydro, whether it be solar, we find the Department of Energy throwing cold water on. I do not have any more questions of you gentlemen, and I would like to thank you very much for taking your time. I appreciate your testimony and hopefully we will put it to good use. Is Dr. Lindmayer here?

Dr. Lindmayer, your entire statement will be printed in the record. If you will identify yourself for the record, and your associate, and proceed in any way you find most comfortable, and most informative to the committee.

STATEMENT OF DR. JOSEPH LINDMAYER, PRESIDENT, SOLAREX CORP., ROCKVILLE, MD.; ACCOMPANIED BY ANTHONY CLIFFORD

Dr. LINDMAYER. Thank you very much, Mr. Chairman. I am president of one of the Nation's leading photovoltaic companies. The gentleman to the left of me is Mr. Anthony Clifford, who is my assistant. Mr. Chairman, I am happy to have this opportunity to testify con-

cerning such an important bill which, for the first time, makes a long-term commitment to photovoltaics.

It is a great satisfaction to see that in the past 5 years photovaltaics has become one of the most promising alternative energy sources for the future. However, it is this very rapid success that now invites continuous debate and assessment of the future of photovaltaics. So much so, that it now appears that we are living in an era of continual assessment and reassessment of photovaltaics.

While the intellectual exercise of assessing future directions could be very constructive, photovoltaics at the present may be characterized as a field that has been extensively overexamined. Rather than get involved in the details of domestic policy reviews, venture studies, commercialization studies, et cetera, I would like to offer a recent memo concerning the venture study that was written by Denis Hayes of Solar Action to Dr. Schlesinger of DOE.

Senator DURKIN. Fine; that will be included in the record, Doctor.

[The memo follows:]

SOLAR LOBBY,
Washington, D.C., July 28, 1978.

Re The DOE Photovoltaic Program in the Aftermath of the SERI Photovoltaic Venture Analysis of June, 1978.

To: James Schlesinger.
From: Denis Hayes.

The three-volume Photovoltaic Venture Analysis asks the wrong questions, and it answers them incorrectly. It does not ask whether federal procurement efforts can accelerate the introduction of commercially viable photovoltaics. Rather, it examines the costs and benefits (with benefits very narrowly defined) of one proposed "D.O.E. initiative"—an initiative, incidentally, that is much more modest than that envisioned in H.R. 12874. The Venture Analysis reaches pessimistic conclusions about this narrow issue, but the model it employs is based upon some very peculiar assumptions (which will be examined a few pages hence.)

The quality of the study, however, may be less important than its limited scope. Some senior D.O.E. officials are apparently distorting the narrow, qualified conclusions of the Venture Analysis into a negative appraisal of all possible D.O.E. procurement programs, and claiming that near-term federal photovoltaic programs should therefore be limited to research and development.

Even if the Venture Analysis had been correctly done—and I believe it wasn't—the study is too limited in scope to form the basis for broad policy decisions. The 3-year, $80 million J.P.L. study of the prospects for 50 cents silicon photovoltaics is still the definitive work on the broader issues—and its conclusions are glowing optimistic.

In recent days, several senior people in the Department have cited the SERI report to me as a rationale for reductions in federal photovoltaic purchases. When pressed, each of these officials admitted that he had not read the report, or even the summary, but had only heard oral reports of its contents. In anticipation of a possible D.O.E. decision that could influence the expenditure (over the next several years) of many hundreds of millions of dollars, and which could place the Department at loggerheads with the House of Representatives (which voted overwhelmingly for H.R. 12874), I am submitting this brief critique of the Photovoltaic Venture Analysis, and some recommendations for the kind of balanced program that I would hope to see emerge from the Solar Domestic Policy Review.

WHAT THE PHOTOVOLTAIC VENTURE ANALYSIS DOES

The Venture Analysis undertakes a very narrow "cost-benefit" study of the relative advantages of a "baseline" purchase program ending in 1982 and a procurement program called the "D.O.E. initiative" which is considerably more conservative than the one called for in H.R. 12874. It treats the government like a private investor expecting a 10 percent return on all investments (presumably in constant dollars, meaning that the government actually expects a 15 to

17 percent return after inflation). Benefits are allowed only for the dollar amounts saved in reduced prices for photovoltaic cells, as compared with prices which would have been expected without the initiative.

The analysis assumes that prices will fall with cumulative volume following a patched-up "learning curve" which makes some very curious assumptions about "learning" in the current industry. It assumes that current silicon processes cannot continuously move to a price of 50 cents per peak watt but can only approach this price asymptotically. The model makes it impossible to reach the 50 cents goal before an "R&D breakthrough" occurs in 1990. This assertion, widely believed to be a conclusion produced by the SERI model, is instead an assumption of the model.

The basic learning curve approach is further distorted with an assumption that sellers will choose to keep prices as high as possible during periods when sales are growing rapidly, increasing profits rather than encouraging a market expansion by keeping prices low (page 151). Not surprisingly, this assumption yields very high array prices in 1986. The table on page 168 indicates that the lowest array price the study anticipates in 1986 is $1.79 per peak watt, and this is an extremely "sentsitivity" excursion. Most baseline prices range from $2.50–$6.80 per peak watt. Obviously, by using this method the study has completely discounted the thorough analysis conducted by JPL which indicates that a 50 cent goal is credible in 1986. It is a mystery why this work is rejected. The U.S. taxpayers have funded JPL for more than 3 years (and spent over $80 million) in an effort that concluded (rather than assumed) that a 50 cent silicon solar cell is possible by 1986.

A recent (June 1978) report by the Congressional Office of Technology Assessment that the 50 cent goal was technologically possible for both silicon and cadmium sulfide devices.

The Venture Analysis uses four different estimates of the size of markets for photovoltaics at prices greater than $1 per peak watt. The smallest estimate (without an initiative) assumed a 1982 market of 140 kw and a 1986 market of 1200 kw. (page 162) This is peculiar since the 1978 market for photovoltaics was 1000 kw. Solarex now has an annual production capacity of about 2000 kw, and ARCO Solar has just installed a production facility which will yield an additional 1000 kw next year. Other firms are also expanding significantly. The "very large" markets forecast by earlier BDM studies are given only a 10 percent probability of occurring although the assessment makes no attempt to discredit the BDM work.

Pulling all of this together, the study concludes that there is a very large probability that the net costs to the government of the procurement initiative will outweigh the net (allowed) benefits. This conclusion is reversed if "foreign benefits" are included in two of the four cases examined (page 170). One of the cases in which foreign benefits do not reverse the conclusion is the case assuming absurdly small markets.

These conclusions are buttressed by a study performed under commission by Gnostic Concepts, Inc. In brief, the study concludes that the JPL goals are unattainable and that the procurement initiative would be counterproductive. It is difficult to contest the Gnostic conclusions, since the document is filled with statements whose only foundation is "the opinion of Gnostic Concepts". What this opinion is worth weighted against JPL work in the same area is questionable.

For example, the Gnostic estimate of the value of the procurement initiative is based on an assumption that the photovoltaic industry cannot grow faster than 70 percent per year until 1982 and 50 percent per year from 1983–1986. Since it is assumed that markets grow at a faster rate, a "sellers market" results and in such a situation federal purchase would be a hindrance and not a help. The study has, of course, assumed this conclusion by accepting the low growth rates for supplies. Yet in a dynamic young industry as small as the current photovoltaic industry, a far higher rate of annual expansion is plausible. No acquaintance of mine in the photovoltaics industry believes a "sellers market" is even remotely possible.

FUNDAMENTAL FAILINGS OF THE VENTURE ANALYSIS AS A BASIS FOR BROAD POLICY

The basic problem with the Venture Analysis is that it misunderstands the purpose of a federal demonstration program. Using the logic and the analytical methods described in the report, no federal demonstration program could ever be justified. Federal demonstrations of advanced nuclear fuel cycles, breeder

reactors, and synfuel plants could never be shown to have a positive cost-benefit defined along the lines described in the SERI work. Yet a successful photovoltaic demonstration program would produce benefits in a number of ways not shown in immediate price reductions.

(*a*) Much of the money directed to the procurement program will be used to design integrated photovoltaic systems, conduct detailed engineering studies of these systems, and measure the performance of these systems in realistic environments. The engineering work is badly needed since, as the study indicates, the "balance of systems cost" is already beginning to present barriers to the expansion of the industry. Reducing these costs will be useful whatever the ideal solar cell turns out to be. Field experience will provide invaluable information to guide research on array encapsulation and structural design.

(*b*) Á demonstration program will provide an opportunity to test a variety of different photovoltaic concepts in realistic environments. Such concepts include silicon flat plate arrays, advanced thin film arrays, concentrator systems, congeneration devices, and other approaches. Most clearly will work, but their real costs and attractiveness must be field tested. It will be necessary, for example, to examine the performance of cogeneration systems with different kinds of storage, different heat exchange mechanisms, and different concentrator cells. The number of concepts is sufficiently large to justify a substantial procurement program for demonstration purposes alone.

