SOLAR ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACT OF 1974

HEARINGS

BEFORE THE

SUBCOMMITTEE ON ENERGY

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS U.S. HOUSE OF REPRESENTATIVES

NINETY-THIRD CONGRESS

SECOND SESSION

ON

H.R. 15612

JULY 30; AUGUST 2, 1974

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SOLAR ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACT OF 1974

TUESDAY, JULY 30, 1974

U.S. House of Representatives,
Committee on Science and Astronautics,
Subcommittee on Energy,
Washington, D.C.

The subcommittee met, pursuant to notice, in room 2318, Rayburn House Office Building, at 10 a.m., Hon. Mike McCormack presiding.

Mr. McCormack. The meeting of the subcommittee will come to order.

This morning the Subcommittee on Energy begins hearings on H.R. 15612, the "Solar Energy Research, Development, and Demonstration Act of 1974." This bill provides for an aggressive, carefully integrated national program for solar energy research and demonstration.

[H.R. 15612 follows:]

93D CONGRESS
2D SESSION

H. R. 15612

IN THE HOUSE OF REPRESENTATIVES

JUNE 25, 1974

Mr. MCCORMACK (for himself, Mr. TEAGUE, Mr. MOSHER, Mr. GOLDWATER, Mr. DAVIS of Georgia, Mr. WYDLER, Mr. FUQUA, Mr. FREY, Mr. SYMINGTON, Mr. HANNA, Mr. FLOWERS, Mr. ROE, Mr. CONLAN, Mr. COTTER, Mr. CRONIN, Mr. BERGLAND, Mr. PICKLE, Mr. BROWN of California, Mr. MILFORD, and Mr. GUNTER) introduced the following bill; which was referred to the Committee on Science and Astronautics

A BILL

To further the conduct of research, development, and demonstrations in solar energy technologies, to establish a solar energy coordination and management project, to amend the National Science Foundation Act of 1950 and the National Aeronautics and Space Act of 1958, to provide for scientific and technical training in solar energy, to establish a Solar Energy Research Institute, to provide for the development of suitable incentives to assure the rapid commercial utilization of solar energy, and for other purposes.

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 Energy Research, Development, and Demonstration Act of 1974".

I

FINDINGS

SEC. 2. The Congress hereby finds that—

(1) the needs of a viable society depend on an ample supply of energy;

(2) the current imbalance between supply and demand for fuels and energy is likely to persist for some time;

(3) the demands on nonrenewable sources of energy are rapidly becoming unacceptably large and must be augmented;

(4) solar energy offers a nonpolluting inexhaustible source of energy available for the benefit of all mankind;

(5) insofar as practical utilization is concerned, the various solar energy technologies today are at widely differing stages of development, with some already at the stage of commercial application and others still requiring basic research;

(6) the early development and export of viable equipment utilizing solar energy, consistent with the established preeminence of the United States in the field of high technology products, can make a valuable contribution to our balance of trade;

(7) the mass production and use of equipment utilizing solar energy will help to eliminate the depend-

ence of the United States upon foreign energy sources and promote the national defense;

(8) the national effort in research, development, and demonstration activities relating to the utilization of solar energy has been extremely limited; and

(9) the resources of the Federal Government must supplement those of private industry in research, development, and demonstration of solar energy technologies.

POLICY

SEC. 3. The Congress declares that it is the policy of the United States to pursue a vigorous and adequately funded program of resource assessment, research and development, and demonstrations with the objective of utilizing solar energy as a major source for our national energy needs.

DEFINITIONS

SEC. 4. For purposes of this Act—

(1) The term "solar energy" means energy which has recently originated in the sun. It includes direct and indirect solar radiation and intermediate solar energy forms such as wind, ocean thermal gradients, products of photosynthetic processes, organic wastes, and others.

(2) The term "byproducts" includes, with respect to any solar energy technology or process, any solar energy products (including energy forms) other than

those associated with or constituting the primary product of such technology or process.

(3) The term "insolation" means the rate at which solar energy is received at the surface of the earth.

(4) The term "Project" means the Solar Energy Coordination and Management Project established by section 5.

SOLAR ENERGY COORDINATION AND MANAGEMENT PROJECT

SEC. 5. (a) There is hereby established the Solar Energy Coordination and Management Project.

(b) (1) The Project shall be composed of six members as follows:

(A) the Administrator of the Federal Energy Administration;

(B) an Assistant Director of the National Science Foundation;

(C) an Assistant Secretary of Housing and Urban Development;

(D) a member of the Federal Power Commission;

(E) an Associate Administrator of the National Aeronautics and Space Administration; and

(F) the General Manager of the Atomic Energy Commission.

(2) The Administrator of the Federal Energy Administration shall act as Chairman of the Project.

(c) The Project shall have overall responsibility for the provision of effective management and coordination with respect to a national solar energy research, development, and demonstration program, including—

(1) the determination and evaluation of the resource base, including its temporal and geographic characteristics;

(2) research and development on solar energy technologies; and

(3) the demonstration of appropriate solar energy technologies.

(d) (1) The Project shall carry out its responsibilities under this section in cooperation with the following Federal agencies:

(A) the National Science Foundation, the responsibilities of which shall include basic and applied research and overall funding pursuant to section 6 (b);

(B) the National Aeronautics and Space Administration, the responsibilities of which shall include the provision of management capability and the development of technologies pursuant to section 7 (b);

(C) the Atomic Energy Commission, the responsibilities of which shall include the development of technologies;

(D) the Department of Housing and Urban Development, the responsibilities of which shall include fostering the utilization of solar energy for the heating and cooling of buildings; and

(E) the Federal Power Commission, the responsibilities of which shall include fostering the utilization of solar energy for the generation of electricity and for the production of synthetic fuels.

(2) Upon request of the Project, the head of any such agency shall detail or assign, on a reimbursable basis or otherwise, any of the personnel of such energy to the Project to assist it in carrying out its responsibilities under this Act.

(e) The Project shall have exclusive authority with respect to the establishment or approval of programs or projects under this Act, except that the agency involved in any particular program or project shall be responsible for the operation and administration of such program or project.

AMENDMENT TO NATIONAL SCIENCE FOUNDATION ACT OF 1950

SEC. 6. (a) Section 3 of the National Science Foundation Act of 1950 (42 U.S.C. 1862) is amended by redesignating subsections (e) and (f) as subsections (f) and (g), respectively, and by inserting after subsection (d) the following new subsection:

"(e) The Director shall provide support for programs relating to solar energy research, development, and demonstration, as provided in section 6(b) of the Solar Energy Research, Development, and Demonstration Act of 1974.".

(b) (1) The Director of the National Science Foundation shall support and fund solar energy research, development, and demonstration programs initiated and approved by the Project.

(2) The provisions of paragraph (1) shall not be construed as a restriction upon the authority of the Director to support and fund basic research. Such provisions shall not be construed as authorizing the Director to support or fund any demonstration project not included in a program initiated and approved as described in paragraph (1) if such authority is not otherwise granted by any other provision of law.

AMENDMENT TO NATIONAL AERONAUTICS AND SPACE ACT OF 1958

SEC. 7. (a) Section 203 of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2473) is amended by redesignating subsection (b) as subsection (c), and by inserting immediately after subsection (a) the following new subsection:

"(b) The Administration shall carry out research, development, and related activities in solar energy technology, as provided in section 7 (b) of the Solar Energy Research, Development, and Demonstration Act of 1974.".

(b) The National Aeronautics and Space Administration is authorized to undertake and carry out those programs assigned to it by the Project.

RESOURCE DETERMINATION AND ASSESSMENT

SEC. 8. (a) The Project shall initiate a solar energy resource determination and assessment program with the objective of making a regional and national appraisal of all solar energy resources, including data on insolation, wind, ocean thermal gradients, and potentials for photosynthetic conversion. The program shall emphasize identification of promising areas for commercial exploitation and development. The specific goals shall include—

(1) the development of better methods for predicting the availability of all solar energy resources, over long time periods and by geographic location;

(2) the development of advanced meteorological, oceanographic, and other instruments, methodology, and procedures necessary to measure the quality and quantity of all solar resources on periodic bases;

(3) the development of agreements and programs with other countries to facilitate the exchange of in-

formation and data relating to solar energy resource assessment; and

(4) the development of activities, arrangements, and procedures for the collection, evaluation, and dissemination of information and data relating to solar energy resource assessment.

(b) The Project, acting through the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, and other appropriate agencies, shall—

(1) develop and carry out a general plan for inventorying all forms of solar energy resources associated with Federal lands and (consistent with property rights) non-Federal lands;

(2) conduct regional surveys based upon such general plan, using innovative meteorological, oceanographic and space-related techniques, in sufficient numbers to lead to a national inventory of solar energy resources in the United States;

(3) publish and make available maps, reports, and other documents developed from such surveys to encourage and facilitate the commercial development of solar energy resources; and

(4) make such recommendations for legislation as

may appear to be necessary to establish a Federal leasing policy for solar resources (including public lands and waterways to be devoted to the collection of direct or indirect solar radiation or to the utilization of photosynthetic processes) consistent with known inventories of various resource types, with the state of technologies for solar energy development, and with evaluation of the environmental impacts of such development.

RESEARCH AND DEVELOPMENT

SEC. 9. (a) The Project shall initiate a research and development program for the purpose of resolving the major technical problems inhibiting commercial utilization of solar energy in the United States.

(b) In connection with or as a part of such program, the Project shall—

(1) perform basic research in all aspects of solar energy in order that basic limitations are better understood and ultimate potentials realized, and in order that signficant practical applications can be made to national energy requirements;

(2) carry out systems, economic, social, and environmental studies to provide a basis for research and development planning and phasing; and

(3) perform or cause to be performed technology assessments relevant to the utilization of solar energy.

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(c) The specific solar energy technologies to be addressed or dealt with in the program shall include—

(1) solar heating and cooling of housing and of commercial and public buildings;

(2) direct solar heat as a source for industrial processes, including the utilization of low level heat for process and other industrial purposes;

(3) thermal energy conversion, and other methods, for the generation of electricity and the production of chemical fuels;

(4) the conversion of cellulose and other organic materials (including wastes) to useful energy or fuels;

(5) photovoltaic and other direct conversion processes;

(6) sea thermal power conversion; and

(7) windpower conversion.

(d) The Project shall implement a coordinated program of research and development in order to demonstrate the technical means for securing and utilizing the resource base, including any byproducts of such base, with specific attention being directed to—

(1) the improvement of technical capability to predict environmental impacts resulting from the development of solar energy resources, and the assuring of

compliance with applicable standards and performance criteria;

(2) the identification of social, legal, and economic problems associated with solar energy development (locally, regionally, and nationally) for the purpose of developing policy and providing a framework of policy alternatives for the commercial utilization of solar energy resources;

(3) the provision of an adequate supply of scientific and engineering manpower to perform the necessary solar energy research and development activities; and

(4) the development of agreements and programs with other countries to facilitate the exchange of information and to support cooperative research and development programs relating to solar energy.

DEMONSTRATION

SEC. 10. (a) The Project shall initiate a program to design and construct, in each of the specific solar energy technologies referred to in section 9 (c), facilities or powerplants of sufficient size to demonstrate the technical and economic feasibility of utilizing the various forms of solar energy. The specific goals of such program shall include—

(1) the development of economical solar heating and cooling systems and components which meet performance and environmental standards;

(2) the design and construction of solar thermal electric powerplants;

(3) the design and construction of electric powerplants utilizing direct conversion processes;

(4) the design and construction of electric powerplants utilizing windpower;

(5) the evaluation of designs (and construction, if feasible) of plants generating electricity utilizing ocean thermal gradients;

(6) the design and construction of plants utilizing organic materials (including wastes) to produce electricity or synthetic fuels;

(7) the utilization of all thermal and other byproducts from any of the plants referred to in the preceding paragraphs;

(8) the design and development of hybrid systems involving the concomitant use of solar and other energy sources;

(9) the continuous operation of such plants for a period of time;

(10) the provision of experimental test beds for component testing and evaluation by laboratories operated by the Federal Government, industry, or institutions of higher education; and

(11) the provision of an adequate supply of trained

solar energy engineers and technicians to carry out the demonstrations provided for under this section.

(b) (1) In carrying out its responsibilities under this section, the Project may provide for the establishment of a separate demonstration project with respect to each solar energy resource base involved; and each such project shall include, as appropriate, all of the resource determination, siting, pilot plant construction and operation, demonstration plant construction and operation, and other facilities and activities which may be necessary for the generation of electric energy, the heating and cooling of buildings, the production of synthetic fuels, and the utilization of by-products.

(2) Plants and other real property utilized or involved in any demonstration project under this section may be purchased, leased, constructed, or otherwise established or obtained by the Project through the appropriate Federal agencies. Such agencies may obtain such plants and other real property under appropriate contracts or arrangements with other public or private persons or agencies.

(3) (A) During the conduct of any demonstration project under this section the agency designated by the Project to conduct such project shall take such steps as may be necessary to dispose of all of the electric energy and other

byproducts of such project, in such manner and on such terms and conditions as such agency may determine to be feasible and in support of the objectives of this Act.

(B) To the maximum extent possible the disposition of byproducts under paragraph (1) shall be accomplished through the sale of such byproducts for commercial utilization, on such terms and conditions and in accordance with such plans as such agency may prescribe or develop.

(4) At the conclusion of the program under this section or as soon thereafter as may be practicable, the agencies designated by the Project to conduct demonstration projects under this section shall, by sale, lease, or otherwise, dispose of all projects which they have undertaken pursuant to this section on such terms and conditions as such agencies determine to be reasonable, or, if the disposition of any such project or any part thereof on reasonable terms and conditions is not possible or feasible, the agency involved shall under appropriate contracts or other arrangements provide for the disposition of all of the electric energy and other byproducts of such project or part thereof.

(5) In selecting solar energy technologies for demonstration under this section, preference shall be given to those with the best opportunity for commercial success and environmental acceptability.

SCIENTIFIC AND TECHNICAL EDUCATION

SEC. 11. (a) It is the policy of the Congress to encourage the development and maintenance of programs through which there may be provided the necessary trained personnel to perform required solar energy research, development, and demonstration activities under sections 8, 9, and 10.

(b) The National Science Foundation is authorized to support programs of education in the sciences and engineering to carry out the policy set forth in subsection (a). Such support may include fellowships, traineeships, technical training programs, technologist training programs, and summer institute programs.

(c) The National Science Foundation is authorized and directed to coordinate its actions, to the maximum extent practicable, with the Project or any permanent Federal organization or agency having jurisdiction over the energy research and development functions of the United States, in determining the optimal selection of programs of education to carry out the policy set forth in subsection (a).

(d) The National Science Foundation is authorized to encourage, to the maximum extent practicable, international participation and cooperation in the development and maintenance of programs of education to carry out the policy set forth in subsection (a).

SOLAR ENERGY RESEARCH INSTITUTE

SEC. 12. (a) There is established a Solar Energy Research Institute, which shall perform such research, development, and related functions as the Chairman of the Project may determine to be necessary or appropriate in connection with the Project's activities under this Act or to be otherwise in furtherance with the purpose and objectives of this Act.