(*c*) Procurement initiatives take maximum advantage of privately financed research programs and are most effective in attracting private capital to the industry. They do this by directly subsidizing the industry and by demonstrating a consistency of federal interest in the area. See, for example, the results of the "supply workship" cited on page 77 of the Venture Analysis. The manufacturers concluded that the procurement initiative would attract 0.5 to 1.0 billion dollars in private capital to the industry six years sooner than this capital would otherwise have become available. They estimated that the initiative would accelerate a cost breakthrough from private R&D by three to four years. The significance of this should not be underestimated since it seems more likely that a significant "breakthrough" will emerge from a proprietary research project than from a federally sponsored project. Moreover, private breakthroughs are more likely to be introduced into manufacturing facilities quickly.

(*d*) Demonstrations will also give utilities an opportunity to experiment with the load management problems associated with the technologies. If the goal of marketing grid-connected systems by the mid-1980's is to be accomplished such experiments must be initiated in the next few years.

(*e*) Waiting for a "breakthrough" in research and then building an industry would mean years of subsequent delay as manufacturing, marketing, sales, distribution, engineering, and other capacities are developed. This infrastructure will require years to assemble and the sooner it is in place the better.

(*f*) There is real political and psychological value in insuring that the market price for photovoltaic devices continues to decrease. The price has fallen dramatically in recent years, largely because of efforts made by private industry. In fiscal year 1977, only $5,330,000—or 9.7 percent—of the $55 million federal dollars spent on photovoltaics went to current producers, and less than half of this was for procurement.

If prices do not fall during the next 3–5 years because the government and industry are investing exclusively in advanced research, a great deal of the momentum behind the program will be lost. It will then be much more difficult to persuade skeptics that progress is possible.

(*g*) Demonstrating photovoltaic devices in real environments can have a dramatic effect in attracting the interest and attention of both potential suppliers and prospective consumers. In attracting customers, there is simply no substitute for having a solid piece of apparatus performing useful work in a realistic situation. Placing such facilities in widely dispersed geographic regions would increase the impact of the demonstrations. For example, I think this would be great merit in outfitting a handful of small towns to obtain all of their electricity from solar cells.

(*h*) The use of markets to stimulate regular industrial growth is clearly the best way to insure that small companies have a chance to compete. Current delays and consequent future needs for very rapid expansion would effectively limit the market to corporate giants.

A SENSIBLE PHOTOVOLTAIC POLICY

A persuasive body of evidence suggests that the 50 cent goal for photovoltaic arrays can be met in the mid-1980's, and that federal procurement will be needed to encourage the necessary investments in the private sector. At the same time, an aggresssive research and development program should explore advanced approaches that might prove capable of lowering costs still further in subsequent years.

PROCUREMENT

In many federal applications a photovoltaic system at near-term prices can provide electricity at competitive rates, if just the engineering and design work is paid for by D.O.E. In such cases, the solar program should be charged only for this engineering work and the benefitting agency or department should pay for the equipment. This would greatly magnify the impact per dollar of the D.O.E. program. There should be no "market penetration lag" in such purchases; the decision to meet federal energy needs with renewable resources wherever it is cost-effective (assuming a reasonable discount rate and likely escalations in fuel prices) can be made by Presidential fiat.

Photovoltaics also make economic sense today for a vast number of remote Third World applications. The decision to substitute solar cells (or windmills or other renewable options) for diesel generators (or other nonrenewable options) in our foreign assistance program is presumably at the discretion of the President. Again, this should not represent a D.O.E. expense: AID will buy some energy technology in any case, and should buy photovoltaics wherever they make sense at prevailing prices.

The Department of Energy should have an additional procurement program designed to provide a meaningful incentive to the private sector to accelerate investments in cost-cutting technology. Two basic approaches have been suggested:

A federal agreement to purchase specified volumes at a specified price in each of a series of years. The unit price paid would be reduced, and the volume purchased would increase, each year.

A federal agreement to purchase from producers investing in equipment meeting a set of criteria that federal studies indicate should lead to a low-cost production facility.

On attractive feature of the former option is that the federal outlays are contingent upon specific performance. If industry does not deliver the agreed-upon volume of cells at the agreed-upon price on the agreed-upon date, the federal government will have no obligations. If, on the other hand, the specifications are met, the program will have necessarily been a success. While this approach appears to have some support within the D.O.E. hierarchy, the sums of money commonly mentioned are generally so small that industry would almost certainly refuse to respond.

The D.P.R. formally requested Bennett Miller to instruct his Solar E.T. Budget Review Conference to produce photovoltaic price and volume goals that would stretch the industry to the limits of its learning curve. I hope the conclusions of that conference will be carefully considered by the D.P.R. I have a hunch that an aggressive program could produce a 50 percent Wp product earlier than 1986.

RESEARCH AND DEVELOPMENT

The object of the federal R&D effort should be to ensure technological pluralism and to encourage private R&D expenditures. Studies of the D.O.E. influences in the semiconductor industry conclude that cost reductions did not result from direct federal efforts but from federal support and encouragement of promising initiatives in the private sector.

Innovative thinking should be supported wherever it is found. But there should also be a recognition that our goal is commercial energy—not elegant reports. In F.Y. 1977, only 9.7 percent of all federal photovoltaic money spent for all purposes went to commercial manufacturers. I am unprepared to say what fraction of R&D funding should go to firms with a demonstrated commitment to the technology, but I think the current level is probably too low.

Photovoltaic cells are arguably the most attractive solar-electric option we have. They consume no fuel, produce no pollution, have no moving parts, require little maintenance, have long lifetimes, produce an extraordinary net energy yield,

and are modular in nature and thus easily decentralized. The Department of Energy has invested considerable money and effort to learn whether they can be made economically competitive for general use, and the answer appears to be "yes". The time has come to settle down to the serious business of creating a successful diverse innovative industry.

Dr. LINDMAYER. In my testimony today I would like to concentrate on some of the broader impacts of Government policy and my hopes for S. 3392. At present, a very basic argument rages in Government as to whether photovoltaics should be thrown back into the laboratory or whether evolutionary industrial development should be fostered. In other words, the issue in current assessments is typically polarized between industrial development and research. This is, I believe, an artificial separation.

Photovoltaics is an incredibly diverse technological phenomenon. The photovoltaic effect is present in a wide variety of materials. Some materials like silicon can be cost effective with utilities by the mid-1980's. Other materials have the promise of low cost, but need much more device research and development. There is no need to polarize one photovoltaic technology against another.

While such technologies as cadmium sulfide definitely require more laboratory research at the device level, and many system level problems are applicable to all photovoltaic technologies, and while each device approach has its own technical challenges, there is a considerable degree of commonality.

Those individuals who advocate minimum emphasis on industrial development and major focus on laboratory research on advanced devices, clearly do not see the big picture in photovoltaics.

The past efforts of the Government have accomplished a number of good things, and among them is continuous industry cost-reduction efforts, which were verified through Government procurements.

This has generated both rapid industry growth and widespread optimism about future cost reductions. A series of Government paper studies and laboratory verification activities have shown that silicon solar cells can be cost competitive by 1986.

However, while industry cost reduction and Government development efforts paint an optimistic future for photovoltaics, policy decisions to be made this year, in light of current assessments, will really determine if photovoltaics become cost competitive in the mid-1980's or closer to the year 2000.

Certainly, the latter will be true if the Government adopts an approach dominated by device-oriented long-term research. Moreover, it could also happen if current debate and indecision continues much longer. Time will catch up with the national program. The 1982 DOE goal is $2 per watt. This is a production goal, and the technologies and manufacturing plants to make this happen will have to be in place reasonably quick.

Unless Government soon provides some market support and programs designed to move technologies out of the laboratory and into production, we will fall short of the 1982 goals, and valuable industrial momentum will be lost.

The 1982 goals will only be met if a coherent Government policy emerges out of the current debate. I am not optimistic that the Department of Energy, if left to its own devices, can formulate such a policy.

Some guidance from the Congress, as is contained in the McCormack/Matsunaga bill, S. 3392, would certain assure that industry momentum continues and the future of photovoltaics remains bright.

Obviously, a range of Government organizations, research and development labs and solar cell manufacturing companies must work together harmoniously if DOE's goals are to be met. However, since the overall goal is to develop a commercial industry capable of producing even cheaper solar cells, significant Federal resources should be channeled directly to solar cell manufacturers.

In this respect, it is ironic to note that less than 10 percent of the total Government photovoltaic budget between fiscal years 1975 and 1977 actually went to companies manufacturing solar cells. The budget share illustrates a clear DOE contracting bias toward the central research facilities of large corporations that have made no corporate commitment to photovoltaics.

If program goals are to be met, this situation must be revised and a substantial share of the DOE budget must be specifically allocated to corporations that have a genuine corporate commitment to manufacturing photovoltaic devices.

Markets for photovoltaic systems exist at all price levels from the current $10 to $12 per watt for flat plate arrays down to the 10-cent to 30-cent prices projected for central utility systems. Major intermediate markets include:

One, extensions of current markets, larger system sizes for communications, cathodic protection, et cetera. Two, developing country markets; the potential markets for water pumping and village electrification in developing countries is huge. Three, remote military and other Government sites; recent studies have indicated huge life cycle cost competitive markets for photovoltaic systems.

In terms of size, these markets get very interesting at the $5- to $6-per-watt level and become extremely large at the $1.50- to $3-watt level.

Somewhere between $1 and $2 per watt, a significant shift occurs for the industry. At this point intermediate markets are huge and self-sustaining, and, more importantly, we will see the beginning of grid penetration. If Government policies can get photovoltaics to this price level in the next 4 or 5 years, then achievement of cost competitiveness in the mid-1980's is virtually assured.

At $1 to $2 per watt large sustaining markets will generate resources to maintain industry growth, and substantial amounts of private capital will be readily available to support further cost reduction efforts, in anticipation of even larger markets at prices less than $1 per watt.

Risk capital is beginning to move into photovoltaics. Solarex had very little difficulty in attracting private capital for Semix, a subsidiary recently formed to produce potentially inexpensive "semicrystalline silicon." Moreover, the actions of some of our competitors that are subsidiaries of larger corporations indicate that corporate boards are also more willing to invest in photovoltaics. Reasons for this include:

One, technology has proven itself with rapid cost reduction. Two, ways to utility cost competitiveness are much more clearly defined. Three, significant Government funding has given "stamp of approval" to photovoltaics.

While flow of private capital is increasing, Government funding is crucial for the next few years before the industry reaches the large,

sustaining $1- to $2-per-watt market level. Moreover, any significant shifts in Government funding at this time will directly impact the level of private investment.

Passage of S. 3392 would certainly enhance it, while a shift in emphasis to a long-term development program could and will dry up private investment capital.

Senator DURKIN. Doctor, may I interrupt there and ask a question? I am not sure I understand. If I understand you correctly, you say that passage of the bill would improve conditions. Are you saying that the Department of Energy testimony, if you will, on the long-term development program, could actually adversely impact and dry up private investment capital? Is that the thrust of that sentence?

Dr. LINDMAYER. That is correct. I have been advocating photovoltaics since 5 years ago, and at that time cost-competitive R. & D. for this technology was placed in the next century. If I could devise an antiphotovoltaic argument I would say you surely should go back to the lab and emphasize device development.

The fact is that for the last 5 years private capital has moved in, and this year there doesn't seem to be any difficulty to raise any amount of capital you might want for photovoltaics. But if the Government says, "Well, we are not ready for all this, let's go back to the lab," this will surely stop——

Senator DURKIN. Oh, I see. That is what I thought you were saying. Thank you.

Dr. LINDMAYER. In closing, I would like to say, Mr. Chairman, that I am the president of the major companies in this field, both in terms of mass manufacturing and research and development. In this capacity, I wish to offer wholehearted support for Senate bill 3392, a bill whose passage could have a major impact on photovoltaic development.

Moreover, I urge you, if at all possible, to pass the bill during this session of Congress. While some organizations and individuals may argue for caution and continued study, I already have a conference room full of Government-sponsored studies of photovoltaics. The problems of developing low cost photovoltaic systems cannot be resolved on paper; and debate over development strategies will only end when cost competitive arrays are on America's rooftops.

Passage of this bill will go a long way toward insuring that this will be a reality in the 1980's.

Senator DURKIN. Thank you, Doctor. We are working on a boiler that will handle and be fired by Government studies. I think we could greatly reduce the balance of payments problems. [Laughter.]

How is the State of Maryland treating you? Are you having any problems with the State of Maryland?

Dr. LINDMAYER. Not particularly. They are extremely interested in developing the whole industry.

Senator DURKIN. I was going to say if they do we would love to have you up in New Hampshire.

Dr. LINDMAYER. I'll make a note of that. [Laughter.]

Senator DURKIN. I am serious. We have a very large population of extremely capable workers, with a high degree of manual dexterity, from the shoe industry and the textile industry. We are always looking for growing industries, especially in such a field as this. Now before Senator Sarbanes walks into the room and asks for equal time, I had

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better get back to my question you said in your testimony that less than 10 percent of DOE's photovoltaic budget between 1975 and 1977 actually went to companies manufacturing solar cells.

Where did the rest of it go?

Dr. LINDMAYER. It went to first of all paper studies, Government laboratories, and then to large companies whose isolated research laboratories used up the remaining money.

Senator DURKIN. You mentioned the problems of small business. I am concerned that small businesses must be given an adequate opportunity to participate. We had a little backroom shop in New Hampshire not too many years ago, that was a small business, and it is now Sandoz Associates.

There has been an awful lot of backdoor, garage operations in the electronics field that are now major contributors to our industrial productivity capability. The DOE authorization bill directs or suggests that we ought to do more for small business with the amount of funds available.

Do you think we should go further and mandate that, and do you think there should be a definite percentage, 10 percent, 20 percent, 30 percent, go to small business. I do not mean downstream small businesses created by multinational, for purposes of qualifying for the small business program.

Mr. LINDMAYER. Yes; I think it would be proper to set some kind of minimum threshold for small businesses. We have been a small business throughout, even though we believe we are the largest manufacturer. We have about 200 people at the present time, and everyone is very much committed to develop this field.

I think that kind of commitment can only be found, really, in companies that have been formed for the specific purpose of exploring this new field. There is no other business in Solarex so everyone knows his well being, and career and everything else depends on the success of photovoltaics.

That really helps, and for that reason I really think that small businesses should be helped to grow.

Senator DURKIN. So you would recommend a definite set aside.

Dr. LINDMAYER. Yes.

Senator DURKIN. Do you think photovoltaics can realistically compete with large utility electricity markets, and eventually displace much of the energy or some of the energy that we now employ?

Mr. LINDMAYER. I would first of all like to make clear that I absolutely believe in that. I have quit a very highly paid job with Comsat Laboratories, to form this company. Everyone at Solarex believes that, and this belief is not just a religious point of view. There is a tremendous technology backlog right now. There are technologies that have been tried out in the laboratory but have not yet been put into production.

I think a buy program, a program that enlarges the market, would surely pull out these technologies. It's just not the case that we need to expand into newer and newer research activity because we are overgrown with technology. It is the absolute fact that photovoltaics can be made in so many ways, and it's really at the production floor level that you will find out which one is cost competitive.

All research activities will have to be slanted in the way of how to make solar cells less expensive.

Senator DURKIN. What about the Middle East? Are you aware of what, if anything, Israelis are doing with respect to photovoltaics. I would think, even though in the recent—in light of the recent success of Camp David, they have a severe energy problem, an import problem.

I would think from a national security point of view, that they would be moving faster and further than anyone. To your knowledge is that true, is there any substance to that?

Dr. LINDMAYER. I think there is great interest in and I do not believe they are very much develop in terms of photovoltaics. There is much more in solar thermal, but in photovoltaics there is a certain amount of activity, but not a great amount. That's probably due to limited resources.

Senator DURKIN. The prior testimony, excepting the Department of Energy, is that if we do not move, with the subsidized competition in France, Germany, and Japan, that we will lose the next round of Sonys to our overseas competitors. Do you agree with the thrust of that testimony?

Dr. LINDMAYER. There are a few points I would like to make about that. We have first of all expanded into forming a joint venture in Australia, we have a company in Switzerland, and a joint venture just starting in France. So we are very much involved in the international scene, and look for local partners to cooperate with.

I think there are two points that can be made. One is that in a foreign delegation to DOE, the foreign delegation is full of industrial members. The American delegation only contains DOE or Government laboratory people, the industry is totally cut out of that.

Senator DURKIN. Why is that, do you think?

Dr. LINDMAYER. I assume there is much closer cooperation in foreign countries between government and the industry than there is here.

Senator DURKIN. What would you recommend that we in the committee could do to rectify that situation?

Dr. LINDMAYER. I think it is somewhat of a decision that DOE should maybe include industry in some of these negotiations. Last Thursday there was an agreement signed between Italy and the United States for photovoltaic cooperation, solar cooperation, and the Italian group was full of industrial members with whom we deal, actually. But the American side was strictly DOE people.

I don't think this is correct, and in fact it seems to me there is going to be a gradual separation between DOE and the industry. The industry will pursue its own goals, and DOE's leadership will be lost. But on the other hand I would like to make this general statement that there is really not much new about this.

In the last 5 years, since photovoltaics have been discussed and pushed, DOE was never the leading agency, it was the Congress.

Senator DURKIN. Do you think photovoltaics have a potential on the grid, and what about storing energy?

Dr. LINDMAYER. I think storage is something that will find its place, and the technological problems and cost factors will be resolved along the way. At the present time the storage cost of any system being sold today is only about 10 percent. It is 90 percent for these arrays, for

the photovoltaic parts of the system, so no wonder everyone is very much concentrating on that aspect of the system.

Really, I believe that the storage ultimately will not be a big problem, and something like 5 years down the road there will be more attention paid to storage. But I don't see that as a basic barrier. Even today in my own home I could store a lot of energy from acid batteries at a reasonable cost.