(b) The Institute may be located (as designated by the Chairman of the Project) at any new or existing Federal laboratory (including a private laboratory performing functions under a contract entered into with the Project or with any of the agencies represented in the Project as well as a laboratory whose personnel are Federal employees).

SOLAR ENERGY TECHNOLOGY UTILIZATION

SEC. 13. (a) (1) In carrying out his functions under this Act the Chairman of the Project, utilizing the capabilities of the National Science Foundation, the National Aeronautics and Space Administration, the Department of Commerce, the Atomic Energy Commission, and other appropriate Federal agencies to the maximum extent possible, shall establish and operate a Solar Energy Information Data Bank (hereinafter in this subsection referred to as the "bank") for the purpose of collecting, reviewing, processing, and disseminating information and data in all of the solar energy technologies referred to in section 9(c) in a timely and accurate manner in support of the objectives of this Act.

(2) Information and data compiled in the bank shall include—

(A) technical information (reports, journal articles, dissertations, monographs, project descriptions, etc.) on solar energy research, development, and applications;

(B) similar technical information on the design, construction, and maintenance of equipment utilizing solar energy;

(C) physical and chemical properties of materials required for solar energy activities and equipment; and

(D) engineering performance of equipment and devices utilizing solar energy.

(3) In accordance with regulations prescribed under section 15, the Chairman shall provide retrieval and dissemination services with respect to the information described under paragraph (2) for—

(A) Federal, State, and local government organizations that are active in the area of energy resources (and their contractors);

(B) universities and colleges in their related research and consulting activities; and

(C) the private sector upon request in appropriate cases.

(4) In carrying out his functions under this subsection, the Chairman shall utilize, when feasible, the existing data base of scientific and technical information in Federal agencies, adding to such data base any information described in paragraph (2) which does not already reside in such base.

(b) The Chairman of the Project shall establish a solar energy incentives task force comprised of such individuals and organizations as he may consider appropriate to carry out the following functions: (1) report to the President and the Congress within one hundred and twenty days following the date of the enactment of this Act, and at least annually thereafter, recommendations for a viable program of specified, time limited, incentives or modifications to existing or proposed incentive programs to accelerate the commercial application of solar energy technology; and (2) carry on a program of research and investigation into the barriers to innovation in the field of solar energy, the barriers to the acceleration of the commercial application of solar energy technology, and the programs needed to remove such barriers.

(c) The Chairman of the Project shall enter into such arrangements and take such other steps as may be necessary or appropriate to provide for the effective coordination of solar energy technology utilization with all other technology utilization programs within the Federal Government.

REPORTING REQUIREMENTS

SEC. 14. Each Federal officer and agency having functions under this Act shall include in his or its annual report to the President and the Congress a full and complete description of his or its activities (current and projected) under this Act, along with his or its recommendations for legislative, administrative, or other action to improve the programs under this Act or to achieve the objectives of this Act more promptly and effectively. In addition, the Chairman of the Project shall submit annually to the President and the Congress a special report summarizing in appropriate detail all of the activities (current and projected) of the various Federal officers and agencies having functions under this Act, with the objective of presenting a comprehensive overall view of such programs.

REGULATIONS

SEC. 15. The Chairman of the Project, in consultation with the heads of the Federal agencies having functions under this Act and with other appropriate officers and agencies, shall prescribe such regulations as may be necessary or appropriate to carry out this Act promptly and efficiently. Each such officer or agency, in consultation with the Chairman, may prescribe such regulations as may be necessary or appropriate to carry out his or its particular functions under this Act promptly and efficiently.

TRANSFER OF FUNCTIONS

SEC. 16. Within sixty days after the effective date of the law creating the Energy Research and Development Administration or any other law creating a permanent Federal organization or agency having jurisdiction over the energy research and development functions of the United States (or within sixty days after the enactment of this Act if the effective date of such law occurs prior to the enactment of this Act), all of the research and development functions (and other functions) vested in the National Science Foundation and the National Aeronautics and Space Administration under this Act (and under the amendments made by sections 6(a) and 7(a)), along with related records, documents, personnel, obligations, and other items to the extent necessary or appropriate, shall, in accordance with regulations prescribed by the Office of Management and Budget, be transferred to and vested in the Energy Research and Development Administration or such other organization or agency.

INFORMATION TO CONGRESS

SEC. 17. Notwithstanding any other provision of law, the Chairman of the Project (or the head of its successor agency) shall keep the appropriate committees of the House of Representatives and the Senate fully and currently informed with respect to all activities under this Act.

COMPREHENSIVE PROGRAM DEFINITION

SEC. 18. (a) The Chairman of the Project is authorized and directed to prepare a comprehensive program definition of an integrated effort and commitment for effectively developing solar energy resources. Such Chairman, in preparing such program definition, shall utilize and consult with the Federal Energy Administration, the National Science Foundation, the Department of Housing and Urban Development, the Federal Power Commission, the National Aeronautics and Space Administration, the Atomic Energy Commission, and other appropriate Federal agencies, State and local government agencies, and private organizations.

(b) The Chairman of the Project shall transmit such comprehensive program definition to the President and to each House of the Congress. Interim reports shall be transmitted not later than October 31, 1974, and not later than January 31, 1975. The comprehensive program definition shall be transmitted as soon as possible thereafter, but in any case not later than June 30, 1975.

AUTHORIZATION OF APPROPRIATIONS

SEC. 19. (a) There is authorized to be appropriated to the National Science Foundation for the fiscal year ending June 30, 1976, not to exceed $2,000,000 to be made available for use in the preparation of the comprehensive program definition under section 18.

(b) There are authorized to be appropriated to carry out this Act, for fiscal years beginning after June 30, 1976, such sums as the Congress may hereafter authorize by law.

Mr. McCormack. Our series of solar energy hearings held during the last few months has produced a thorough record on the technical aspects of utilizing various forms of solar energy. Today and Thursday, therefore, we will concentrate on the funding and administrative structure which we need to mount the kind of effort envisioned in the bill.

Incidentally, I detected, I thought, some confusion down at the table. There are two bills. I think you have the second one, but they are equal bills.

Mr. Sawhill. All right.

Mr. McCormack. Several considerations guided us in drafting the legislation and, I think, will serve as a good starting point for our discussion. First, to insure effective coordination and to avoid redundancy of effort, all Federal solar energy activities must be placed under unified management authority. Second, no technological effort in solar energy can contribute significantly to the solution of the energy crisis if it stops short of commercial demonstration. Third, as far as funding is concerned, we feel that a sound, systematic program definition is a necessary prerequisite to rational funding decisions.

Solar energy has very significant advantages as an alternative energy source: It is free; it is clean; and its supply can never be cut off. The Congress has already taken the initiative in solar energy development by passing the Solar Heating and Cooling Demonstration Act of 1974, which is now in conference and which we hope to have out this week. The Solar Energy Research, Development, and Demonstration Act is directed at those solar technologies which, unlike solar heating and cooling, are not ready for immediate commercial demonstration. This is the crucial next step in getting positive, realistic programs underway to help solve the energy crisis now.

The Senate Interior Committee has already held hearings on companion legislation introduced by Senators Humphrey, Jackson, and others. I hope both they and we can move the bills rapidly toward enactment.

Today we are honored to have with us spokesmen from three Federal agencies which are concerned with the practical use of solar energy.

Our first witness is Mr. John C. Sawhill, Administrator of the Federal Energy Administration. John, we certainly welcome you today and invite you to introduce the staff members whom you have brought with you. If you want, you may submit your testimony for the record and then proceed as you like.

STATEMENT OF MR. JOHN C. SAWHILL, ADMINISTRATOR, FEDERAL ENERGY ADMINISTRATION

Mr. Sawhill. Thank you very much, Mr. Chairman. We are delighted to join you in a discussion of House bill 15612, which I think is what we are discussing today, although our testimony says H.R. 15635.

Mr. McCormack. We can use the numbers interchangeably. It won't make a bit of difference.

Mr. Sawhill. With me today is Dr. Alvin Weinberg, Director, Office of Energy Research and Development; Mr. Duke R. Ligon, Assistant

Administrator, Energy Resource Development of FEA; and Mr. Robb Thomson, technical assistant to the Director, Office of Energy Research and Development, FEA.

GENERAL OBSERVATIONS ON SOLAR ENERGY

As you know, there are many ways to capture solar energy and convert it to useful purposes, including direct heating and cooling of buildings, hydropower, bioconversion, central station thermal conversion, photovoltaics, winds, ocean thermal gradients and wave action, river and ocean currents. In some of these techniques (solar thermal, etc.), the sunlight is used directly, while on others (wind etc.), the energy is a secondary effect of sunshine (solar's "children").

In my mind there are two generic reasons for Government involvement in this area, one technical and one economic. You have already heard in some detail from the scientific community on the technical aspects of solar energy in your background hearings on this bill, but with your indulgence, I would like to sketch briefly the perspective we in FEA have on the matter.

The basic technical facts are well known. The total radiation on the planet is an extremely large quantity compared to human needs. In concrete terms, the solar energy incident on a mere 5,000 square miles of the Earth is equal to the entire energy consumption in 1970 in the United States. Thus, the continuing supply of solar energy is enormous. In addition, it also has the important feature of being renewable forever. Third, and perhaps most important, solar energy comes to the Earth in a natural and unpolluting form, so that its use should have a minimum impact on public health and the environment. Thus, the advantages of solar energy as a major national energy source are very high.

However, in spite of this great potential, the practical application of solar energy is very difficult. Engineering and economic roadblocks are the reasons solar energy is not now widely used. Simply put, solar engineering is a problem because the general trend in modern engineering relating to energy is toward ever higher temperatures and energy densities limited only by the capabilities of the confining materials, while solar energy represents a technology of an opposite type. Basically, solar energy is a low temperature form of energy, and it is very diffuse, requiring collection over large areas with the attendant distributed bulk and complicated plumbing, mirrors, et cetera. Engineering infeasibility is, of course, simply another way of saying that solar energy costs are high, which brings me to the other reason why solar energy has not provided the panacea many would seek, and why the Government has a large role to play now and in the future as we develop this resource.

The high cost of solar energy relative to the more concentrated fossil and nuclear fuels has the consequence that there is no present significant industrial base in the private sector developing and marketing terrestrial solar energy systems and devices. Therefore, to the extent that there exists a national interest in developing solar energy, then it will be necessary for the Government to be involved in it. Of course, in our view, the three goals of energy self-sufficiency, energy cleanliness, and adequate energy availability (through programs in energy conservation and augmented supply) provide adequate driving force for the national interest of which I speak.

Over and beyond these very general points, we believe solar energy has a special importance, which I would like to explain. In analyzing the entire energy R. & D. picture recently, I have asked Dr. Weinberg's staff at FEA to focus its attention on a small number of central issues. In doing so, and in making judgments about these issues, we have had to visualize plausible, long-term energy futures. One that seems highly plausible involves a mix of nuclear (fission or fusion) and solar. As a matter of fact, Dr. Weinberg and I were discussing some figures this morning, indicating one plausible scenerio is that by the year 2000 we could be consuming between 15 percent and 20 percent of our total energy from solar energy—in other words, about 37×10^{15} Btu out of an estimated consumption of 200×10^{15} Btu. It is therefore, in our minds of the utmost importance to establish as rapidly as possible whether solar can indeed play so central a role in our long-term energy future. Our reasoning is that the state of solar energy technology is such that it is impossible to judge at this time whether the commercial costs of solar power can ever be brought low enough to compete with fossil and nuclear power.

Briefly, the capital costs for nuclear power are estimated to be in the neighborhood of $500 per kilowatt. Present solar power costs are much higher than this, but estimates of eventual costs vary widely because of the large extrapolation necessary. In addition, no experience has been obtained in construction of the large solar systems. Often, estimates of labor and maintenance are difficult to make. Another factor is the problem of intermittent operations of solar devices due to clouds, wind changes, et cetera, and the necessity to install a large storage capacity. Overall electric power system compatibility has also not yet been explored.

The stakes being what they are in the competition between fossil, nuclear, and solar, it is therefore imperative that the solar power R. & D. program be funded at a level sufficient to assure for energy policy reasons that firm estimates of these costs can be obtained as quickly as possible. Solar heating and cooling of buildings, although not singled out for special attention, is important also because it has the most promise for commercial feasibility of all the solar energy technologies in the short term.

THP SOLAR R. & D. PROGRAMS

I will not attempt a complete analysis of the R. & D. issues in solar energy, because Administration spokesmen following me will be speaking more directly to these points. However, I believe a few comments are needed to illustrate our conclusion that solar energy is a major issue in energy R. & D.

As the lead agency, NSF has structured the program in six categories. These are: (1) solar heating and cooling of buildings, (2) wind energy conversion, (3) photovoltaic conversion, (4) solar thermal conversion, (5) ocean thermal conversion, and (6) bioconversion.

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In the area of house heating, the major problem is to bring down the costs by the exhaustive engineering and attention to detail which goes on during product development and during the initial stages of commercialization. Presently, the costs are too high, and they can be brought down only after commercial organizations gain experience and develop scale.

This process will have to be Government-assisted in many ways in order to cut the time required. An important research problem in solar heating is to develop heat pumps for a mixed or hybrid system which makes the best use of solar power and conventional electrical heating in climates where solar heating cannot carry the entire load. Also, before solar cooling of houses can become feasible, it will be necessary to develop a practical absorption refrigeration system which can operate at the low temperatures typical of solar applications. That development will require considerable additional research.

The major research challenge for solar energy rests in the area of generation of electrical power. For example, photovoltaic devices for generating electricity directly from the Sun have been developed in the space program, but are too costly by a factor of about 100. To decrease these costs will require a major research effort. Similarly, the development of practical methods for concentrating enough solar energy to run a large size steam turbine and to couple the turbine or other conversion device to the solar flux will require research also on a large scale. Also, since solar energy is intermittent, provision must be made for large amounts of energy storage in batteries, fly wheels, or other devices. No practical method yet exists for handling the large storage which will be needed.

Wind energy conversion is an example of a secondary form of solar energy in the sense that wind is the result in the atmosphere of the heating of the surface of the Earth by the Sun. Exploitable wind energy, that is average wind of greater than about 12 mi/h, is not so widely available as direct solar radiation, but there are enough locations in the Great Plains, the Northeast coast and, incidentally, on some drilling platforms, et cetera, where the wind is sufficiently intense and constant to be of real interest. This technology, like building heat and cooling, is also relatively near term, because of previous experiments with wind turbines, and because of the sophisticated aerodynamics already developed for aircraft. Large prototypes of megawatt size are expected to be under evaluation by fiscal year 1976.

In all forms of solar energy, cost is the crucial factor. However, cost becomes an overriding consideration in the case of those systems which have a potential for generating a large fraction of our electrical energy needs, for the reasons we have already discussed in regard to the competition with nuclear. Unfortunately, except for the case of wind, which does not have the potential to develop all or most of our total electric power, the technology is still sufficiently in the research stage for ultimate costs to be very uncertain. Thus, it is imperative for us to get on with the development of solar energy in the most expeditious manner possible.