Senator DURKIN. The committee has been told that one of the laboratories in New Mexico, and the University of Wisconsin, have come up with a storage cell, probably the size of the diameter of this glass, and a little longer, that will carry as much energy as a cable 3½ feet in diameter. They are now exploring the possibility of using that in a circulating system, and could store enough electricity whether it be small source generators, hydro, photovoltaic.

They look forward to having one in each area, say a State the size of New Hampshire, two or three in a State the size of California, and with this breakthrough could store up to—I think the latest projection is 20 hours of energy. Are you familiar with that?

Dr. LINDMAYER. Just vaguely, but there are other efforts that I know about, too, and this has to do with iron-redox batteries, and there's a central element stored in tanks, pumped into tanks. There are a few other aspects, but I think the storage is not a basic barrier to photovoltaics.

Senator DURKIN. Is the utility industry a barrier. We have found in other areas that they and their financiers are very jealous of their central generating distribution system, very-capital-intensive distribution system, and have been reluctant to incorporate low-head hydro or solar installations. Do you find that is true also in photovoltaics?

Dr. LINDMAYER. I had the opportunity to debate phototvoltaics with utility representatives here and there. I would say that the utilities do not like phototvoltaics. After all, the proposition is a distributed power system which consumers could reasonably go out and buy their own power system from five competing companies. That's not the proposition that utilities would like to see.

Senator DURKIN. No. Do you see any difficulties in a Federal procurement program that would freeze the technology, that the Government would end up buying the obsolete equipment, and thereby creating a disincentive to move on with another generation?

Dr. LINDMAYER. I think this is a made-up argument, basically. I don't think that anyone requests that the Government buys equipment or build production lines. At least I am against that idea. I think there is sufficient private capital so you don't need the Government to buy equipment or install a production line, you do this at your own risk.

I think we should give more credit to private industry in America that would be flexible and mobile enough to change to another system, if it turns out to be less expensive. I don't think we should argue whether a thin-film cadmium sulfide versus silicon is the main issue.

For one, Solarex is pushing silicon very hard because it's capable of continuous cost reductions, and I would like to show this panel to you, Mr. Chairman.

Senator DURKIN. Sure.

Dr. LINDMAYER. But should it be that someplace down the road

some thin-film technology is looking very good, I am sure everyone will be switching over to it. I know we will.

Mr. CLIFFORD. Senator, I would like to add to that by saying, say, the current goal for 1982 is $2 a watt, and we see a way of being able to get to that point, if we are at the $2 a watt level, and with continuing production, experience, and manufacture, down to that level, I think we could see our way clear to get to 50 cents a watt from that point.

At the same time I know we will be able to convince private investors that we knew enough to do this in order to get as much capital as we needed to finance a production line at the 50 cents a watt level. It's a different story to go out and tell an investor when you are at $10 and $12 a watt that you have the answers for 50 cents a watt.

There's more technical risk involved, but you could certainly go to $2 a watt and then get the capital to make the other push.

Senator DURKIN. What do you see as the time frame for 50 cents?

Dr. LINDMAYER. We stick by the old goal of 1986, that that is a feasible goal, assuming that Government policies remain coherent.

Senator DURKIN. That is an assumption that is dangerous to make.

Dr. LINDMAYER. Yes, but I think the only one who can really basically derail that goal is DOE.

Senator DURKIN. From my experience, they are batting close to 100 percent. They say they went to get off oil, they oppose the low-head hydroprogram, they want us to shift to coal, there is no way to get coal in New England unless we fly it in.

They oppose our efforts to provide funds to rehabilitate the rail system so we can get coal there. On the solar thermal, they reduce the amount of money for demonstrations. You may disagree but I for one do not think we are going to see many residential installations of solar thermal until we can drive down the street and see someone on your block that has a general reputation for good sense, has one on his roof, and you go in and see it, and he tells you it's working, and is happy with it.

Dr. LINDMAYER. Exactly.

Senator DURKIN. I have said before that I think Dr. Schlesinger's goal was to put a breeder reactor in every closed gas station in America.

[Laughter.]

Senator DURKIN. I think that policy has trickled down through the Department of Energy, and anything that does not meet that unstated goal is giving the soft shoe.

Dr. Lindmayer, do you have any suggestions with respect to a system of incentives for photovoltaics such as tax credits, or loan guarantees, so that photovoltaics would be better able to compete with some of our subsidized forms of conventional energy.

Mr. CLIFFORD. Senator, I would like to answer that if I may. I think photovoltaics or any of the solar technologies should be put on as equal footing as possible, with technologies they are competing against. There was a recent study by Batelle Laboratories that talked about the amount of direct and indirect Government subsidies that went to the different fossil fuels and nuclear programs over the last 30 or 40 years. The amounts are absolutely staggering.

If you look at the amount of direct investment that has gone into photovoltaics, or any solar technologies for the last 6 or 7 years, when there has been a Government program, it's absolutely miniscule. That's

one thing. We are not competing on an equal, economic basis. The other thing is in terms of specific recommendations, I think the incentives should be placed more toward the users of photovoltaic systems than the manufacturers themselves.

We can qualify for investment tax credits and maybe accelerated depreciations, but what we need is some incentive to get to bigger markets, and I think those would be the ones directed toward potential users of photovoltaics, so that you're getting toward tax credits similar to those being proposed for solar thermal systems right now.

Senator DURKIN. You said the problem is analagous to the installation. Unless we get it installed and someone sees it work, they will not believe it.

Mr. CLIFFORD. That is certainly the case.

Senator DURKIN. To be honest with you, I am not sure whether the tax credit includes photovoltaics or just thermal.

Mr. CLIFFORD. The language was written in such a way that it says solar energy, and if photovoltaic systems for cost competitive, then they could be used.

Senator DURKIN. It is your recommendation that we move in that direction, of increasing the end utilization by the consumer.

Mr. CLIFFORD. I think what you've heard a lot of people say from industry is from what they are really concerned about is market support, whether it be direct Government market support, or indirect.

Senator DURKIN. Let me ask you this question. In light of the combined testimony of you two gentlemen, is there any need for the bill in your view?

Dr. LINDMAYER. Yes, absolutely. I don't think much has been discussed about the fact that 99.9 percent of the population do not know, does not know, what photovoltaics is. It is through demonstrations that you make people aware of the thing, that it exists. It is a tremendous experience. For example, on Sunday, May 3, we put out an array that pumped water from the Reflecting Pool on the Mall, and at the same time operated a whole band, a popular Rock band, with all its amplifiers, full blast, and there was no utility power nearby.

All of those people nearby, it was just a tremendous mental exercise to explain to them what this is about. You see this tremendous gap as soon as you display something like that and expose it. There is a system with no moving parts and everything works, except the pump is rotating. But there are no other moving parts, and loud speakers are blasting, and they could not comprehend who was doing what.

We have a tremendous educational gap to overcome, and the only way we can do this is if there are big systems out there and they work and produce large power. We were involved with this Mississippi—the Mississippi County Community College in Arkansas, and it would be something on the order of 300 kilowatts put up there for a whole school.

This is the kind of thing we need that people can see, and have a direct experience with photovoltaics. It's something highly unusual, and after all, everyone can relate to heating systems because everyone knows that objects become hot under the Sun. But how do you relate to this business of a steady panel with no moving parts and an electric part coming out of it.

Senator DURKIN. That is like the guy selling solar-operated clothes dryer. It was just a 50-foot piece of clothesline.

[Laughter.]

Senator DURKIN. I appreciate very much your testimony, and Dr. Lindmayer, if you would, at your convenience, drop me a line. Hopefully we are going to adjourn some day, and those sites that are using photovoltaics, if my schedule permits, I would like to see some of those in operation. If you could drop me a line as to where those places were, and if my schedule permits——

Mr. CLIFFORD. Senator, I know we have at least one in your State that we have installed, in the State of New Hampshire.

Senator DURKIN. Put that one first on the list.

Where is it?

Mr. CLIFFORD. It's with the National Park Service, or one of the State forestry organizations. It is a radio communication system on one of the mountain tops, fire-tower-type communications where it was miles from utility lines.

Dr. LINDMAYER. We will surely give you a list of these.

Senator DURKIN. Yes; because again there is a certain skepticism in the committee, a certain skepticism in the Senate, and I imagine the House too, that we have to overcome. There is nothing like a demonstration to overcome it.

Dr. LINDMAYER. Maybe that emphasizes the importance of Government support. It is the larger installations that will really show the world.

Mr. CLIFFORD. Senator, if I may, I would like to make one comment about the net export potential of photovoltaics. Something that was talked about a bit today, but never directly came out. One of the things about photovoltaic systems is the unique potential for export. If you look around at the solar-thermal industry, there are 300 or 400 companies making solar-thermal systems. There are only half a dozen in photovoltaics in this country and we have three or four competitors around the world.