I have spent this first portion of my time with you in covering background material because, as the first administration spokesman before you, I feel that the basis for the Government involvement in solar energy and its general thrust must be clearly stated. Let me turn now to some of the administrative and funding issues.

COMMENTS ON H.R. 15635

I would like to begin by commenting on the Senate and House bills. Both bills contain provision for ultimate transfer of the solar energy research function to a Federal organization having jurisdiction over energy research and development should such legislation be enacted. I support this provision in both bills.

However, in the absence of the creation of the energy research and development administration or comparable agency, House bill 15635 creates a Solar Energy Coordination and Management project composed of the key officials in the cognizant energy research agencies. By comparison, Senate bill 3234 creates an Office of Solar Energy Research within the Atomic Energy Commission to perform these functions. We have discussed the need for special interim organizations to deal with particular energy R. & D. areas in the context of the geothermal bills so you know our general views on the subject. The administration still feels that ERDA should be enacted as soon as possible and that no interim organization is required. As you know, the NSF is currently the lead agency in solar energy R. & D., and is pursuing a vigorous program.

You have asked my views on the funding authorization arrangements in the bill. Generally speaking, I believe them to be sound. An interagency solar energy panel is currently preparing a 5-year plan for the Government organization, and presumably their report could serve as the basis for the comprehensive program definition as described in section 18. The timing of the required submissions, of course, should reflect adequate time for preparation after the project is formed.

You have asked specifically if a total cost of the project should be authorized in the beginning. I do not believe that would be wise in view of the early stages some aspects of solar energy technology are currently in. On the other hand, as explained earlier, buildup in the program should proceed as quickly as sound management will allow.

On the matter of incentives to promote rapid commercial utilization, I agree that these issues are central to the success of the program. Solar energy has the potential to encompass so many different sectors of American life and industry that it defies exhaustive comment at this time. Each of the separate technologies will require separate analysis. In broad terms, administrative flexibility and ingenuity will be required across the whole front from information flow to Government regulations, and considerable interagency activity will be required.

I can conceive of situations where demonstration programs may not be necessary at all, for example, in water heating, while in others, relatively massive demonstration programs may be required which slowly fade into non-subsidized Government markets as the commercial sector picks up speed. We, therefore, believe that mandated demonstrations in all areas as specified in section 10 of H.R. 15635 is too rigid in view of the needed flexibility. The comprehensive program definition is the appropriate place and time for a more complete discussion of this point.

SOLAR LABORATORIES

The bill creates a Solar Research Institute to carry out the solar R. & D. program. This is a new attractive approach that deserves serious study. I would, therefore, like to devote the rest of my testimony to this subject.

Solar energy as a major source of primary electric energy is beset with many uncertainties. Much of this uncertainty stems from the relatively small effort that has been devoted thus far to solar energy. The scientific feasibility of solar energy in most of its various manifestations is not at issue, but it is impossible at this time to predict when, if ever, large-scale solar central power generation will become a technical and commercial reality. Solar energy thus shares with fusion, and to some degree with fission breeders, the uncertainty of timing. No one can now say how long it will take to develop solar central power generation, or what energy from such a source will cost.

This long-term character of solar research and related lack of commercial incentive suggests that the laboratories that conduct research for solar ought to possess a longevity and stability that matches the long-term character of solar research itself. One way of achieving these objectives would be to organize solar energy research around one or a few solar energy institutes or laboratories as a part of the ERDA. In this way, scientists of all disciplines who are interested in and committed to the solar dream will be able to form a community dedicated to that goal. Only the best science can survive in such a setting; solar energy research deserves no less.

We note, however, that in one version of the ERDA legislation, responsibility for only part of the NSF solar program, that for heating and cooling of buildings, is transferred to ERDA. This, we believe, is unduly restrictive; ERDA should bear the central Federal responsibility for all solar R. & D. in the event that agency is created.

A solar institute might be comparable in character to, though probably smaller than, the national Nuclear Energy Laboratories. One attractive possibility would be to designate parts of existing laboratories, like Los Alamos, or Sandia or a NASA laboratory as solar laboratories, and presumably the administrator of ERDA, if that agency is created, will decide on this matter. This pattern has been used in fusion research; there are four fusion laboratories—Princeton, Las Alamos, Livermore, and Oak Ridge. Each fusion laboratory possesses longevity and stability as is appropriate for conducting long-term research and development on an open-ended though potentially commercial important energy system.

A natural structure might be a mix of stable and fairly large solar institutions and university or industry-based contracts and grants. The main point, however, is that a structure be organized wherein the long-range commitment to solar energy can be nurtured and where much of the long-term planning and research initiative can be delegated away from Washington. This will be the case if laboratories dedicated to solar energy are sufficiently independent and stable, and their continued survival is not an issue because they are part of some interim solution or organization. On the other hand, the performance of these laboratories must be subject to ongoing budgetary and management scrutiny. Most important, there must develop between the laboratory management and the Washington bureau the kind of mutual trust and understanding that has characterized the most successful arrangements—notably, the AEC weapons laboratories and the NASA laboratories.

I would stress again that the whole matter of an institute deserves further careful study, and that the administrator of ERDA should be the central figure in this study.

In conclusion, I want to emphasize the point that the administration as a whole, and the Federal Energy Administration in particular, believe that it is definitely in the national interest to establish an important role of solar energy in our Nation's future. This is a commitment that is reflected in the rapid growth of our budget requests for solar energy over the past several years. It is a commitment that carries into the future through the President's 5-year energy R. & D. program, and through our continuing desire to try varied approaches to solve these problems (such as through solar labs) if they can be managed through a proper organization. These are the first, but they are not the last, of the necessary and effective actions we must take as we move to meet our commitment to solar research.

Thank you very much, Mr. Chairman. I certainly would be happy to answer your questions.

Mr. McCormack. Thank you, Mr. Sawhill. I want to make a couple of very quick comments and then I am going to ask the other members of the committee to ask their questions first.

I would like to expand on one point you made on page 12 of your testimony when you talked about the fact that under the proposed ERDA legislation only the solar heating and cooling of buildings is included in ERDA and presumably all other solar energy research demonstration would be someplace else.

In a real sense then, this legislation would actually expand the mission of ERDA if ERDA came into being. I think this is a very important concept.

Mr. Sawhill. Yes.

Mr. McCormack. In a de facto sense, it really enlarges the scope of ERDA by first creating this solar energy research management project and then, having established it, transferring it later to ERDA or a similar organization

In a sense, what we are doing is correcting what I think was one of the original weaknesses in the ERDA legislation.

Mr. Sawhill. Yes.

Mr. McCormack. I want to say that I very much appreciate your comment that solar energy research and development should be independent and stable and your comparison of a solar energy institute to the laboratories managed by the Atomic Energy Commission and by NASA.

One thing that is absolutely essential in this entire program is our ability to develop long-range solar energy research and development programs and to know in advance that they are indeed long-range, continuing research programs. There is no way that we can conduct a viable research, development, and demonstration program in energy, and in particular in solar energy, if we are going to be uncertain from year to year what we have or who is going to be doing it or how much money is going to be appropriated for it.

Mr. SAWHILL. Yes. I think this is the reason to establish these laboratories as separate, independent institutions, not physically separate necessarily from existing laboratories but physically separate from Washington certainly.

Mr. MCCORMACK. Thank you.

Mr. Brown, do you care to ask questions?

Mr. BROWN. I have just a brief question. I appreciate the testimony of Mr. Sawhill. I perceive a very obvious and definite commitment to the importance of solar energy and the research and development necessary to make it practical. Frankly, I think the concern of this committee has been more to see that that attitude developed in the administration than to advocate the details of specific legislation.

In your statement you indicate that you have already proceeded with the organization of an interagency panel, which is in effect going through this project definition phase of solar energy R. & D. As you note, this is one of the things stipulated in section 18 of the bill.

Just as a matter of clarifying the record, how have you set this panel up? What are its constituent members? What kinds of guidelines have you given to this panel?

Mr. SAWHILL. We felt very strongly that, when the goal of Project Independence was announced—that is, to step up the energy resource development effort in the country and also the energy conservation effort so that by 1980 we would no longer be vulnerable to an Arab oil embargo—that we should review our whole 5-year energy research and development plan to make sure that its goals were consistent with those of Project Independence.

So Dr. Weinberg joined the FEA and established an interagency panel, which I believe consists of the National Science Foundation, the Department of Interior, the AEC, and NASA, to study the whole solar research program that had been put forward in the 5-year energy research and development program to insure that its goals were consistent with Project Independence and did not need to be expanded. We currently have a draft report from that panel, which is quite comprehensive. We will certainly be glad to make it available to the committee when that does become available. But they have done considerable work to review all of the different fields of solar energy that I touched on, like wind energy conversion and solar thermal conversion, and so forth.

The objectives of the panel are very similar to the objectivs of the legislation. What the legislation would do would be to make this a permanent, ongoing management organization.

Mr. BROWN. This committee would like to have the benefits of that study. I presume it will be possible to obtain that at the appropriate time?

Mr. SAWHILL. Yes, sir.

Mr. Brown. I know this is somewhat extraneous, but you have referred to the importance of energy conservation several times. Do you happen to have a similar interagency panel or other mechanism exploring the possibilities of energy conservation in terms of this 5-year program?

Mr. Sawhill. Yes; we do. It is looking at a broad range of options, including expanding funds for public transportation, as well as looking at ways of making more energy efficient in cars, and providing economic incentives for insulating homes. It's also coming up with a very comprehensive report on what we can do to reduce the growth rate in energy demand.

Mr. Brown. I for one, and I'm sure other members of this committee would join me, attach a great deal of importance to that type of study.

Mr. Sawhill. Thank you.

Mr. Brown. I have no further questions at this time, Mr. Chairman.

Mr. McCormack. Thank you.

Mr. Wydler?

Mr. Wydler. Thanks, Mr. Chairman.

It's good to have you here today, John.

Mr. Sawhill. Thank you, Mr. Wydler.

Mr. Wydler. I want to congratulate you and your organization on the job you're doing.

Mr. Sawhill. Thank you.

Mr. Wydler. Can you tell me what is the current situation with the ERDA legislation? It's in the background of your testimony. Can you give us a little clearer idea of the situation for purposes of trying to project where we really are?

Mr. Sawhill. The bill has passed the House of course, and in the Senate the bill has come out of committee and is waiting to go to the floor. Of course there are differences between the House and Senate bills so, in the event the bill passes the Senate, there will be some reconciliation to do between the two bills.

Mr. Wydler. There is still no action in the Senate?

Mr. Sawhill. No, there is no action.

Mr. Wydler. I presume that one of your problems with legislation of this type is the fear or concern that if we pass this kind of bill we will have everything running that ERDA could do anyway, so the pressure to have ERDA will lessen.

Mr. Sawhill. I don't think we are so concerned with that.

Initially we felt we were going to get ERDA through very quickly. Now the prospects, every day that goes by, indicate that there is some less prospect of getting the ERDA legislation passed, although of course we are still supporting it.

Our feeling was that setting up this and then immediately getting the ERDA legislation would be somewhat redundant. That was the reason, when we testified on the geothermal bill, we talked about the advisability of structuring in legislation a formal interim organization which then would be replaced by ERDA. I think this was taken into account in this bill, and also in the geothermal bill, by providing that once ERDA was created this management project would become a part of the ERDA organization.

Mr. WYDLER. The bill does that. It seemed to me fairly obvious that if we passed all the bills concerning all the activities that ERDA would undertake, gave them all these management projects and a home to operate out of, then of course the pressure to have ERDA at all is somewhat diminished.

Mr. SAWHILL. Somewhat, although I think there still is pressure to bring all research and development together so that priorities can be established. These management projects would still be somewhat independent of each other, except to the extent that you had the same people serving on the management projects and the same chairman of the management projects.

Mr. WYDLER. If I understand what you are saying, you say if this type of legislation were passed you would like the operator of it to be the National Science Foundation?

Mr. SAWHILL. Yes; I think they are the lead agency for solar energy.

Mr. WYDLER. Do you think they are properly organized to carry out the functions as set forth in this bill?

Mr. SAWHILL. The National Science Foundation has moved very aggressively in the field of solar energy and probably has more expertise than anyone else in the Government. I am not sure that I am in a position to say whether they are better than NASA might be, for example. I think both agencies would be in a good position to operate the program.

Mr. WYDLER. Maybe Dr. Weinberg would like to comment on this next question. During the course of our hearings we had some testimony on the form of solar energy I had never heard of before. That was in effect to use the differences in water temperature in the oceans as a method of generating energy and electricity. It seemed like a fascinating proposal. I don't know how practical it is. How practical is that proposal?

Dr. WEINBERG. Mr. Wydler, you might recall that in the bill there is something described as ocean temperature differences. The idea there is that in many parts of the ocean, particularly in the Caribbean, there is about a 40-degree Fahrenheit difference between the top of the ocean and the bottom of the ocean. That difference can be used to run a very low efficiency steam generator. As a matter of fact, a French inventor by the name of Claude in the 1920's actually built a huge device. I think he intended it to produce 8,000 kilowatts of electricity. I don't know whether it ever did produce that much. It wasn't successful at the time. Since then there has been a good deal in France in using other working fluids than Claude used.

It's one of those possibilities that has very strong, ardent and articulate, emotionally committed people. Then there are the skeptics who say the best way to use the cold water on the ocean is simply to take the reject heat from a powerplant that is located on the ocean, put what is called a bottoming cycle on that powerplant and simply use that cold water at the bottom of the sea as a cooling water for the condenser for the bottoming cycle that is attached to the affluence of the powerplant.

Of the various solar modalities, ocean thermal gradients is one that has its proponents, very ardent, very articulate, very able people, and it has its skeptics.

The intent and the viewpoint of my own office is that this is an idea that should be looked at again with modern technology, that the Claude idea was not a bad idea in some ways and there have been advances since then, so let's look at it again.

Mr. WYDLER. It's an idea whose time has not come?

Mr. SAWHILL. It's very difficult to say, Mr. Wydler. We really don't know. As I say, it's a matter that creates a great deal of emotional discussion among proponents and opponents.

Mr. WYDLER. Mr. Sawhill, a general question on this whole energy situation. A few months ago, it wasn't too many, energy was the No. 1, 2 and 3 topic of discussion in the country and in the Congress. It seems to have slipped a bit since then. Do you feel a loss of momentum in either the administration's or the Congress' handling of the problems relating to the development of energy for our country?

Mr. SAWHILL. There is no question that we are not as frantic about energy as we once were and it's not on the front pages of the newspapers every day. To some extent I welcome that, because it's giving us and the Federal Energy Administration, and I think the Congress as well, an opportunity to really reflect on what a national energy policy should be for this country.

We are in the process of preparing a blueprint for Project Independence which we hope to have ready by November. This will lay forth our broad recommendation for a national energy policy.

The fact that the day-to-day activity has slowed down a little bit is giving us an opportunity to focus on some of the longer-range considerations, of which this legislation is a part. So I sort of welcome the opportunity to think a little bit more about some of the important issues that we have to face in the Nation.

Mr. WYDLER. Thank you, Mr. Chairman.

Mr. MCCORMACK. Thank you, Mr. Wydler.

Are there any questions; Mr. Bergland?

Mr. BERGLAND. No questions.

Mr. MCCORMACK. Mr. Cronin?

Mr. CRONIN. Thank you, Mr. Chairman.

Mr. Sawhill, would like to congratulate you on excellent testimony in an area that several of our committees have shown a good deal of interest in—solar energy.

On page 4 you talked about, "The capital costs for nuclear power which are estimated to be in the neighborhood of $500 a kilowatt. The present solar costs are much higher than this."

That $500 figure is including a substantial amount of Federal investment, I would assume, to get it to that price.

Mr. SAWHILL. Yes. There has been a considerable amount of Federal funding of research and development. There is no question about it. As I parenthetically added in my testimony, I think with inflation there are probably some who would dispute that $500 figure and say it was more like $600 or $650.

Mr. Cronin. But in reality the real cost, if we were to amortize the tremendous Federal investment in nuclear over several years, would be substantially higher than that $500 figure.

Mr. Sawhill. There is no question about it.

Mr. Cronin. That gets me into a second part. When you were talking about ERDA bearing the central Federal responsibility for all solar R. & D., would you visualize ERDA or the administrator of ERDA having an allocation of funding for solar and other non-nuclear and non-fossil types of fuel on the same level that we have seen for nuclear over the last 10 years?

Mr. Sawhill. I think what would happen would be that we could build up to a very large funding, such as we have for nuclear today. I don't think we could move into it right away because the nuclear development is at a different stage than solar development. In other words, in the nuclear program we are spending a lot of money on the demonstration of the liquid metal fast breeder reactor, which is very, very expensive. Until solar energy got to the stage where we were building big demonstration projects, I think the level of funding would be different for solar than for nuclear. But that is because the rate of buildup would be different. At some point the solar funding might be higher than nuclear.

Mr. Cronin. What I am getting at is that you have said many times, and I certainly agree with you, that the solution to the energy problem is no one source but an investment in every source that we can possibly get our hands on through the year 2000.

My concern is that one of the reasons that we are in this energy bind with oil, or one of the reasons why the boycott was so effective, was that in effect we had become hooked on oil over the last 10 or 15 years in preference to other sources of energy. Our use of coal, for instance, had dropped back, and we had not really gone into a lot of other newer sources.

Mr. Sawhill. Yes.

Mr. Cronin. Now, my concern is that we don't get hooked on nuclear to the detriment of all of these other sources. Granted we should recognize the great value of nuclear and maximize it to the best of our abilities, but I would be hopeful that we would be doing similar things across the very broad spectrum of possible energy sources.

Mr. Sawhill. We agree with that position. That is why we support this bill.

Mr. Cronin. Fine. Thank you.

I have no further questions, Mr. Chairman

Mr. McCormack. Thank you, Mr. Cronin.

Mr. Sawhill, I want to congratulate you not only on this testimony today and your support for this organization that we propose in the bill but also for the outstanding work that you and your staff in FEA have been doing. I want to take this opportunity to say how proud we are of you and how great a job we think you are doing.

Mr. Sawhill. Thank you.

Mr. McCormack. I want to make a couple of comments and ask a couple of questions. I would like to pick up one made by Mr. Cronin just now. I want to say that I agree with him that we should not be hung up on any type of energy and that we should not under any circumstances allow ourselves to be mesmerized by one form of energy to the detriment of another. We should put all the support we can into every feasible type of energy development. That is the reason for this legislation today.

However, I don't think we should make the mistake of distorting the actual dollar input into nuclear energy research and development as compared to the total cost of it.

So we don't get that out of perspective, I did a hasty calculation. If we assume that the Federal Government has put $10 billion into nuclear energy research and development, which I think is an extremely generous figure, the fact is that this would be only a small percentage of the cost of 100 nuclear plants that we now have on the line or are built. The Federal R. & D. investment is only a few percent of the actual capital cost. I am making this point so we don't get it distorted.

Mr. CRONIN. Would the gentleman yield at this point?

Mr. McCORMACK. Yes.

Mr. CRONIN. I agree with your point, and I think it's very well taken. The point I was trying to get into is, for example, the discrepancy between current energy R. & D. appropriations for nuclear this year and over the past 5 years and the current R .& D. investment in solar. Granted the administration and the Congress have done great things in the last couple of years in increasing the investment in solar R. & D., but my point is that the solar base from which they began was ground zero. The base for the nuclear was rather substantial.

I fully recognize that these technologies are at different stages of development, but my concern is that this distortion—there is a technical reason as opposed to a policy reason for it at this point—should not be maintained over the next 10 to 20 years. That is the thrust of my statement.

Mr. McCORMACK. I very much agree with you. I think we have to establish a policy for solar energy research and development, and I think you will agree that it will not be budget limited. The only limitation on solar energy research and development will be technological. This philosophy has been essential to the policy we have been carrying out for 20 years in nuclear research and development. This is really the goal we have.

The fact is, of course, that 20 years ago we made a policy to pursue nuclear energy. If we had eyes in the back of our head, we might have done the same thing for solar then as well.

Mr. SAWHILL. It is true that fortunately solar research is cheaper than nuclear research, just by the very nature of the technology.

Mr. McCORMACK. That is right, by a couple of orders of magnitude.

Mr. SAWHILL. Yes. In solar technology you have a very diffuse source so you can set up a small pilot plant and then just replicate it over a very large area.

Mr. CRONIN. Would the gentleman yield 1 second further?

Mr. McCORMACK. Sure.

Mr. CRONIN. Mr. Sawhill is in the unique position here of being the current Administrator. I think I would like to throw a question at him comparing his present position with his past experience in OMB. What would your initial reaction be to Mike's comment that solar energy should not be budget limited, that we should approach it much the same as we have nuclear energy over the last 20 years?

Mr. SAWHILL. I would tend to agree with that.

Mr. CRONIN. Do you think the administration would be apt to support this type of effort?

Mr. SAWHILL. I think we generally have, in the sense that we have expanded the budget about as rapidly as we felt the technology could take this kind of expansion and that there were people available to work on solar problems.

Mr. CRONIN. I thank the gentleman for yielding.

Mr. MCCORMACK. I would like to pick up the theme of this discussion. This is in no sense to debate it, but just to help clarify it. As you recall, we have appropriated $50 million this fiscal year for basic research in addition to what we have for the Solar Heating and Cooling Demonstration Act and in addition to what we have put into the AEC. There is no question about the fact that solar energy R. & D. is cheaper by a factor of 10 to 100 than comparable nuclear energy R. & D. In other words, this is similar to putting into nuclear R. & D. from $500 million to $5 billion this year alone. I think we are doing a good job in this area even though we aren't as well organized as we should be.

Mr. Sawhill, how much money do you think we should be putting in? Do you have any feel, or have you or your staff come up with any figures, or how much money we should be putting into the broad spectrum of solar energy R. & D., including all the aspects you have mentioned, over the next 5 years and over the next 10 years?

Mr. SAWHILL. We have a tentative proposal that suggests that something in the range of $1 billion over the next 5 years may be appropriate. But I should hasten to add that I think that still needs a good deal more work before we could really come to you with a well-structured program. That is, of course, one of the intents of the bill, to do that very thing.

Mr. MCCORMACK. If you have any further information on that while we are in conference on this bill, as I expect we will be, we would certainly appreciate it. There may be a desire on the part of the conferees to set out certain tentative guidelines.

Mr. SAWHILL. This staff paper which I referred to earlier is an attempt to arrive at such a figure. We should certainly have an analysis for you as you move into conference on the bill.

Mr. MCCORMACK. Let's assume that the ERDA legislation does not pass. Certainly its prognosis is modest at best at the moment. What administrative structure do you think we need for solar research development and demonstration? Would you consider what is laid out in this bill as being an appropriate administrative structure for solar research, development, and demonstration?

Mr. SAWHILL. I think the only issue is how formally do you want to establish such a structure. Clearly you need a structure that cuts across more than one agency, because more than one agency will be involved here.

The question is do you want to formally set this up in the bill, or do you want to provide some flexibility in doing this? That is the issue that we face, I believe.

Mr. McCormack. Then you would go along with this? You have endorsed in general the organizational concept as prescribed in this bill, at least for the short run?

Mr. Sawhill. Yes. But, of course, it would be our hope that an ERDA would be created which could then take over the project established here.

Mr. McCormack. Can I go back to the question asked a minute ago by Mr. Brown. In the comprehensive program you are developing, what methodology is being used? In the past we have had groups of solar supporters who have put together a program of things they would like to do and then they have gone along and sort of arranged a budget accordingly. Is there some systems approach to this?

Mr. Sawhill. Yes. We are really trying to look across the broad spectrum of all energy research and development and trying to determine what contribution we think solar energy can make and then how much research we have to do in order to realize this contribution. Rather than looking at a smorgasbord of ideas, we are really trying to establish the need for solar research in the total energy picture in order to arrive at the kind of research we are trying to do.

Mr. McCormack. Going back to page 4, you ad-libbed some figures there which I do not have in my printed version.

Mr. Sawhill. We have done some analysis, indicating that about 37×10^{15} Btu of energy could come from solar energy by the year 2000. We suspect total energy supply in this country would be about 200×10^{15} Btu. So I said it would be in the 15 percent to 20 percent range.

Mr. McCormack. Are you saying 15 percent to 20 percent by the year 2000?

Mr. Sawhill. Yes.

Mr. McCormack. Have you broken that down into categories, such as wind, ocean, et cetera?

Mr. Sawhill. Yes, heating and cooling would be about 3½; wind would be 5; bioconversion would be about 15; ocean gradients that we discussed earlier would be 2; photovoltaic would be about 7.2 perhaps; and solar thermal would be 3.8.

Mr. McCormack. You mentioned photosynthesis. Which did you say, is 15?

Mr. Sawhill. Bioconversion.

Mr. McCormack. Is this including the incineration of wastes?

Mr. Sawhill. Yes. That may be a little optmistic. This is with the accelerated program of development.

Dr. Weinberg. I ought to interject here, we are trying to project what is going to happen in the year 2000. One has to take numbers like this cum grano salis. I won't be here in 2000 to be able to say that these are correct. But there are some responsible people who believe that you could, with great push, get 37×10^{15} Btu's of solar energy by the year 2000. I personally think that is something of an over-estimate.

Mr. McCormack. I would very much appreciate having a copy of those figures for the record, even if they are tentative, with whatever parameters you want to put on them and whatever background information that you used in developing them.

SUMMARY OF POTENTIAL IMPACTS OF SOLAR ENERGY TECHNOLOGIES

[Units of 10^{15} Btu of equivalent fossil-type fuels]

	1980	1985	1990	1995	2000
Heating and cooling	0.3	0.6	1.5	2.4	3.5
	(0.01)	(.3)	(.6)	(1.3)	(2.3)
Solar thermal	0	.005	.05	.7	3.8
	0	(.005)	(.05)	(.4)	(1.9)
Wind conversion	.01	.5	2.0	3.4	5.0
	(.002)	(.1)	(.4)	(.7)	(1.0)
Bioconversion	.1	.5	2.0	5.0	15.0
	(.001)	(.003)	(.01)	(.03)	(.1)
Ocean thermal	0	.1	.5	3.1	20.0
	0	(.1)	(.3)	(1.3)	(5.0)
Photovaltaic conversion	.00003	.012	.3	3.3	7.2
	(.00003)	(.006)	(.07)	(.3)	(1.5)

Note: Tentative data supplied from a solar energy task force to project independence. Assumptions include (1) a success-oriented program plan in all program areas; (2) an "accelerated" (includes incentives) implementation plan; and (3) conventional fuel equivalent prices of $11 per barrel of oil. Impacts of a "business as usual" implementation in place of the "accelerated" plan are shown in parenthesis.

Mr. McCormack. I would also like to ask the same thing for the year 1990.

Mr. Sawhill. We have an analysis for the year 1985, which shows about 2×10^{15} Btu. In this report I mentioned to you we have a table that lays this out for 1980–85.

Mr. McCormack. So you are showing a little bit more than 1 percent in 1985, including incineration of wastes?

Mr. Sawhill. Yes.

Mr. McCormack. On page 6, you mentioned that development of absorption refrigeration for low temperature solar applications will require considerable additional research. Are you aware of the fact that there are now two operating demonstration units in this area, one that has been developed by NASA and one by the Institute of Gas Technology?

Mr. Sawhill. I was aware of the NASA system. I was not aware of the other.

Mr. McCormack. There is also one which I visited in Chicago. It looks very good. It uses molecular sieves. They have what I think is almost a commercially available model.

Mr. Sawhill. We said it would be necessary to develop a practical absorption refrigeration system. It depends on how you define the word "practical."

Mr. McCormack. I am just nitpicking, but just for the record I would like to put in at this point that there are a couple of demonstration units in this area that are looking pretty good, that are looking as though we are close to field tests, which might lead to commercially available units.

Mr. Sawhill. Yes.

Mr. McCormack. This does not, of course, assume that they are economically competitive. Probably the main reason they wouldn't be economically competitive would be either that we don't have enough field tests to check their dependability on that the cost of the solar panels to collect the heat is still too high.

Mr. Sawhill. Yes, sir.

Mr. McCormack. The units themselves looked good to me.

On page 8 you talked about using wind. You said that large prototypes of megawatt size were to be under evaluation by fiscal year 1976. Do you have any further information on this that you can give us?

Mr. Sawhill. This is a NASA project, as I understand.

Mr. McCormack. I wanted to be sure I was not missing something there. I don't have any other questions.

Mr. Pickle?

Mr. Pickle. Thank you, Mr. Chairman.

I was sorry I was not here for the testimony of Mr. Sawhill.

It is good to see you and your associates here. In view of the time, I would just like to ask a general question. In effect, you do support this bill?

Mr. Sawhill. Yes, sir.

Mr. Pickle. In general, whatever agency administers the program?

Mr. Sawhill. Right.

Mr. Pickle. Thank you, Mr. Chairman.

Mr. McCormack. Thank you, Mr. Pickle.

Mr. Sawhill, I am going to meet your schedule for you. You said that you had to leave at 11 o'clock. It is 1 minute after. I think we have asked all the questions that we need to ask.

Mr. Sawhill. Thank you.

Mr. McCormack. We thank you and the members of your staff for coming here and giving us this testimony.

Our next witness this morning is Hon. John Nassikas, Chairman of the Federal Power Commission.

We welcome you here today. We enjoy having you come and testify before us.

STATEMENT OF JOHN N. NASSIKAS, CHAIRMAN, FEDERAL POWER COMMISSION; ACCOMPANIED BY EMMETT J. GAVIN, ASSISTANT TO THE CHAIRMAN; CHARLES A. BERG, CHIEF ENGINEER; BERNARD B. CHEW, CHIEF, DIVISION OF POWER SURVEYS AND ANALYSES, BUREAU OF POWER; RICHARD F. HILL, ADVISER ON ENVIRONMENTAL QUALITY, AND MARIE HOGAN, LEGAL INTERN, OFFICE OF THE GENERAL COUNSEL

Mr. Nassikas. Thank you, Mr. Chairman.

Mr. McCormack. At your pleasure, you may submit your statement for the record or read it and talk from it.