It is very high technology, in manufacturing the cells, yet at the same time major pieces of the system are easily assembled in foreign countries. However, the solar cell itself is a high technology device that will not be easily or quickly made in many countries. The country that develops leadership in the solar-cell device can be in a net export position for a decade or more.

This is where America has been in the semiconductor industry for the last 15 years, and we can develop the same kind of leadership position in solar cells. If we don't, West Germany or Japan will.

Senator DURKIN. Well, we did it with the calculators. Now you feel guilty if you don't have one in each pocket, it seems. We saw what happened, the textile industry left New England. The shoe industry was right behind them. The electronics industry is facing an assault, and we've got to do more than just talk about the balance of payments.

I don't think it will solve the problem tomorrow, but there is the next generation's balance of payments problem, and if we don't move aggressively we will lose the market and its job. It's not only balance of payments, but it's jobs all across the country.

I am going to terminate this hearing. For the record, Mr. Madison of Optical Coating Laboratory, his statement will be included in its entirety in the record.

Also I would like to include in the record a statement of a cosponsor, Senator Mathias of Maryland. And statements of the Solar Energy Industry Association in support of the bill by Sheldon Butt, president, and a statement by Sun Trac Corp.

[The statements follow:]

STATEMENT OF HON. CHARLES McC. MATHIAS, JR., A U.S. SENATOR FROM THE STATE OF MARYLAND

Mr. Chairman, I am pleased that the Subcommittee has met to consider S. 3392, a bill to assist in the rapid development of solar photovoltaic cells as alternate energy sources. I was delighted to be able to join with my distinguished colleague from the State of Hawaii, Mr. Matsunaga, in cosponsoring this important legislation that will provide an opportunity to move this needed technology ahead.

Mr. Chairman, we have been talking about an energy crisis in this country ever since the Arab oil embargo of 1973–74. Highly qualified experts still differ strongly on the nature of our energy problem and on what we should do about it. The public is divided and confused. Many people don't think there is a problem. Others, who admit there is a problem, simply aren't willing to face up to it.

There are a good many reasons for this national inertia. The most disturbing one is that energy experts and policymakers alike, including the President, tend to talk about the energy problem as if it were down the road a piece. But it's not, and that kind of talk has been a terrible mistake.

I'm told that at the rate things are going, U.S. energy consumption will increase by more than three percent this year. As columnist David Broder said recently, "these statistics are irrefutable evidence that we are living in a fool's paradise."

The energy crisis is with us now. It doesn't lie in wait for us sometime 20 or 30 years from now when we run out of fossil fuels. It began thirty years ago when we first had to import oil, and it becomes more serious every year in direct proportion to our mounting appetite for energy.

The picture I've drawn is pretty grim. But there is one strong element of hope. We are beginning to see signs of the development of alternate sources of energy. We must find supplies of new, clean, abundant, and inexpensive energy sources that can be developed and made available. Mr. Chairman, that's why this bill should be considered as a major step in the right direction.

We have said so much recently about the value and vitrues of solar energy. We've sung its praises about how far down the road it will take us to a resolution of our energy problem. We like the idea of solar energy for many reasons: it is clean, abundant and renewable, with little or no harm to our environment.

Photovoltaic conversion of sunlight to electricity has proven to be a dependable method of providing power. We've used it to propel and provide power to our space vehicles for the last 20 years. Widespread use of the proven technologyhas not occurred because of its prohibitively high cost. If photovoltaic conversion is to play a substantial role in the resolution of our energy problems, and supplying energy to the Nation, the Federal government must play a substantial role in fostering methods by which the conversion can be done cheaply. This bill provides our method of assuring the necessary research and demonstrations will take place. It is our hope that within ten years the photovoltaic system will be able to achieve commercial application. To do so, however, the costs associated with it must be reduced by a factor of 10 to 20 over the next ten years.

Our colleagues in the House have already taken the lead by enacting a companion measure, H.R. 12874. I hope the Senate will do the same.

PRESENTATION OF TESTIMONY

TO

UNITED STATES SENATE

COMMITTEE ON ENERGY AND NATURAL RESOURCES

SUBCOMMITTEE ON

ENERGY RESEARCH AND DEVELOPMENT

WASHINGTON, D. C.

September 19, 1978

Presented by

OPTICAL COATING LABORATORY, INC.
2789 Giffen Ave., P.O. Box 1599
Santa Rosa, CA 95402

Telephone: 707/545-6440
TWX/Telex: 510/744-2083

SUMMARY OF OCLI POSITION ON S.3392

SUPPORT IMMEDIATE IMPLEMENTATION OF BILL

- Photovoltaics are becoming a viable alternate energy source.
- Emerging U.S. photovoltaic industry needs government support through 1988 to
  - reduce dependence upon conventional energy;
  - stimulate and accelerate U.S. research, development, and production;
  - motivate U.S. manufacturers and end-users to risk investment in alternate energy development;
  - transfer new technologies to production;
  - meet growing foreign competition.
- Technology commercialization and transfer of process know-how is essential for cost reduction and volume production.

LIFE CYCLE COST COMPARISONS OF PHOTOVOLTAICS WITH CONVENTIONAL ENERGY

- Apply minimum 10% to 15% compound inflation rate per year to conventional energy forms over life of project.
- Simple payback or first cost alone understates real impact of rising costs of conventional energy.

COST SHARING PROVISIONS OF BILL APPEAR ADEQUATE TO REDUCE INFLATIONARY IMPACT OF INCREASED SPENDING

- Industry/end-user share at 90% by 1988.

FUNDING NEEDED NOW TO PREVENT FOREIGN DOMINANCE BY MID 1980s

- Foreign installations of photovoltaics increasing more rapidly than in United States.
  - 30% to 40% now;
  - 70% to 80% by 1987.
- Foreign production will outpace U.S. production of photovoltaics by mid 1980s without immediate U.S. Government support.
- Provide U.S. with technology and market leadership through export incentives and "cost-sharing" partnerships with selected countries.
  - Japan, Western Europe, USSR expected to develop aggressive photovoltaic export programs by early to mid 1980s.
- Prevent U.S. dependence upon importation of photovoltaics by late 1980s.

FEDERAL ROLE RECOMMENDED

PROVIDE "SEED MONEY" TO STIMULATE U.S. TECHNOLOGY AND PRODUCTION

	DOE Funding Percentage
• Applications Development - Flat plate, Concentrators, and Thin Films - Total Energy Systems - Government agency installations - Utility grid interface - Foreign projects - System monitoring and analysis	55%
• Low Cost Silicon Processes - Improve yields and transfer to production - Transfer licenses and process know-how to small firms (sales < $100 million) - Low cost loans for private industry to install process in U.S. based facilities	10%
• Advanced Research & Development - Thin film devices and materials - Novel systems and processes	35%
	100%

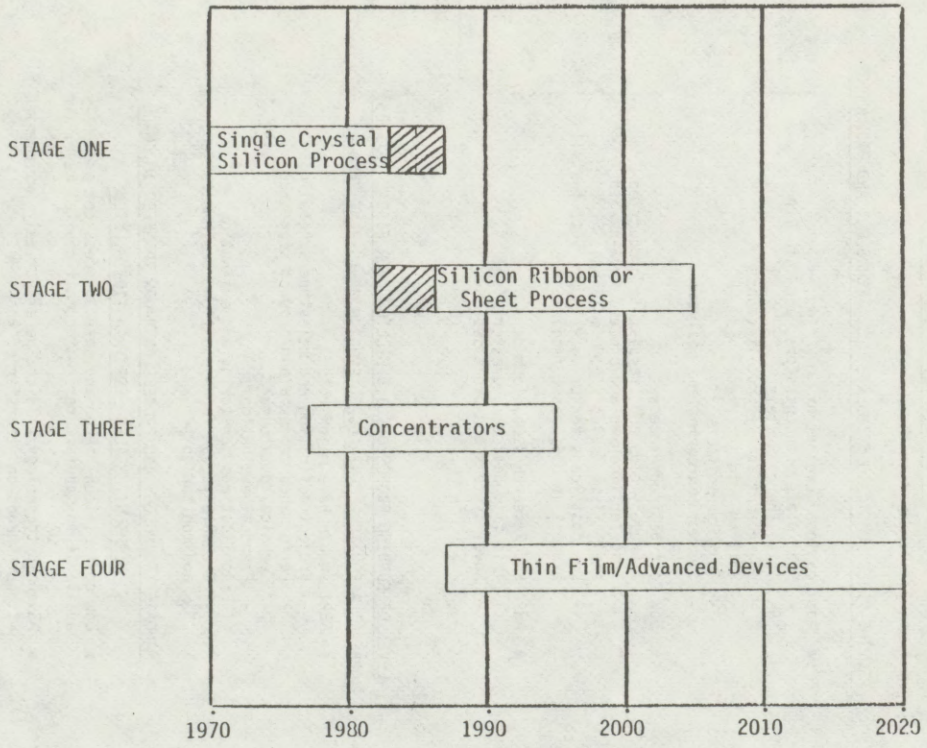
LEVEL OF FUNDING PROPOSED ($1.5 BILLION OVER FISCAL 1979-88) APPEARS ADEQUATE. CENTRALIZED PROGRAM MANAGEMENT NEEDED.