Mr. Nassikas. I am pleased to be here, Mr. Chairman and members of the committee. I think this is my fifth appearance before the House Committee on Science and Astronautics. I will present my entire statement for the record and try to summarize at appropriate places and read parts of it.

Mr. McCormack. If there is no objection, it will be submitted for the record at this point.

[The statement and biographical sketch follows:]

STATEMENT OF JOHN N. NASSIKAS
CHAIRMAN, FEDERAL POWER COMMISSION

BEFORE THE
SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE AND ASTRONAUTICS
UNITED STATES HOUSE OF REPRESENTATIVES

JULY 30, 1974

Mr. Chairman, I am pleased to present my comments on your pending proposal, H. R. 15612, the "Solar Energy Research, Development and Demonstration Act of 1974." As noted in your letter of July 18, 1974, the objective of the program this bill would establish is "to bring to commercial demonstration as soon as possible a broad spectrum of solar energy technologies." I share your view of the importance and the urgency of this proposal.

Our current reliance on non-renewable fossil fuel resources must be displaced by new, inexhaustible, environmentally acceptable energy forms and technologies. Solar energy is among the most promising of these new energy forms and I support this legislation's emphasis on its expedited development and commercial utilization.

Your letter of invitation to appear at this hearing specifically requested my views on (1) the administrative structure provided for in the bill to implement solar R&D efforts; (2) the adequacy of the bill's approach to the funding of solar R&D; and (3) the steps necessary to achieve the bill's emphasis on commercial utilization of the results of solar research. I will, therefore, concentrate on these aspects of the bill.

Administrative Structure

H. R. 15612 would establish a Solar Energy Coordination and Management Project, composed of the Administrator of the Federal Energy Administration (who would act as Chairman of the Project), an Assistant Director of the National Science Foundation, an Assistant Secretary of Housing and Urban Development, a member of the Federal

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Power Commission, an Associate Administrator of the National Aeronautics and Space Administration, and the General Manager of the Atomic Energy Commission. The purpose of the Project would be to carry out the Congressional policy of a "vigorous and adequately funded program of resource assessment, research and development, and demonstrations, with the objective of utilizing solar energy as a major source for our national energy needs."(§3) The Project would have the exclusive authority to establish programs or projects under the Act, but the programs would be carried out by the National Science Foundation, NASA and the AEC. Upon establishment of the Energy Research and Development Administration, or an equivalent agency, the National Science Foundation, NASA and AEC functions would be transferred to it.

I am in basic agreement with the bill's framework for the management of solar research and development, especially the placing of ultimate management responsibility in the Energy Research and Development Administration (ERDA) if and when it is created. In testimony before this Committee in May of 1973 1/ and again in my February 6, 1974 statement to this Committee on geothermal legislation, 2/ I emphasized that it is essential that we unify the presently fragmented energy related activities of the Federal government. In the area of energy research and development, I believe the Administration's proposal to establish ERDA should be enacted and that that agency should manage and coordinate all energy R&D programs.

In the interim, however, pending the creation of ERDA I share your belief, Mr. Chairman, that action on essential R&D programs, such as your geothermal and solar

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1/ Hearings before the Subcommittee on Energy, Committee on Science and Astronautics, House of Representatives on the Assessment of the Energy Problem and Implications for Energy R&D, May 17, 1973.

2/ Hearing before the Subcommittee on Energy Committee on Science and Astronautics, House of Represnetatives on HR 11212 "Geothermal Energy Research, Development and Commercial Demonstration Act of 1973," February 6, 1974.

R&D bills, should go forward on an expedited basis. Therefore, I endorse your proposal to create without further delay a Solar Energy Coordination and Management Project under the leadership of a policy group of Federal officials intimately familiar with the energy and energy research needs of the Nation. I also support the bill's selection of the National Science Foundation, NASA and the AEC as the agencies best equipped to move forward on solar R&D projects under the management leadership of the Federal officials designated as the members of the Project. These agencies have the facilities, the experience, and the staff expertise to devise and implement necessary solar R&D programs.

In effect, the bill provides for management by a committee of officials with full time responsibilities in other agencies of Government. Were it not for the interim nature of this management arrangement (pending creation of ERDA) I would not endorse this aspect of the bill because I do not believe that effective policy can be formulated and administered in this manner on a permanent basis. A matter as important as energy R&D requires full time administration such as ERDA will provide.

While the bill expressly states in §16 that the functions of the National Science Foundation and NASA will be transferred to ERDA within sixty days of the date on which ERDA is established, it is silent with respect to the continued existence of the management group, the Solar Energy Coordination and Management Project. I believe it should be expressly provided that the Project will be terminated upon ERDA's assumption of the solar R&D responsibilities of the National Science Foundation, NASA and the AEC. It would, in my view, be inconsistent with the fundamental purpose of centralizing energy R&D authority in ERDA to retain the Project and its management oversight responsibilities. 3/

3/ Similarly, while I support the provision in §13 for the creation of a Solar Energy Information Data Bank I think it should be clearly provided that if a centralized Energy Data Bank is established as now proposed the Solar Data Bank would be incorporated within it.

Also, during the period when the Project is exercising the management responsibilities under the bill it should be clear on the face of the legislation that the collective management responsibilities specified in §5 are in fact being exercised on a collective basis. Sections 12, 13, 14, 15, 17 and 18 depart from the earlier provisions of the bill in that they appear to delegate extensive individual responsibilities to the Chairman of the Project independent of the collective membership of the Project. Since presumably these sections are not intended to depart from the explicit designation of a management committee in §5, they should be clarified to indicate that the functions and responsibilities prescribed in those sections are the collective responsibility of the Project membership.

I would like to offer one final point with respect to the bill's administrative structure. Section 5(d)(1) specifies that the Project shall discharge its responsibilities in cooperation with five specific agencies, including the Federal Power Commission. Subsection 5(d)(2) states that "[u]pon request of the Project, the head of any such agency [including the FPC] shall detail or assign, on a reimbursable basis or otherwise, any of the personnel of such agency to the Project to assist it in carrying out its responsibilities under this Act." This provision could be construed to deny the head of an affected agency such as the FPC of the right to exercise discretion in the assignment of personnel to the Project. It should be made clear in the bill that the assignment of personnel is within the discretion of the agency involved. The workload on our Commission, for example, is intense and I believe I must have the discretion to decide when and on what terms we can spare our staff members for other activities. I hasten to add that I would cooperate with the Project to the fullest extent possible in all respects, including the delegation of FPC personnel to assist in the Project's work, but it is essential to my responsibilities as

Chairman of the FPC to determine when such delegation of staff is consistent with our statutory responsibilities and priorities.

Funding Solar R&D

It is well recognized that the cost of solar energy R&D, particularly its adaptation to the commercial production of electric power, will require extremely large financial outlays. Dr. Dixy Lee Ray's R&D report recommends a Federal expenditure of $200 million for solar R&D for FY 1975-1979, 4/ and the National Science Foundation budget for FY 1975 provides $50 million for solar research.

The Technical Advisory Committee on R&D of the FPC's current National Power Survey has recommended the expenditure of $885 million for solar energy R&D over the next ten years. Table 1 contains the Advisory Committee's specific solar R&D funding recommendations by program priorities, funding sources, total program costs, duration

4/ The Nation's Energy Future, A Report to Richard M. Nixon, President of the United States, submitted by Dr. Dixy Lee Ray, Chairman AEC, 1 December 1973.

and end product.

In addition, as you noted in your June 27, 1974 statement to the Senate Interior Committee on S.3234, the Solar Energy Research Act of 1974, the $600 million figure for an initial six-year solar R&D effort provided for in that bill is also a reasonable estimate of the level of funding required.

Ultimately, I believe hundreds of millions will be well invested in solar R&D programs. For the moment, however, I support your concept in H.R. 15612 to provide for an initial $2 million appropriation for the preparation of a comprehensive solar R&D program definition in fiscal 1975 with future funding levels contingent on the results of that evaluation.

An evaluation of necessary funding levels for solar R&D should include an assessment of the contribution that should be made by the private sector. In general, it is my belief that Federal R&D expenditures should be concentrated in those areas where the amount of required investment is so large or the risks of commercial success are so speculative so as not to warrant substantial private investment as a matter of management responsibility. For example, there are areas of solar R&D that are long-range in scope, such as central-station solar power generation. Therefore, the Electric Power Research Institute (EPRI), the electric utility industry's R&D organization, has thus far not concentrated its efforts in this area. On the other hand, the application of solar energy to space heating and cooling is a fairly well-proven technology and because commercial utilization is a strong near-term possibility private enterprise can and should be expected to provide a substantial portion of the funds necessary to bring the technology to the market place.

Therefore, in order to resolve the appropriate source and level of solar R&D funding I support your concept in H.R. 15612 in defining our goals and priorities before specifying the level of Federal commitment.

Commercial Utilization

I concur in H.R. 15612's emphasis on "resolving the major technical problems inhibiting commercial utilization of solar energy in the United States." (§9(a)) We are most in need of practical, workable energy alternatives to our current unavoidable preoccupation with the supply of fossil fuel resources. Therefore, I also agree with the directive in §10(B)(5) of the bill that "[i]n selecting solar energy technologies for demonstration under this section, preference shall be given to those with the best opportunity for commercial success and environmental acceptability."

In this regard, I would like to suggest, Mr. Chairman, that the mandatory language of §10(a) to the effect that the Project shall initiate a demonstration project for each specific solar energy technology listed in §9 may be too inflexible. It would appear to me that in keeping with the bill's emphasis on expediting those solar technologies most likely to achieve commercial success and environmental acceptability that the language of §10(a) should be discretionary in order to allow those charged with management responsibilities to concentrate more of the Project's talent and funds in areas most likely to result in successful commercial applications in the near future.

In fact, the prospect of successful commercial development of some aspects of solar research is so promising that I would recommend that a priority for these projects be included in the bill itself. Specifically, the use of solar energy for space heating, hot water heating and air conditioning of buildings is technologically feasible and, in most areas of the country, economically justifiable. There are no major technical problems precluding the adoption of solar energy for these purposes. Moreover, the quantity of primary fuel which could be saved by applying solar energy to these services is immense. For example, hot water heating in residences and commercial buildings uses more than four times as much fuel as all the aluminum refining done in the U. S., and it may be feasible to provide 50 percent or so of our national hot water requirement through solar energy. I would, therefore, recommend that the application of solar energy to space heating, hot water heating and air conditioning receive especially strong emphasis in this legislation.

I would like to stress another point in this respect. One of the essential prerequisites to commercial success of a technological innovation is public acceptance. I would suggest, therefore, that this legislation provide for a public information program to promote market acceptance of solar energy systems, especially for heating and cooling systems for homes, where drastic changes in architectural design will almost certainly be required.

This concludes my formal comments, Mr. Chairman. I will be pleased to respond to any questions.

TABLE 1 *

TAC-R&D RECOMMENDATIONS FOR SOLAR ENERGY, 1975-1984
(Millions of 1973 Dollars)

	Priority	Funding Sources	1975-79	1980-84	Total Program Cost, Duration, and End Product
IMPROVEMENT OF PRESENT TECHNOLOGY					
Solar Space Heating and Cooling	A	1	50	—	Commercial introduction in 1979
DEVELOPMENT OF FUTURE ENERGY SOURCES					
Solar Thermal Electric Conversion	B	1	41	183	Central station pilot plant, 1989; $1150 M/15 yrs.
Photovoltaic Conversion	B	1	47	130	Central station pilot plant, 1989; $315 M/15 yrs.
Photosynthesis of Organics and Hydrogen	C	1	89	176	Pilot plant, 1989; $370 M/15 yrs.
Effluent Control	C	1,2,3	24	20	
Wind Power Generator	D	1	25	—	Exp. development
Ocean Delta T	D	1	25	75	Pilot plant; $100 M/10 yrs.
TOTALS			301	584	
Allocation: U. S. Government			285	571	
Elec. Util. Industry			6	5	
Other Industry			10	8	
GRAND TOTAL:			885		

KEY

Priority:
A - Potentially high impact on the energy system if successful and most worthy of R&D support.
B - Potentially lower impact but should be included in a balanced R&D program.
C - Could contribute to the achievement of R&D goals and merits R&D support if funds are available.
D - Marginal worth for R&D support.

Funding Sources:
1 - U. S. Government
2 - Electric Utility Industry
3 - Other Industry

* Research and Development for the Electric Utility Industry, Final Draft of the Report to the Federal Power Commission of the TAC on R&D, April 1974, page 2.6.

FEDERAL POWER COMMISSION

Biographical Release of
John N. Nassikas, Chairman
Federal Power Commission

February 1974

John N. Nassikas, Republican, of New Hampshire

Took Office: First term, August 1, 1969; Second term, May 21, 1970

Term Expires: June 22, 1975

John N. Nassikas was born in Manchester, New Hampshire on April 29, 1917. He attended public schools in Manchester, and received his A. B. degree (with distinction in his major subject of sociology) from Dartmouth College in 1938. He then attended the Harvard Graduate School of Business Administration where he received his M. B. A. degree in 1940.

He entered the U.S. Naval Reserve in June 1942 as an Ensign and served until January of 1946. He held the rank of Lt. senior grade, when he returned to inactive duty. Mr. Nassikas then entered Harvard Law School in 1946, receiving his J.D. degree in 1948. He received an Honorary Doctor of Laws degree from Notre Dame College in Manchester, New Hampshire, in June 1972.

He entered private law practice in 1948, and from July of 1950 to September of 1953 served as Assistant and Deputy Attorney General of the State of New Hampshire. He was a senior partner of Wiggin, Nourie, Sundeen, Nassikas & Pingree from 1953 to 1969. Mr. Nassikas served as chief counsel for the Republican Minority of the U.S. Senate Committee on Commerce from March 1968 to February 1, 1969.

Mr. Nassikas' specialized public utility experience includes: State's Counsel in litigated rate cases before New Hampshire Public Utilities Commission and New Hampshire Supreme Court, 1950-53; special counsel to the New Hampshire Public Utilities Commission in 1961 and 1962 on telephone rates; and special counsel for the State of New Hampshire in 1958 and 1959 on electric power rates; trial and appellate practice, State and Federal Regulatory Agencies and Courts.

He is admitted to practice in New Hampshire, Massachusetts, Supreme Court of the U.S., U.S. District Courts of New Hampshire, Vermont, and the U.S. District Court for the District of Columbia, First Circuit Court of Appeals.

He is a member of the New Hampshire, Massachusetts and American Bar Associations. He also is a member of the Newcomen Society in North America, Ahepa, Bald Peak Colony Club, Congressional Country Club, and the Prouts Neck Country Club.

A Republican, Mr. Nassikas' nomination as a member and Chairman of the Federal Power Commission was announced by President Nixon on May 19, 1969. The nomination was sent to the Senate on May 20 where it was confirmed on June 17. He took office on August 1, 1969, for the term expiring June 22, 1970. President Nixon nominated Chairman Nassikas for reappointment to a full five-year term on March 23, 1970. The nomination was confirmed by the Senate on April 30, and he took the oath of office on May 21, 1970.

Chairman Nassikas is a member of the Water Resources Council (serving as Vice Chairman from July 1, 1970 to June 30, 1971); member of the Board of Directors, U.S. National Committee of the World Energy Conference; member of the Administrative Conference of the United States and also serves on its Rulemaking Committee; and a member of the Executive Committee of the National Association of Regulatory Utility Commissioners. He served on the President's Cabinet Task Force on Oil Import Control (1969-1970); is a member of the Energy Subcommittee of the Domestic Council; a member of the President's Joint Board on Fuel Supply and Fuel Transport; Member of the Energy-Related Regulatory Agency Study Committee; a member of the Council of the Greek Orthodox Archdiocese of North and South America (1970-1972); and serves as a member of the Executive Advisory Council of Junior Achievement of Metropolitan Washington. He also is a member of the Council of the National Harvard Law School Association, and a member of the Board of Directors of The Madeira School.

Mr. Nassikas is married to the former Constantina Andreson of Worcester, Massachusetts. They have four children: Constance (Mrs. John J. Hohenadel, Jr.) of Woodside, California; Mary (Mrs. Robert C. Hall) of McLean, Virginia; and Elizabeth, age 20, and John N. III, age 15, of the home address. Mr. Nassikas is currently a resident of McLean, Virginia.

-FPC-

Mr. NASSIKAS. To start off with, I support the bill, if the bill should pass, and I would like to see it pass today.

Our current reliance on nonrenewable fossil fuel resources must be displaced by new, inexhaustible, environmentally acceptable energy forms and technologies. Solar energy is among the most promising of these new energy forms and I support this legislation's emphasis on its expedited development and commercial utilization.

Mr. MCCORMACK. Introduce your staff.

Mr. NASSIKAS. On my right is Dick Hill, who heads up our Office of Environmental Quality.

To my left is Emmett Gavin; and far right, Dr. Berg, our chief engineer, who concentrates largely on problems of energy conservation.

Your letter of invitation to appear at this hearing specifically requested my views on (1) the administrative structure provided for in the bill to implement solar R. & D. efforts; (2) the adequacy of the bill's approach to the funding of solar R. & D.; and (3) the steps necessary to achieve the bill's emphasis on commercial utilization of the results of solar research. I will, therefore, concentrate on these aspects of the bill.

ADMINISTRATIVE STRUCTURE

H.R. 15612 would establish a Solar Energy Coordination and Management project, composed of the Administrator of the Federal Energy Administration (who would act as chairman of the project), an Assistant Director of the National Science Foundation, an Assistant Secretary of Housing and Urban Development, a member of the Federal Power Commission, an Associate Administrator of the National Aeronautics and Space Administration, and the General Manager of the Atomic Energy Commission. The purpose of the project would be to carry out the congressional policy of a "vigorous and adequately funded program of resource assessment, research and development, and demonstrations, with the objective of utilizing solar energy as a major source for our national energy needs" (section 3). The project would have the exclusive authority to establish programs or projects under the act, but the programs would be carried out by the National Science Foundation, NASA and the AEC. Upon establishment of the Energy Research and Development Administration, or an equivalent agency, the National Science Foundation, NASA and AEC functions would be transferred to it.

I am in basic agreement with the bill's framework for the management of solar research and development, especially the placing of utimate management responsibility in the Energy Research and Development Administration (ERDA), if and when it is created.

If the bill is passed as is, we will have taken one very important step forward. We will have taken action to meet the energy crisis and not simply evading it with constant talk and dialog and committee after committee trying to establish policies and then not succeeding in establishing them.

Mr. MCCORMACK. We thank you for that statement, Mr. Chairman.

Mr. NASSIKAS. Thank you.

As you know, I really mean it and have said so time and again to this and other committees.

In testimony before this committee in May of 1973 and again in my February 6, 1974, statement to this committee on geothermal legislation, I emphasized that it is essential that we unify the presently fragmented energy related activities of the Federal Government. In the area of energy research and development, I believe the Administration's proposal to establish ERDA should be enacted and that that agency should manage and coordinate all energy R. & D. programs.

In the interim, however, pending the creation of ERDA I share your belief, Mr. Chairman, that action on essential R. & D. programs, such as your geothermal and solar R. & D. bills, should go forward on an expedited basis. Therefore, I endorse your proposal to create without further delay a Solar Energy Coordination and Management project under the leadership of a policy group of Federal officials intimately familiar with the energy and energy research needs of the Nation. I also support the bill's selection of the National Science Foundation, NASA and the AEC as the agencies best equipped to move forward on solar R. & D. projects under the management leadership of the Federal officials designated as the members of the project. These agencies have the facilities, the experience, and the staff expertise to devise and implement necessary solar R. & D. programs.

In effect, the bill provides for management by a committee of officials with full-time responsibilities in other agencies of Government. Were it not for the interim nature of this management arrangement (pending creation of ERDA) I would not endorse this aspect of the bill because I do not believe that effective policy can be formulated and administered in this manner on a permanent basis. A matter as important as energy R. & D. requires full-time administration such as ERDA will provide.

Perhaps I might mention that I serve and have served for a number of years as a member of the Water Resources Council. It has a structure that is similar. It is composed of people with other full-time activities, such as the Secretary of Interior, Chairman of the FPC, and others, and they operate by way of committee management. The Water Resources Council is not functioning well that way. It has not been. In fact there is a bill to abolish it as soon as the Department of Energy and Natural Resources, is established.

While the bill expressly states in section 16 that the functions of the National Science Foundation and NASA will be transferred to ERDA within 60 days of the date on which ERDA is established, it is silent with respect to the continued existence of the management group, the Solar Energy Coordination and Management project. I believe it should be expressly provided that the project will be terminated upon ERDA's assumption of the solar R. & D. responsibilities of the National Science Foundation, NASA and the AEC. It would, in my view, be inconsistent with the fundamental purpose of centralizing energy R. & D. authority in ERDA to retain the project and its management oversight responsibilities.

Mr. McCormack. Let me ask a question at this point.

Assuming that ERDA were to come into existence, we anticipate a protracted period of reorganization and, in particular, a protracted period of reorganization of the AEC. For this reason, as I constantly fumble with the concept of this transfer of authority to ERDA from the solar energy management project, it strikes me that it would take place at some time after ERDA was actually functioning, rather than immediately upon its creation.

Mr. NASSIKAS. I think that is a very practical suggestion. Perhaps it could be continued for a time and then terminated sometime after the initial formation of ERDA when it is in full function.

Is that what you had in mind?

Mr. McCORMACK. Yes.

Mr. NASSIKAS. That is a good suggestion.

Mr. McCORMACK. The transfer would take place 6 months or a year after the establishment of ERDA, at which time the management of ERDA would be ready to take over and do the job.

Mr. NASSIKAS. Certainly.

Also, during the period when the project is exercising the management responsibilities under the bill, it should be clear on the face of the legislation that the collective management responsibilities specified in section 5 are in fact being exercised on a collective basis. Sections 12, 13, 14, 15, 17, and 18 depart from the earlier provisions of the bill in that they appear to delegate extensive individual responsibilities to the chairman of the project independent of the collective membership of the project. Since presumably these sections are not intended to depart from the explicit designation of a management committee in section 5, they should be clarified to indicate that the functions and responsibilities prescribed in those sections are the collective responsibility of the project membership.

I might add, if that is what you intend. I assume it is what you did intend.

I would like to offer one final point with respect to the bill's administrative structure. Section 5(d)(1) specifies that the project shall discharge its responsibilities in cooperation with five specific agencies, including the Federal Power Commission. Subsection 5(d)(2) states that upon request of the project, the head of any such agency [including the FPC] shall detail or assign, on a reimbursable basis or otherwise, any of the personnel of such agency to the project to assist it in carrying out its responsibilities under this act." This provision could be construed to deny the head of an affected agency such as the FPC of the right to exercise discretion in the assignment of personnel to the project. It should be made clear in the bill that the assignment of personnel is within the discretion of the agency involved. The workload on our Commission, for example, is intense and I believe I must have the discretion to decide when and on what terms we can spare our staff members for other activities. I hasten to add that I would cooperate with the project to the fullest extent possible in all respects, including the delegation of FPC personnel to assist in the project's work, but it is essential to my responsibilities as Chairman of the FPC to determine when such delegation of staff is consistent with our statutory responsibilies and priorities.

FUNDING SOLAR R. & D.

It is well recognized that the cost of solar energy R. & D., particularly its adaptation to the commercial production of electric power, will require extremely large financial outlays.

Although the funding is modest, as you pointed out earlier, Mr. Chairman, when compared to the outlays for the Manhattan project or for the Apollo project, for that matter.

Dr. Dixy Lee Ray's R. & D. report recommends a Federal expenditure of $200 million for solar R. & D. for fiscal years 1975–79, and the Natonal Science Foundation budget for fiscal year 1975 provides $50 million for solar research.

The Technical Advisory Committee on R. & D. of the FPC's current National Power Survey has recommended the expenditure of $885 million for solar energy R. & D. over the next 10 years. Table 1 contains the advisory committee's specific solar R. & D. funding recommendations by program priorities, funding sources, total programs costs, duration, and end product.

In addition, as you noted in your June 27, 1974, statement to the Senate Interior Committee on S. 3234, the Solar Energy Research Act of 1974, the $600 million figure for an initial 6-year solar R. & D. effort provided for in that bill is also a reasonable estimate of the level of funding required.

Whether the necessary funding is $600 million or $1 billion I don't know, but it seems to me that is about the area. Someplace between $600 million to $1 billion over the period in question.

Ultimately, I believe hundreds of millions will be well invested in solar R. & D. programs. For the moment, however, I support your concept in H.R. 15612 to provide for an initial $2 million appropriation for the preparation of a comprehensive solar R. & D. program definition in fiscal 1975 with future funding levels contingent on the results of that evaluation.

An evaluation of necessary funding levels for solar R. & D. should include an assessment of the contribution that should be made by the private sector. In general, it is my belief that Federal R. & D. expenditures should be concentrated in those areas where the amount of required investment is so large or the risks of commercial success are so speculative so as not to warrant substantial private investment as a matter of management responsibility. For example, there are areas of solar R. & D. that are long-range in scope, such as central-station solar power generation. Therefore, the Electric Power Research Institute (EPRI), the electric utility industry's R. & D. organization, has thus far not concentrated its efforts in this area. On the other hand, the application of solar energy to space heating and cooling is a fairly well-proven technology and because commercial utilization is a strong near-term possibility private enterprise can and should be expected to provide a substantial portion of the funds necessary to bring the technology to the marketplace.

Therefore, in order to resolve the appropriate source and level of solar R. & D. funding I support your concept in H.R. 15612 in defining our goals and priorities before specifying the level of Federal commitment.

I might add parenthetically here that it is important, as you have provided in your bill, to determine pragmatically what expenditures can be committed. While I am totally committed to more investment in research and development, I do think, nevertheless, that there may be constraints upon the return on R. & D. dollars that are invested unless there is a very careful evaluation of our capacity to absorb the dollar commitment and to receive a return on those dollars in an efficient way by utilizing available scientific resources.

I think that is an important point.

One other point parenthetically. I happen to be a trustee of a school called the Madeira School, in Greenway, Va., and they are building, upon my urging—I was happy the board adopted my recommendation—a science building, a very modest one, with solar heating and cooling. Our estimate is that the cost of that particular project—it is about a $60,000 investment in the solar cooling and heating aspect of it—in an overall cost of $500,000 for the building. We estimate that the fuel savings will recover that investment in approximately 12 years, on the assumption that fuel costs would triple from the time we started this, which was about 18 months ago.

The fuel costs have already doubled. Our tripling was based on the 20-year life of the building. You see, there could be actual savings in the use of solar energy, economic savings apart from conservation aspects or environmental aspects, which we all tend to emphasize.

COMMERCIAL UTILIZATION

I concur in H.R. 15612's emphasis on resolving the major technical problems inhibiting commercial utilization of solar energy in the United States—section 9(a). We are most in need of practical, workable energy alternatives to our current unavoidable preoccupation with the supply of fossil fuel resources. Therefore, I also agree with the directive in section 10(B)(5) of the bill that "in selecting solar energy technologies for demonstration under this section, preference shall be given to those with the best opportunity for commercial success and environmental acceptability."

In this regard, I would like to suggest, Mr. Chairman, that the mandatory language of section 10(a) to the effect that the project shall initiate a demonstration project for each specific solar energy technology listed in section 9 may be too inflexible. It would appear to me that in keeping with the bill's emphasis on expediting those solar technologies most likely to achieve commercial success and environmental acceptability that the language of section 10(a) should be discretionary in order to allow those charged with management responsibilities to concentrate more of the project's talent and funds in areas most likely to result in successful commercial applications in the near future.

In fact, the prospect of successful commercial development of some aspects of solar research is so promising that I would recommend that a priority for these projects be included in the bill itself. Specifically, the use of solar energy for space heating, hot water heating and air-conditioning of buildings is technologically feasible and, in most areas of the country, economically justifiable.

Here again I might note that H.R. 11864, the Solar Heating and Cooling Demonstration Act, which was introduced by you, Mr. Chairman, has passed both Houses of Congress and is in conference, and I am happy it is. The bill has two purposes, to demonstrate within 2 years the practical use in large scale of solar heating technology; and second, demonstrate on a large scale within 5 years the practical application of combined solar heating and cooling technology.

I found this out after I had my prepared statement ready and here again you were ahead of me in any event, so that I am not suggesting anything to you that you have not already thought of.

Mr. McCormack. I think we are completely in accord on this point, Mr. Nassikas.

Mr. Nassikas. There are no major technical problems precluding the adoption of solar energy for these purposes. Moreover, the quantity of primary fuel which could be saved by applying solar energy to these services is immense. For example, hot water heating in residences and commercial buildings uses more than four times as much fuel as all the aluminum refining done in the United States, and it may be feasible to provide 50 percent or so of our national hot water requirements through solar energy. I would, therefore, recommend that the application of solar energy to space heating, hot water heating and air-conditioning receive especially strong emphasis in this legislation or through the other bill that you introduced.

I would like to stress another point in this respect. One of the essential prerequisites to commercial success of a technological innovation is public acceptance. I would suggest, therefore, that this legislation provide for a public information program to promote market acceptance of solar energy systems, especially for heating and cooling systems for homes, where drastic changes in architectural design will almost certainly be required.

In other words, if one is addicted to Royal, Barry, Wills and New England architecture as I am, maybe one ought to be educated in using some other type of roof design and settling for something more practical, even if it may not be as good looking.

This concludes my formal comments and I will be happy to respond to questions.

Mr. McCormack. Mr. Nassikas, John, Mr. Chairman, I want to say that in all sincerity I never received testimony that is more articulate or more constructive than yours.

Mr. Nassikas. I appreciate that.

Mr. McCormack. Your testimony today has been extraordinarily valuable.

I have gone through and followed with you and marked on the margins throughout your statement, "good point * * * check this * * * constructive criticism," and I must say I cannot over emphasize the appreciation that the staff and I and the committee members feel.

Mr. Nassikas. We have a very fine staff at the Federal Power Commission. They are very creative and innovative and cooperative.