- SERI should have major role
  - Project definition and milestone scheduling
  - Performance criteria and product standards
  - Technical data bank
  - Proposal evaluation
  - Applications monitoring and evaluation
  - Technology transfer evaluation, implementation, and monitoring

MANDATE TECHNOLOGY AND PROCESS KNOW-HOW TRANSFER TO SMALL FIRMS WITH SALES LESS THAN $100 MILLION

- Low cost silicon ribbon and sheet process not presently available to manufacturers with small capital base.
- Advanced technology will not be effectively implemented without "hands-on" transfer of know-how.

TERRESTRIAL PHOTOVOLTAIC PRODUCTION DEVELOPMENT



In order to achieve DOE cost goals for photovoltaic power, three competing technologies are being pursued.			
Technology	Comments	Required for significant cost reductions	Comments
Flat plate single crystal silicon	Most mature technology Higher throughput potential with ribbon or sheet processes	• Low cost silicon starting material • Automation of array fabrication • Availability of process to small firms	• Decisions to invest large amounts in capital equipment required in 1979 to bring on-stream by 1982 • Equipment may be obsoleted by 1986
Concentrating	Substitutes less expensive concentrating array for large areas of silicon	• Development of concentrators • Improvement in cell efficiencies	• Best potential for near term cost reductions
Thin Film/Advanced Devices	Long term development	• If efficiencies can be brought up to 10%, systems become "practical"	• Potential for lowest cost conversion devices

APPLICATIONS COST EFFECTIVE FOR PHOTOVOLTAICS

NEAR TERM (Present to 1982)

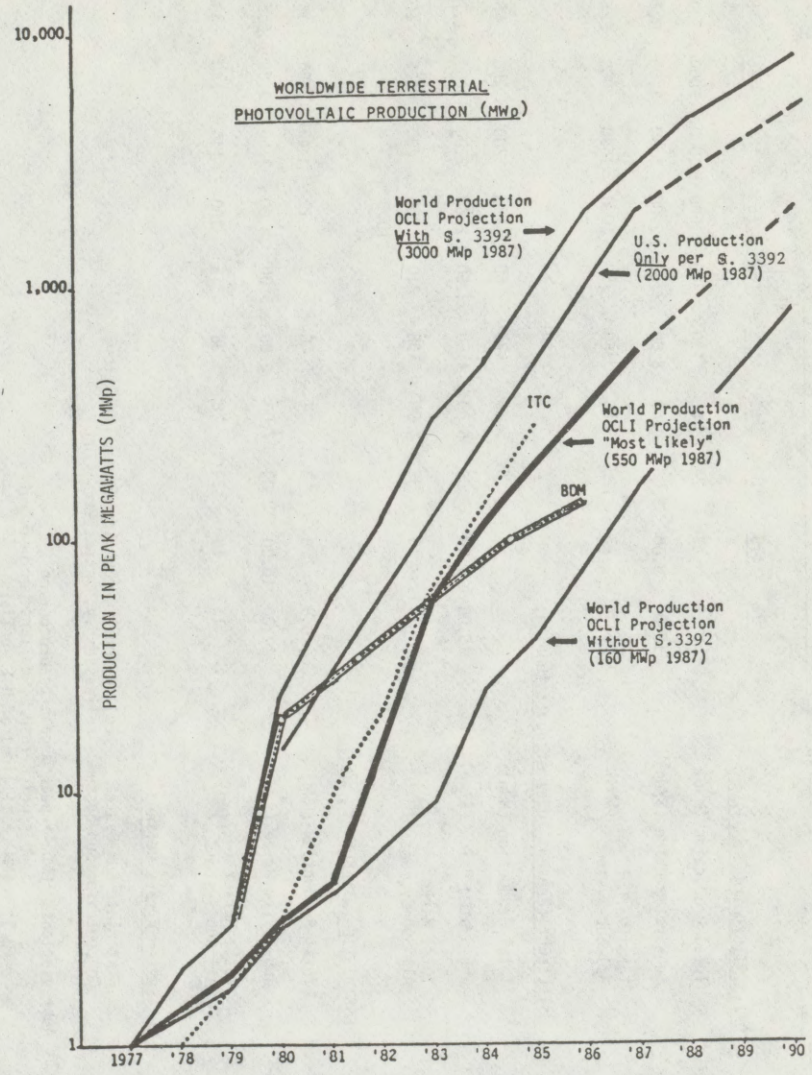
- Remote Power Generation
  - Small to intermediate electrical systems
- Cathodic Protection
  - Pipelines
  - Well casings and wellhead monitoring
  - Controls and pumping
  - Bridges
- Navigation Aids and Signals
- Water Pumping - shallow wells
- Communications and Telemetry
- Monitoring, Sensing, Warning Systems
- Consumer Products

INTERMEDIATE TERM (1982-87)

- Remote Lighting Systems
- Peak Demand Shaving
  - Airports and public works
  - Schools
  - Hospitals
  - Industrial lighting and space conditioning
  - Industrial processes with peak daytime load
- Water Pumping - medium depth wells
- Cathodic Protection
  - Medium and deep oil/gas wells
- Decentralized Power
  - U.S. and foreign small communities
- Agriculture - crop drying, irrigation, etc.

LONG TERM (1987 and Beyond)

- Residential and Small Commercial Buildings
- Decentralized Power
  - Medium size communities
  - Utility peak demand shaving
- Agriculture - plant growth lighting and advanced processes
- Water Pumping - deep wells


WORLDWIDE TERRESTRIAL
PHOTOVOLTAIC PRODUCTION (MWp)
World Production
OCLI Projection
With S. 3392
(3000 MWp 1987)
U.S. Production
Only per S. 3392
(2000 MWp 1987)
ITC
World Production
OCLI Projection
"Most Likely"
(550 MWp 1987)
BDM
World Production
OCLI Projection
Without S.3392
(160 MWp 1987)
PRODUCTION IN PEAK MEGAWATTS (MWp)
10,000
1,000
100
10
1
1977
'78
'79
'80
'81
'82
'83
'84
'85
'86
'87
'88
'89
'90

WORLDWIDE TERRESTRIAL PHOTOVOLTAIC ARRAY MARKET

	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87
OPTIMISTIC (with S. 3392)										
Total Production (MWp)	2	3	24	60	120	300	500	1000	2000	3000
Sub-System Price ($/Wp)	12.00	9.00	5.00	4.00	3.00	2.50	2.00	1.50	1.00	0.75
Total Market All Sub-Systems ($MM)	24	27	120	250	360	750	1000	1500	2000	2250
MOST LIKELY (Present level of gov't funding)										
Total Production (MWp)	1	2	4.5	15	35	60	120	200	350	550
Sub-System Price ($/Wp)	15.00	9.00	7.00	6.00	4.50	3.50	2.50	2.00	1.50	1.10
Total Market All Sub-Systems ($MM)	15	18	32	90	158	210	300	400	525	600
PESSIMISTIC (without S. 3392)										
Total Production (MWp)	0.9	1.8	3	4	6	9	25	40	80	160
Sub-System Price ($/Wp)	17.00	10.00	8.00	7.00	6.00	5.00	4.00	3.50	3.00	2.50
Total Market All Sub-Systems ($MM)	15	18	24	28	36	45	100	140	240	400

Sub-System Arrays Defined

Flat Plate Sub-System = cell assembly, mounting frame, regulator
Concentrator Sub-System = cell assembly, optics, tracking

Abbreviations: MWp = peak megawatts production
$/Wp = price in U.S. dollars per peak watt
$MM = millions of U.S. dollars

DETAILED MARKET PROJECTIONS

- Optimistic (with S. 3392)
- Most Probable (present level of government funding)
- Pessimistic (without S. 3392)

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WORLDWIDE TERRESTRIAL PHOTOVOLTAIC ARRAY MARKET--OPTIMISTIC

	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87
Flat Plate Subsystems (MWp)	1.6	2.5	4	10	20	100	200	500	1000	1500
Price--Cell Assy, Frame, Regulator ($/Wp)	15	10	7	5	3.50	3.00	2.00	1.50	1.00	0.75
Flat Plate Subsystems ($MM)	24	25	28	50	70	300	400	750	1000	1125
Price--Cell Assy. Only ($/Wp)	12	8	5	3.50	2.00	1.50	1.00	0.75	0.50	0.50
Flat Plate Arrays ($MM)	19	20	20	35	40	150	200	375	500	750
Concentrator Subsystems (MWp)	0.03	0.5	20	50	100	200	300	500	1000	1500
Price--Cell Assy, Optics, Tracking ($/Wp)	7.50	6	5	4	3	2.50	2.00	1.50	1.00	0.75
Concentrator Subsystems ($MM)	0.23	3.0	100	200	300	500	600	750	1000	1125
Price--Cell Assy. Only ($Wp)	5	3.00	2.50	1.75	1.00	0.60	0.40	0.25	0.15	0.10
Concentrator Arrays ($MM)	0.15	1.5	50	88	100	120	120	125	150	150
Concentration Ratio (x suns)	(30)	(40)	(50)	(50)	(60)	(70)	(80)	(90)	(100)	(100)
Total Production All Subsystems (MWp)	2.03	3	24	60	120	300	500	1000	2000	3000
Total Market All Subsystems ($MM)	24	28	128	250	370	800	1000	1500	2000	2250
Total Market All Arrays--Cell Assys ($MM)	19	21.5	70	123	140	270	320	400	650	900