Mr. McCormack. I want to make a couple points, if I may, just at this point, so everyone involved will know. In the bill there is a typographical error which is a substantive one. In the last paragraph of the bill, next to the last line, it says:

> There are authorized to be appropriated to carry out this Act, for fiscal years beginning after June 30, 1976, such sums as the Congress may hereafter authorize by law.

That should have been 1975.

In the preceding paragraph:

> **There is authorized to be appropriated to the National Science Foundation for the fiscal year ending June 30, 1976 * * *.**

That should have been 1975.

We are talking about the $2 million for this fiscal year.

Mr. NASSIKAS. Yes. That is all the better.

Mr. McCORMACK. We feel we are ready to go. This will be corrected. It was a typographical error.

May I say that I want to thank you for your comment about the fact that we obviously cannot afford ultimately to pursue indefinitely all the avenues of R. & D. in solar energy. It appears there is an obvious limit there. This prudence has been practiced in other areas of R. & D. In nuclear fusion, for instance, in the breeder program, we have taken one out of three breeder programs and fusion. We are now down to fundamentally one concept to pursue out of several.

We have to do this in other areas. I hope advocates of solar energy and supporting energy will understand that as we go along.

I have a couple of questions for you now. We included, as you mentioned in your statement, NASA, NSF and AEC to carry out research and development programs. Do you see any need to include any other agencies?

Mr. NASSIKAS. None came to mind. There are perhaps others, but I know of none.

Mr. McCORMACK. I wondered if we missed something.

Mr. NASSIKAS. I don't believe you have.

Mr. McCORMACK. As you recognize, our choice of chairman, the Administrator of FEA, is a completely arbitrary one.

Mr. NASSIKAS. That is a good choice.

Mr. McCORMACK. We chose him because he was sort of a neutral referee with ability to do the job.

Mr. NASSIKAS. I think the whole concept of FEA seems to be a policy evaluation concept, even though they have somewhat limited powers, except in the area of mandatory fuel allocations. They are in an evaluation position. I think that the FEA Administrator would be an excellent choice. The only point I had as to the project as defined here, it did seem to me if you wished to center policymaking responsibility on the project, that is the management, board of directors so to speak, it seemed to me that perhaps the Administrator of the FEA should not be permitted by the legislation to embark on policies where he is not accountable to the board.

Mr. McCORMACK. In other words, he should act strictly as a chairman?

Mr. NASSIKAS. That is correct. That is what I believe, as a matter of administration.

Mr. McCORMACK. Fine.

You mention on page 7 that in section 12 through 18 there are departures from the early provisions of the bill. Hasty reanalysis of this indicates you thought this was an accident of drafting and not intentional. I appreciate your pointing that out to us.

Also, your comments on page 8 about the right of the individual agencies to manage their own personnel. This question came across my mind as I read the bill after we drafted it. I am glad that you made that point. You made it in a very articulate manner, and I am sure we are going to be looking at that critically, trying to do the best job we can and avoid any pitfalls there. I appreciate that one, too.

One question and then I will be through here. You mention on page 14 that you thought it would be feasible to provide 50 percent of our national hot water requirement through solar energy.

Mr. NASSIKAS. That is right.

Mr. McCORMACK. I have to say when?

Mr. NASSIKAS. So do I. I agree with your comment. This is an extremely high figure. It is a benchmark, so to speak. It is an objective that could be attained but it really is in here for illustrative reasons to point out that there are dramatic amounts of energy that can be created by solar energy. But as to whether it will be 50 percent, as to when, maybe never. It depends on our policy.

Mr. McCORMACK. It is attainable?

Mr. NASSIKAS. It is attainable. Probably not as a practical matter.

Mr. McCORMACK. You and I agree that it is highly desirable and that we should pursue it as aggressively as we possibly can. This is not likely to occur in the next 10 or 15 years?

Mr. NASSIKAS. That is correct. Sometimes before the end of the millenium but after 15 years.

Mr. McCORMACK. Thank you very much.

Mr. Fugua?

Mr. FUQUA. Mr. Chairman, I don't have any comments to make other than to commend the chairman on his very fine statement. I think that we are moving into a very critical area. As you pointed out, we need to have moved yesterday.

Mr. NASSIKAS. That is right.

Mr. FUQUA. I think your statement is very good. We appreciate your support and interest.

Thank you, Mr. Chairman.

Mr. McCORMACK. Mr. Cronin.

Mr. CRONIN. Thank you, Mr. Chairman.

I think it was an excellent statement, thoroughly enjoyable to listen to. I would like to followup on that last point of Mr. McCormack's I think your point on hot water requirements is a very viable one. That is an area where we do not need technological breakthroughs. For example, the State of Florida received a majority of its hot water from solar power until after World War II. It was not until after World War II, when so-called cheap energy came along in the form of gas and electric-powered hot water heaters, that that system changed.

My question relates perhaps to your Federal Power Commission role. Do you think that you could provide some incentives for our present utilities to get into the rental of solar hot water heaters as an incentive to cut down on the fossil fuel they are currently absorbing? In other words, we might complete this cycle.

Mr. FUQUA. Would the gentleman yield? I think that, where we rely almost completely on residual fuel and the fuel adjustments in the utility bills now, it will probably take care of that.

Mr. CRONIN. A point well made.

Mr. NASSIKAS. Certainly the utilities should be urged to accelerate not only their own research efforts but also the utilization of solar energy to the extent that they can. The difficulty is that central station solar energy is something that is a long way off, whereas your question relates simply to the rental of solar units of a smaller scale.

Mr. CRONIN. I agree that centralization units are a long way off. Your point here is that in solar energy for water we just provide the hot water for residencies and commercial buildings, four times as much fuel as the aluminum refining. My concern is that in the Northeast we have had these fuel adjustment rates, as you well know. New England is the largest country in the world that has neither a source of supply nor a refinery. We have an add-on for all our energy costs. Yet with New England inventiveness, ITEK Corp. has produced a very effective solar collector. There was a great deal of discussion recently that Boston Gas might start utilizing these collectors in some sort of fashion to cut the costs of the fuel that is required by their customers to heat hot water. There was talk of doing this by the next heating season. Now, all of a sudden, that seems to have fallen to the back burner because of a wide variety of regulations.

I wonder if there is not some way that the FPC can not really provide some incentive? This committee, as a matter of fact, held some hearings in Los Angeles, where we heard testimony by the utilities out there. They said they had invested money in solar collectors for heating swimming pools but were precluded by regulations from renting them out.

I wonder if perhaps you could provide some incentive to make some of these things happen a little quicker?

Mr. NASSIKAS. I certainly will look into that to see the extent to which, first, solar collectors may be available in different parts of the country and what utilities are in fact doing or not doing about it. I think also that I will perhaps review this matter with some of our technical advisory committees of the National Power Survey. I will look into that.

I know there are reasons as to why these things may not be done, but apart from technical reasons sometimes there is a certain built-in inertia in the electric utility industry to not only not take up an innovative idea but the concept that perhaps the tight structure of their particular service area is going to be threatened by the use of devices that may not be in accord with classic public utility concepts.

Mr. CRONIN. I think it would be fair to say that the image of public utilities for innovation is certainly not at the same level as the ability of the Federal Power Commission Chairman to move forward with new ideas.

Mr. NASSIKAS. They are doing better, Mr. Cronin. They have started the Electric Power Research Institute. It was necessary, and a reaction to moves by the Congress of the United States to take over R. & D. Whatever the reason was, it is a salutary step forward.

Mr. CRONIN. I agree.

One other point I wanted to make was that ERPI recently sent out a letter, in fact just about the time this committee was holding hearings on wind power, to the various utilities around the country to see whether or not they would be interested in getting involved and what their plans were. Since one of the five best areas in the country for wind power is the Northeast coast, particularly Massachusetts, and since there the use of wind would certainly not amount to a fuel adjustment cost for consumers in Massachusetts, I am wondering if there is any way that some incentives can be applied to perhaps expedite the unification of wind tests on the east coast.

Part of the testimony we received in the committee was that one of the advantages, particularly on the east coast, would be that wind generators could tie in directly to the grid. This would eliminate one of the biggest problems of wind power—storage of electricity.

Mr. NASSIKAS. Yes. In answer to your observation, I certainly will review this also. In New England there was an experiment in the 1940's at Grandpa's Knob in Vermont. This experiment worked quite successfully for a while but the constructors of the windmill didn't quite calculate the wind velocities in February and March on this particular knob and it blew down. It has not been reconstructed.

I also am aware of the fact that the New England coast apparently, and the panhandle region of Texas are two of the most promising areas for wind power in the United States because of the constancy of the wind velocity. The beauty of that is clear. One final point and I will send this to you if you have not seen it, the Federal Power Commission issued a pamphlet on wind power about a year and a half ago. There was an FPC engineer back in the 1930's and 1940's who made a number of studies of wind power, and we have perpetuated his researches and brought them up to date in a little pamphlet that I think you will find interesting. I will send it to you.

Mr. CRONIN. I would greatly appreciate that. I have not seen it.

In conclusion, I was very glad to hear you make that statement about the Madeira School. I don't know whether you are aware of it or not, but the first Federal building in the United States that will be an energy-conserving building will be built in your back yard.

Mr. NASSIKAS. I was very pleased to hear that for several reasons. One is it may give me an opportunity to return there to look it over.

Mr. CRONIN. Thank you, Mr. Chairman.

Thank you, Mr. Nassikas.

Mr. MCCORMACK. I want to say that I concur with that comment about the panhandle of Texas, having spent a whole spring in Texas in military service and all day out of doors. I remember the wind blew there for 3 months.

Mr. Bergland?

Mr. BERGLAND. Thank you.

Mr. MCCORMACK. Chairman Nassikas, we want to thank you and your staff for an excellent presentation and very much appreciate your assistance in this matter.

Mr. NASSIKAS. Thank you very much, Mr. Chairman and gentlemen of the committee.

Mr. MCCORMACK. Our next witness is Mr. Michael Moskow, Assistant Secretary for Policy Development and Research, Department of Housing and Urban Development. Mr. Moskow's testimony will be from the point of view of an energy consumer.

Mr. Moskow, we very much appreciate your presence today and would be happy if you would introduce your staff accompanying you. If you wish, you may insert your statement in the record and speak from it, or you may read it directly. It is at your discretion.

STATEMENT OF MICHAEL H. MOSKOW, ASSISTANT SECRETARY FOR POLICY DEVELOPMENT AND RESEARCH, DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT; ACCOMPANIED BY CLAUDE E. BARFIELD, JR., ACTING DEPUTY AND SECRETARY FOR RESEARCH AND DEMONSTRATION; JOSEPH SHERMAN, DIRECTOR OF BUILDING TECHNOLOGY AND SAFETY; GEORGE TAPPERT, SPECIAL ASSISTANT TO SECRETARY FOR ENERGY AFFAIRS

I would like to introduce Dr. Claude Barfield, who is the Acting Deputy Assistant Secretary for Research and Demonstration, Office of Policy Development and Research.

Mr. George Tappert, Special Assistant to the Secretary for Energy Affairs.

Mr. Joseph Sherman, Director of Building Technology and Safety within the Office of Policy Development and Research.

Mr. McCormack. I suppose it is an appropriate moment to congratulate Mr. Barfield on his new appointment. Congratulations.

Mr. Barfield. Thank you.

Mr. Moskow. Mr. Chairman and members of the committee, on behalf of the Department of Housing and Urban Development, I would like to thank you for giving us an opportunity to comment on H.R. 15612, the Solar Energy Research, Development, and Demonstration Act of 1974. HUD recognizes the leadership role that has been played by this committee and its chairman in promoting the widespread use of solar energy as an alternative to the use of depletable fuels, and is pleased to present its views to the committee.

In fulfilling its mission of providing a decent home and a suitable living environment to all Americans, HUD is vitally interested in the establishment of national policies and administrative mechanisms which would assure the availability and promote the efficient utilization of energy at the lowest possible cost to homeowners and renters. Approximately one-fifth of all energy used in the United States is used in residential dwellings, primarily for space heating and cooling and hot-water heating. About one-third of all energy used is used in buildings generally, including commercial structures.

Within the broad technical area of solar energy, HUD's most direct interest is the use of solar radiation in the heating and cooling of residential buildings, because this particular application of solar energy appears close to technical, and perhaps economic, feasibility.

Before discussing the specific provisions of H.R. 15612, I would like to point out that HUD has been interested in the use of solar energy for heating and cooling of buildings for some years.

As far back as 1963, HUD performed an analysis of a residential solar heating system constructed by a Washington inventor and funded privately.

Under a program begun in 1973, we are currently funding a research evaluation of a system of natural heating and cooling utilizing solar energy as the power source in a house in Atascadero, Calif. This home, a 3-bedroom, split-level containing 1,300 square feet of floor area, is heated and cooled only by a solar device. The prototype house will be studied while occupied for 1 year by a team of California Polytechnic scientists.

Because of the sharp increase in energy costs in the past year, the increasing interest within the executive and legislative branches and the public at large in promoting the objective of energy self-sufficiency, and increasing awareness that solar energy holds great promise for the heating and cooling of buildings, HUD has recently broadened its activities related to solar heating and cooling of buildings. In anticipation of a residential building demonstration program, HUD has contracted with the National Bureau of Standards to develop performance criteria both for solar heating and cooling systems themselves and also for the buildings in which such systems will be installed. HUD has also created an interagency advisory committee to oversee the devedopment of these criteria, with the committee including representatives of HUD, NASA, DOD, GSA, NSF, and FEA.

In conjunction with other agencies, HUD is also developing a program plan outlining how such a residential solar heating and cooling demonstration might be administered, drawing on its background of experience in conducting advanced technology housing demonstration programs. You may recall that as part of the Operation Breakthrough program begun in 1969, HUD supervised, planned, and implemented the construction of nearly 3,000 experimental prototype housing units throughout the country.

These units all incorporated advanced technologies, in some cases using materials and techniques never before used in construction. Through Operation Breakthrough, HUD gained valuable and unique experience in managing demonstrations of this type and also in coordinating the activities and contributions of the many Federal agencies who participated. These agencies included the National Bureau of Standards, which developed performance standards, DOD, which tested and evaluated some of the units, and NASA, which helped in the evaluation of high technology adhesives used in some units.

Mr. Chairman and members of the committee, you asked that we discuss, on behalf of the Department of Housing and Urban Development, some of our experience in managing demonstration programs. One demonstration program which we have managed is a total energy demonstration initiated earlier this year in Jersey City, N.J. This is an intriguing R. & D. program, in which HUD serves as the lead agency, with the aim of reducing energy requirements for housing and commercial development projects. We should have preliminary results from this demonstration in the late fall of this year.

Another program, the basic homes program demonstrating new ways of providing low-cost housing to families in rural areas. We will have the first unit built under this program late this fall. We estimate the cost to be $8,000 to $15,000 per unit, including the price of the land.

Before turning to more general observations about H.R. 15612, I would like to comment on two specific questions that the chairman asked the Department to address in his letter to Secretary Lynn inviting us to testify.