WORLDWIDE TERRESTRIAL PHOTOVOLTAIC ARRAY MARKET--MOST PROBABLE

	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87
Flat Plate Subsystems (MWp)	1.0	1.5	2	5	15	30	60	125	250	450
Price--Cell Assy, Frame, Regulator ($/Wp)	15	10	8	6	4.50	3.50	2.50	2.00	1.50	1.00
Flat Plate Subsystems ($MM)	15	15	16	30	68	105	150	250	375	450
Price--Cell Assys Only ($/Wp)	12	8	6	4	2.50	2	1.50	1.20	1.00	0.75
Flat Plate Arrays ($MM)	12	12	12	20	38	60	90	150	250	300
Concentrator Subsystems (MWp)	0.03	0.5	2.5	10	20	30	60	75	90	100
Price--Cell Assy., Optics, Tracking ($/Wp)	7.50	6.50	6.00	5.50	4.50	3.50	2.50	2.35	2.00	1.50
Concentrator Subsystems ($MM)	.23	3	15	55	90	105	150	175	180	150
Price--Cell Assys Only ($/Wp)	5.00	3.50	2.50	2.00	1.60	1.20	0.80	0.50	0.30	0.20
Concentrator Arrays ($MM)	0.15	1.8	6	20	32	36	48	38	27	20
Concentration Ratio (x suns)	(30)	(40)	(50)	(50)	(50)	(60)	(70)	(80)	(90)	(100)
Total Production All Subsystems (MWp)	1	2	4.5	15	35	60	120	200	340	550
Total Market All Subsystems ($MM)	15	18	31	85	158	210	300	425	555	600
Total Market All Arrays--Cell Assys ($MM)	12	14	18	40	70	96	138	188	277	320

WORLDWIDE TERRESTRIAL PHOTOVOLTAIC ARRAY MARKET--PESSIMISTIC

	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87
Flat Plate Subsystems (MWp)	0.9	1.2	1.5	2	2.5	4	10	20	40	80
Price--Cell Assy, Frame, Regulator ($/Wp)	15	11	9	6.50	5.50	4.50	4.00	3.50	3.00	2.50
Flat Plate Subsystems ($MM)	13	13	13.5	13	14	18	40	70	120	200
Price--Cell Assys Only ($/Wp)	12	9	7.50	5.50	4.50	3.50	3.00	2.50	2.00	1.50
Flat Plate Arrays ($MM)	10.8	11	11	11	11	14	30	50	80	120
Concentrator Subsystems (MWp)	0.03	0.5	1.5	2	3.5	5	15	20	40	80
Price--Cell Assy, Optics, Tracking ($/Wp)	8	7	6.50	6.00	5.50	4.50	4.00	3.50	3.00	2.50
Concentrator Subsystems ($MM)	0.24	3.5	9.75	12	19	23	60	70	120	200
Price--Cell Assys Only ($/Wp)	5	3.50	2.75	2.50	2.00	1.50	.80	0.60	0.30	0.20
Concentrator Arrays ($/MM	0.15	1.8	4	5	7	8	12	12	12	16
Concentration Ratio (x suns)	(30)	(40)	(50)	(50)	(50)	(60)	(70)	(80)	(90)	(100)
Total Production All Subsystems (MWp)	0.9	1.7	3	4	6	9	25	40	80	160
Total Market All Subsystems ($MM)	15	18	25	28	35	41	100	140	240	400
Total Market All Arrays--Cell Assys ($MM)	11	13	15	16	18	22	42	62	92	136

STATEMENT OF SHELDON H. BUTT, PRESIDENT, SOLAR ENERGY INDUSTRIES ASSOCIATION

The Solar Energy Industries Association is a trade association representing manufacturers and others active in various solar industries, including photovoltaics. We are convinced that this proposed legislation is both timely and effective.

Many engineering studies have been made which generally support the position that large volume production of photovoltaic devices will induce accelerated development and improvement of manufacturing processes in the competitive marketplace. The result will be product improvement and cost reduction. The argument has been advanced that stimulating the market, as is proposed, in the Photovoltaics Demonstration Act at this time will tend to "freeze" the technology. First of all, there is no reason why Federal support for development of a variety of photovoltaic technologies cannot continue concurrently with the market stimulation of available technologies contemplated by the Act. In addition, the substantial market which will develop for devices based upon the state of the art technology as it exists at the time of each planned purchase of photovoltaic devices will stimulate the private sector to accelerate development of other photovoltaic technologies as a means of participating in this market.

We may compare the situation with that which existed in the computer industry. The computer industry was initially stimulated by large scale government purchases. Initially, computer memories were generally magnetic. It is certainly true that semiconductor memories subsequently were developed, and it appears that the development of a market for computers encouraged—not discouraged—this development. The availability of a substantial market has undoubtedly been the principal factor in the development of MOS memories.

The stated goals of DOE are to reduce photovoltaic array costs to $2 per watt in 1982, 50 cents later in the decade, and ultimately to the 10 cents to 20 cents range. At each level substantial markets will develop. Although the market at the ultimate level is obviously larger than at intermediate levels, there are indeed substantial potential markets which can be reached at cost levels in the $1 to $2 range. We are confident that costs in this range can be reached in a few years given the stimulation provided by the Photovoltaic Demonstration Act.

Thus, we reiterate our initial statement that passage and implementation of the Photovoltaics Demonstration Act of 1978 at this time is both timely and potentially effective.

SUN TRAC CORPORATION

1674 South Wolf Road • Wheeling, Illinois 60090 • (312) 541-2095

TESTIMONY BEFORE THE SENATE SUBCOMMITTEE
ON ENERGY RESEARCH AND DEVELOPMENT

SUN TRAC CORPORATION
SOLAR PHOTOVOLTAIC INDUSTRY GROWTH

Date: September 19, 1978

SUN TRAC CORPORATION

1674 South Wolf Road • Wheeling, Illinois 60090 • (312) 541-2095

SUMMARY

Millions of dollars have been spent, and thousands of pages have been written for studies on the viability of Solar Photovoltaics to supply Electrical or combined Electrical and Thermal Energy. We support the position that the United States photovoltaic companies have the present ability (knowledge) to produce systems at prices which could sustain commercial, (non-government) markets. We also believe that the transition from the present high prices at low volume production to the future low prices at high volume production will not occur without appropriate and sustained multiyear U. S. Government programs.

The government financial role should be to fund large volume production with several companies on a fixed price competitive basis and these systems be used at a variety of commercial as well as local, state and federal government installations. The worldwide markets should not be ignored for they could be the most important near term market and a means to assist in our trade deficits. Government credit or funding must also be available to small business for capital expenditures where such capital is not otherwise available. Use of and sale of systems to all possible consumer applications should be encouraged because consumers will buy large quantities only after they have tried a small quantity and proved to themselves that the product is technically and economically useful. Consumers will not be impressed by data from government installations. Multiyear programs are needed because three to five years will be required for the consumer test and evaluation period.

Legislative provisions should be made to prevent the creation of future monopolies by present large business. A status review would show that small business has produced a large percentage of the solar photovoltaic advanced technology in solar cells and arrays. Sun Trac Corporation, a very small business, has designed, produced and sold the only commercial applications of two axis tracking-solar concentrating systems and only company funding was used. Solar energy utilization is a unique area where small business can provide substantial

innovative solutions to cost reductions and consumer needs. Small business wants to compete on a fair basis as a prime contractor and not just as a subcontractor to large business, however, the government must recognize that a small business has certain problems when competing for step function multimillion dollar contracts.

Sun Trac Corporation has two D.O.E. contracts:

1. Sandia Laboratories Contract #07-7167 "Commercialization of Photovoltaic Concentrator Systems"
2. Phase I of P.R.D.A. EG-78-D-04-0035 "Photovoltaic Concentrator Applications Experiments"

The Sun Trac™ concept is unique (12 U. S. patent claims allowed and 13 foreign patents filed); prototype pictures are enclosed. This system has been uder test and operated continuously at Sandia Laboratories since April, 1977. This system uses a small 1/4 inch square, silicon solar cell at a sunlight concentration (magnification) of 115. This cell technology does not require the massive expenditures of government funds to reduce the cost of silicon cell (raw material) wafers which is a contingency that "flat panel" competitors always make when estimating low cost modules. Small cells with concentration will result in low dollar per peak watt electrical power because:

1. The "small chip" solar cell with high concentration level requirements fits the present technology of the semiconductor industry much better than large area solar cells because that is the size cell that such companies routinely manufacture in large volume at low cost.

2. The semiconductor companies have the experience of high volume and low cost production.

3. The semiconductor industry is very competitive and these companies are the most likely to have continuous updating of equipment and technology. The Japanese will force them to be even more productive in the future.

4. The present, and expected future, excess production capacity in the semiconductor industry means that these small cells can be quickly put into high volume production and without the need for new capital equipment.

All photovoltaic systems which propose low cost large area solar cells must propose new unproven technology and new plants to manufacture these cells, and massive sustained production volume; all at govenment expense. This risk, cost and lead time is not required with the Sun Trac concept which uses existing technology and manufacturing facilities for solar cells.

At a substained volume production of about 15 MW per year, we believe that we can sell at a lower price than competitive companies.

SUN TRAC CORPORATION PHOTOVOLTAIC BACKGROUND

Sun Trac Corporation, and its parent, Opto Technology, are both "small businesses".

Sun Trac Corporation was incorporated for the purpose of becoming totally committed to solar enegy business. Product capability includes flat panel photovoltaic modules as well as the Sun Trac™ two axis concentrator system. Business plans call for total energy systems where applications can also utilize heat energy. Also offered is complete engineering services including intitial design and evaluation of customer requirements, installation and field service. Consultants are employed to add expertise in certain specialized design areas. The prinicipal personnel of Sun Trac Corporation and Opto Technology were also associated in the manufacture of silicon solar cells and systems at companies such as Solar Systems, Inc., and Hoffman Semiconductor Division. They therefore are most familiar with the design of, manufacture and application of solar cells and other light sensitive semiconductor products.

Sun Trac/Opto Technology has two photovoltaic designs which have been sold for commercial installations.

The enclosed picture is of a preproduction model of a low power Sun Trac™ concentrating array which has been sold to commercial firms in the U.S.A., Saudi Arabia and to Sandia Laboratories and Argonne National Laboratory. This system was designed solely with company funds.

In February, 1978, Sun Trac was awarded a contract from Sandia Laboratories, Contract #07-7167 (Commercialization of Photovoltaic Concentrator Systems). This contract is to develop a module with a 4 square meter aperture and is a reflective, wide acceptance angle, concentrator design with a geometric concentration ratio of more than 100. Power output is expected to be about 425 watts minimum.

Sun Trac Corporation teamed with McGraw-Edison and in Jcne, 1978 was selected for an award of contract under PRDA EG-78-D-04-0035 "Photovoltaic Concentrator Applications Experiments". This is an industrial factory lighting application which will use a 50 KWp solar field consisting of about 110 of the modules designed under Contract #07-7167.

MARKETS

Sun Trac Corporation has placed a heavy business emphasis on the future of solar photovoltaic systems for the commercial market. The business philosophy has been to develop a product which is cost viable in the immediate commercial and government markets. These markets are characterized by an acceptable price of $5 to $10 per peak watt in low quantities and $2 to $5 a peak watt at medium production and less than $2 at high production volume. Near term application sizes generally range from 50 watts peak to about 10 kilowatts peak. Our analysis shows that the Sun Trac Concept, after the intermediate market has pulled production volume, will be contender for the larger scale applications above 1 MW peak.

SUN TRAC^{TM} SYSTEM

Sun Trac^{TM} modules are especially well suited for applications where reliability, minimum maintenance, fast (low-cost) installation, and resistance to vandalism and hostile enviroment are important requirements.

The D.O.E. contract will result in a production model to be completed in October, 1978. Production can begin within 8 months after a decision is made on production volume.

Key technical features are (1) a transparent weathertight sphere to eliminate wind loading and corrosive environmental effects and provide for light-weight, low-cost structure, (2) non-focusing, wide acceptance angle (9 degrees), concentrator matrix for high optical efficiency and simple low-cost tracking, (3) use of small 1/4" diameter, solar cells and 115X concentration which results in (a) versatile, redundant connections with reduction in effects of cell shadowing, (b) low cell current for ease of interconnections, (c) elimination of problems of passive cell cooling and cell thermal stress, (d) adaptation to automated assembly, and (e) maximum reliability.

The Sun Trac design also considered "total costs" which includes shipping and installation costs as well as factory costs. Comparison of f.o.b. factory prices of dollar per peak watt can be very misleading. "Flat panel" photovoltaic modules are usually quoted in the literature at price for the module only without installation required structure. Many studies show the flat panel structure to add about $2 per peak watt to the module price. The Sun Trac module includes the structure because it is a necessary part of the sun tracking array concept. Therefore, a Sun Trac price of, say, $4 per peak watt and a flat panel price of $4 per peak watt are not equivalent because with structure the equivalent flat panel price should be $4 + $2 or $6 per peak watt. For the same production volume of peak watts we believe that the Sun Trac module (with structure) can be sold for the same price as the flat panel module without structure.

Certain competitive tracking systems are designed for high power peak module (1 KW peak or greater). The shipping and installation costs will be large because of the physical size of these systems. Compared to these tracking systems, we believe the Sun Trac modules can be sold at lower installed (including shipping) costs.

Senator DURKIN. I don't know what to say as far as how fast we will be able to move this thing this year, inasmuch as the stampede to leave town grows in intensity every day. But if not, if we don't get it out this year, we will resubmit it in light of the recommendations, in the record early next year, and try to move it as soon as possible.

I want to thank you all very, very much.

Mr. MADISON. Sir, may I make a 2-minute statement on the summary of our position?

Senator DURKIN. Please identify yourself for the record.

STATEMENT OF RAYMOND MADISON, OPTICAL COATING LABORATORY, SANTA ROSA, CALIF.

Mr. MADISON. Raymond Madison from Optical Coating Laboratory in Santa Rosa, Calif. Briefly, we support the immediate implementation of the bill and we believe that photovoltaics are becoming a viable, alternate energy source for selected applications.

The emerging U.S. photovoltaic industry meets Government support through 1988 to stimulate and accelerate U.S. research, development and production, and to motivate U.S. manufacturers and end users to risk investment. For example, we are thin film company by tradition, and we believe we need motivation through industry with Government support to further develop our work in amorphous thin film, which we see as the viable, long-term technology for photovoltaic power.

In applying life cycle cost comparisons of photovoltaics with conventional energy, we recommend that a minimum of 10 percent to 15 percent compound inflation rate per year be applied to convetnional energy forms over the life of the project, and avoid the pitfalls of using simple payback, or first cost alone basis.

Senator DURKIN. I don't know that I understand that statement. What do you mean by that statement?

Mr. MADISON. In the use of life cycle costing for various alternate energy projects compared with conventional forms, typically Government agencies look at simple payback analysis or simple return on investment, or first cost alone basis, and they fail to take into account the long-term of energy.

For example, the true impact of conventional energy is accelerating much greater than the 10- to 15-percent level, that we seek today, for example, in the largest part of the United States. All that we suggest here is look at the real impact of conventional energy, and across the whole calculation.

Senator DURKIN. In other words you would like a formula much similar to the one we used for the cost-benefit ratio on public works projects.

Mr. MADISON. Yes, I believe in the old rates, the old FEA rates of 4-percent inflation rate of conventional energy, which was not realistic in today's economy. Further, we believe the cost sharing provisions of the bill appear adequate to reduce the potentially inflationary impact of increased spending. For example, the bill does stipulate an industry or end user's share of 90-percent level by 1988. We concur with this provision as adequate, that the risk as well as the opportunity should be spread among the industries and end uses alike.

We believe funding is needed now to prevent the foreign dominance by the mid-1980's. Foreign installations of photovoltaics are increasing more rapidly outside the United States. Foreign production will outpace the U.S. production of photovoltaics by the mid-1980's, without immediate U.S. Government support.

It has already been stipulated here today that the Governments of Japan, West Germany, and France, do subsidize their industries. But we can take preventive measures now by cooperating between U.S. Government and industry to keep pace with this foreign development.

Senator DURKIN. If we don't we will have a study some day as to why we lost the market.

Mr. MADISON. Hindsight is always 20–20. We wish to further prevent U.S. dependence on importation of photovoltaics by the late 1980's. So by providing investment on cost-sharing basis, and various technologies with applications and systems, split with the advanced research and development, by percentage that we point out in the testimony, we believe that the United States will be providing seed money to stimulate development, to keep pace with the development of photovoltaic and other alternative power sources in the world. This concludes my summary remarks, and I would be pleased to entertain any questions.

Senator DURKIN. Well, we have a time problem. I do appreciate your coming all the way from the west coast, and your statement will be included in the record in its entirety. If we have any questions we will seek an answer in writing. I think the problem that we have is to see if somehow we can move this bill out of the committee and hopefully stick it into one of the gaps or lulls in that very stimulating debate on natural gas.

I suggest that we limit the natural gas debate to new arguments only, and we probably could have finished it in a day. But my suggestion was not adopted. If there is anything else that goes in the record—we will adjourn subject to the call of the Chair, and I want to thank you all very, very much.

[Whereupon, at 12:10 p.m. the hearing was adjourned.]

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