The first related to the adequacy of the funding specified in the legislation. Section 19 of the bill authorizes an appropriation of not to exceed $2 million to NSF for fiscal year 1975 to fund the preparation of a comprehensive solar program definition. We feel that the National Science Foundation in its current lead agency role is in a better position than we to comment on the adequacy of this funding level or even its need in light of existing NSF activities. As to the question of future appropriations, the appropriate level of funding quite obviously will depend on subsequent program definition.

The second specific question related to the issue of what incentives may be needed to promote solar applications and what provisions should be included in the bill for this purpose.

We do not feel at this time that the necessity for nor the precise objectives of a continuing program of incentives have been adequately studied and defined. We think that, at least in the case of heating and cooling of buildings, Federal incentives should be limited at this time to the financing of research and limited demonstrations. The issue of further incentives is one that requires additional study, a fact which has been recognized by the Congress in its consideration of other solar energy legislation.

Turning to a more general consideration of H.R. 15612, HUD strongly concurs with the primary objective of the bill, which is to assure that the Federal solar research, development, and demonstration effort is conducted in an effective and efficient manner and that it is comprehensive in its consideration and study of all issues involved in the future commercial utilization of solar energy in the United States.

The Department fully agrees that such a program should include comprehensive technology assessments related to the utilization of solar energy, including systems, economic, social, and environmental studies. We also recognize that the activities of different Federal agencies must be carefully coordinated to avoid overlapping of programs, to assure that essential activities and studies are not omitted, and also to assure that the skills and expertise of each agency are utilized in an effective manner.

The vehicle established by H.R. 15612 to achieve these objectives is a Solar Energy Coordination and Management project chaired by the Administrator of the Federal Energy Administration and including as members representatives from HUD, NSF, FPC, NASA, and the AEC. In section 5(c) of the bill, the project is given the "responsibiilty for the provision of effective management and coordination with respect to a national solar energy research, development, and demonstration program." In section 5(e), the project is given "exclusive authority with respect to the establishment or approval of programs or projects under this Act, except that the agency involved in any particular program or project shall be responsible for the operation and administration of such program or project."

In section 18(a), the chairman of the project is directed to "prepare a comprehensive program definition of an integrated effort and commitment for effectively developing solar energy resources."

HUD recognizes that its expertise and contribution to the solar program is only one aspect of the overall project. Our major expertise is in the real world application and transfer of new and existing technology to the residential building industry, based on first-hand knowledge of and experience with the kind of problems that are encountered.

We have considerable expertise in dealing with building codes, labor considerations, inspection procedures, financing institutions, and in general with all aspects of the unique and complex homebuilding industry.

However, we recognize with regard to the solar heating and cooling of buildings that we do not have the technical research and development resources possessed by NSF and NASA, for example. HUD, therefore, recognizes the need for a coordination responsibility. The question is how this might effectively be carried out.

HUD believes that the executive branch should have considerable flexibility in achieving this coordination. Currently, the National Science Foundation has been assigned lead agency responsibility for solar energy by the Office of Management and Budget. This responsibility will be transferred to the Energy Research and Development Administration when that agency is established, assuming ERDA is enacted quickly.

Generally speaking, we do not feel that legislative establishment of a "Project" as a separate entity as proposed in H.R. 15612 would achieve anything that cannot now be done under existing arrangements.

Turning to some other aspects of H.R. 15612, HUD defers to NASA and NSF on the establishment of a Solar Energy Research Institute as provided for in section 12 of the bill.

With regard to section 13 establishing a Solar Energy Information Data Bank, HUD feels the committee should consider the relationship of this section to the provisions of H.R. 11864, the Solar Heating and Cooling Demonstration Act, which provide for the Secretary of HUD to establish a solar heating and cooling data bank.

In summary, HUD is in full agreement with the overall objectiveness of H.R. 15612. The basic issue we would raise relates to the need for and wisdom of establishment by legislation of a formal institutional mechanism such as the Solar Energy Coordination and Management project, rather than permitting greater latitude to the executive branch in determining how these objectives are to be met.

We believe in the establishment of an agency like ERDA to coordinate R. & D. in the energy field. Pending the establishment of ERDA we believe that the present arrangement or this project can provide the interim coordination needed. HUD would be happy to cooperate with any interim arrangement established.

Thank you, Mr. Chairman.

Mr. McCormack. Thank you, Mr. Moskow.

Mr. Bergland.

Mr. Bergland. Thank you very much, Mr. Chairman.

Our colleague from Texas, Mr. Pickle, was unfortunately called away. He asked me to direct a question to you, Mr. Secretary, for his information.

Under title 7 of the 1970 Housing Act, new communities have a mandate to innovate. Since HUD seems slated for a key role in implementing the solar energy heating program and will take part in the R. & D. effort under the bill under discussion today, and since title 7 new communities provide ideal sites for solar energy demonstrations at a community scale, what steps will you take to assure their consideration as sites for solar energy demonstrations?

Mr. MOSKOW. We would certainly consider the possibility of demonstrating solar energy appliances and houses in new communities. I think, Mr. Bergland, it would depend on the types of demonstrations that we would be considering. At this point it is probably premature to decide specifically what those demonstrations would include.

There would be a range of different types of demonstrations, some small and some larger scale. Certainly the new communities would be one area where we would give careful consideration to these demonstrations.

Mr. BERGLAND. It would appear to me that that would be a very logical place in which to experiment with some of the innovative applications of solar R. & D. You are building a new community from the ground up and applying all forms of innovative ideas in some of the building modes. It would certainly appear logical to apply some of the energy work in that same plan.

Mr. MOSKOW. Yes; it certainly could be.

Mr. BERGLAND. Thank you very much, Mr. Secretary.

Mr. MCCORMACK. May I followup on that question Mr. Bergland asked. You clearly have the authority to do this, and you have the money to do it, so there is nothing to keep HUD from doing developmental work in solar energy at the present time. Is that true?

Mr. MOSKOW. We do have the authority under our general research and demonstration authority, Mr. Chairman. However, I do not think that we have the funds that would be required for major demonstration programs in this area at this time.

Mr. MCCORMACK. Perhaps we have a semantics problem. What is major, a dozen or 20 houses across the country, if you wanted?

Mr. MOSKOW. I think, as I discussed with you on other occasions, we have funds for the development of the performance criteria for a solar energy demonstration, both for the appliances and the units that would be built. Those criteria should be completed by the National Bureau of Standards this fall. We have an interagency committee advising us on this effort. We will then be in a position to move into the next stage of this effort, and that could involve some additional expenditures, which I believe, pending the outcome of the current appropriations bill we may be able to engage in to some extent in fiscal year 1975.

But any large-scale demonstration involving a substantial number of units would require additional funding.

Mr. MCCORMACK. Do you mind if I pursue that a bit more?

Mr. MOSKOW. Not at all.

Mr. MCCORMACK. We still have a semantics problem.

I assume that you probably know at the present time what the appropriation level is going to be and what range is being considered by the committee.

Mr. MOSKOW. No, Mr. Chairman. That is presently under consideration by the Senate. We received our amount in the House. We have not received a definite amount in the Senate yet.

Mr. MCCORMACK. Under the House bill, could you do 12 or 20 houses?

Mr. MOSKOW. No, sir, we could not. We had requested an appropriation total of $76.3 million, which includes salaries and administrative expenses, and the House mark cut that to $65 million. If the House mark were to stand, we could not engage in the type of demonstration you referred to in fiscal year 1975.

Mr. MCCORMACK. We talked about the cost of doing solar houses. We would be talking presumably in terms of a total cost, including administrative costs, and so on, of $50,000 a unit, or something like that?

Mr. MOSKOW. Yes, that neighborhood is about right.

Mr. MCCORMACK. Perhaps $20,000 a home, or something like that, a total cost of $1 million?

Mr. MOSKOW. Yes, Mr. Chairman. That ball park is approximately correct.

Mr. MCCORMACK. You don't feel that you have that much money in your budget under the program at the present time?

Mr. MOSKOW. That is correct.

Mr. MCCORMACK. I am sure that you heard the discussion between Chairman Nassikas and myself on phasing into ERDA. One of the things that has clearly disturbed us is our awareness of the fact that ERDA was originally conceived in the Atomic Energy Commission as regulatory. Added to it are the Office of Coal Research and that portion of the Bureau of Mines dealing with energy. Later, bits of NASA and NSF dealing with solar heating, cooling, geothermal R. & D., and a little environmental research were added.

Serving on the Joint Committee on AEC as I do, I am acutely aware of the traumatic experience that the personnel of the AEC are going through and will be going through if and when ERDA legislation is passed and implemented. I anticipate that it is going to take a long time, a number of months, to reorganize and to work out the problems associated with bringing nuclear weapons into a nuclear agency, handling without authority all of our national laboratories, and resolving other such problems. These are things that are left dangling in the ERDA bill. For this reason, we have assumed in this bill, and in the geothermal bill, that, with sharp, mission-oriented management projects, we would save a year or maybe even longer in these particular areas of R. & D. demonstration.

This is really the fundamental reason for this type of legislation. For this reason, I am inclined to take exception to the point you made in your testimony that we can get along as we are until ERDA is enacted.

My first point of exception is that I am not at all sure the legislation is ready to be enacted at all. Even if it is, I think it would be at least 9 months to a year at best, before ERDA would be in a position to take effective action on administrative programs. I wonder if you would care to comment on that?

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Mr. MOSKOW. Certainly the time factor is a very important one. I think it's essential for us to develop mechanisms that will enable us to move forward as quickly as possible in further research and demonstration activities in the solar energy area.

I think you are really raising a question as to whether the present arrangements are going to be as rapid and as expeditious in moving forward the solar energy research and demonstration effort as the type of arrangement included in the proposed bill.

Based on my experience in several different agencies, there is always a problem of startup. Whenever a new agency is established, such as ERDA, there is no doubt that there will be a gap or a lag before the activities are coordinated as intended under the bill.

On the other hand, I think that up to this time our experience with the present arrangement has been satisfactory. We have not felt that there has been serious time delay in expeditiously moving the effort forward.

Mr. MCCORMACK. For fiscal year 1974, we had $13 million appropriated to NSF for solar energy R. & D. During this same time, NASA was bootlegging some work, and so was AEC—doing good work, apparently, but it was bootlegging work.

NSF, the so-called lead agency, has no jurisdiction whatsoever to do demonstration or development work. It's a research organ. Of course, the whole thrust of this entire question now is commercialization, development, and demonstration of solar energy, so that we can actually move as quickly as we can to the successful exploitation of solar energy.

This is one of the reasons why we have sought to create an agency that had statutory authority to carry this forward. Of course, this is one of the arguments that has been persuasive in the solar heating and cooling bill and in the geothermal bill. The basis for the overwhelming support they received was that, despite the fact that NSF had been designated the lead agency, it did not have the statutory authority to carry out the assignment given to it. For this reason Congress has enacted the Solar Heating and Cooling Demonstration Act, to try and get the work underway, instead of just talking about it indefinitely.

Mr. MOSKOW. As we know, the agencies—NSF, NASA, HUD, and other agencies—are moving ahead already in many of these areas. In one area that you mentioned, the demonstration of solar heating and cooling, HUD has particular expertise in this area. As part of the current effort with NSF, the lead agency, we have already signed a memorandum of understanding. We are moving ahead already, as I mentioned before, with the establishment of performance criteria for such a demonstration.

Mr. MCCORMACK. I want to congratulate you on that. I think it's good foresight and an excellent step forward. It will be very valuable as we get into the program.

Mr. MOSKOW. Thank you, Mr. Chairman.

Mr. MCCORMACK. Mr. Cronin?

Mr. CRONIN. Yes, Mr. Chairman.

One of the other areas where HUD has a tremendous amount of expertise is in dealing with home mortgages, banks, and interest rates, and several of the other problems that you face each and every day.

Is HUD making any effort to give financial institutions the incentive to provide the lending power for energy-saving innovations similar to what you have done with FHA and reinsurance of mortgages? Is HUD looking into incentives to get solar heating and cooling established by saying, for example, if you got solar heating and cooling in your proposed home we might give you an extra 1 percent of insurance on an FHA mortgage?

Mr. MOSKOW. This is a very important area. I think the willingness of financial institutions to lend money to people who want to build solar energy homes or multifamily dwellings will be crucial to the success of any solar energy effort.

Our planning at this time is to take the performance criteria, once they are developed—which will be this fall—and then start a series of meetings with representatives of various financial institutions to get their reaction as lenders to this type of a home that would include solar energy as an energy source.

Based on that series of consultations we will have a much better idea what incentives are going to be needed to encourage this development.

Mr. CRONIN. Now you are touching on what I am really trying to get at. I am trying to determine if we can make some sort of a guesstimate, some sort of a timetable, assuming that, (*a*) we have technology that is somewhat useful today and is getting better, (*b*) that there is a demand for it, and (*c*) one of the major deterrents to meeting that demand is the willingness of financial institutions to lend the money.

If HUD is going to go through this program and determine the feasibility, determine in effect the risk to these financial institutions who are doing this, how long do you think it will be before there can be a marriage between some sort of a governmental insurance guarantee and lending institutions to provide the proper incentive to get new home starts moving with solar heating and cooling? Is it on a magnitude of a couple of years, a decade, or just a guesstimate?

Mr. MOSKOW. You mean for the construction of the demonstration units?

Mr. CRONIN. No.

Mr. MOSKOW. Or on a wide scale?

Mr. CRONIN. The wide scale use by financial institutions of grants of mortgage money to people who would like to build homes heated and cooled with solar power.

Mr. MOSKOW. Of course, we are all guessing. I would like to ask Mr. Sherman to provide an answer to that question.

Mr. SHERMAN. The first thing that we have to do is point out to the financial institutions, since we do not have any direct control over them in any way, shape or form, that what we have is, indeed, economically and practically feasible; that it's not going to come back to them as a defaulted mortgage, it's not going to be a problem for their portfolio to have a solar house in it.

I think the first time we do the demonstration of a residential dwelling unit we intend to have the financial institution participate so that they get their feet wet, and they understand the problems.

Mr. CRONIN. Hopefully, they won't get their feet wet.

Mr. SHERMAN. That was a bad one. So they understand the problems and actually participate in the decisionmaking process so that they learn what the hangups and the problems are. We can see their reaction, whether they can go right into it or whether they say, "Look, we are afraid." We do have mechanisms under section 233 of the Housing Act, the experimental housing program, to provide special insurance for innovative technology. We can use that, and do intend to use that, if necessary.

Mr. CRONIN. What is your guess for widespread acceptance by financial institutions?

Mr. MOSKOW. We will probably have some basis for guessing just months after the construction starts, after we start construction under the various demonstration programs that are now being proposed. Then we would have interim acceptance. We would have private money from financial institutions involved in the program. But whether they will continue when we pull out won't be known until 2, 3, or 4 years hence.

Mr. CRONIN. That was very helpful.

Mr. MOSKOW. I would hasten to add this is only a guess on our part at this point.

Mr. CRONIN. I appreciate that.

Mr. MOSKOW. I think we would have a great deal more understanding of the time frame after we started this consultation period this fall.

Mr. CRONIN. So we might expect to have an update on this about this time next year?

Mr. MOSKOW. Yes, sir.

Mr. CRONIN. A much better feel for it?

Mr. MOSKOW. Absolutely.

Mr. CRONIN. Thank you very much. I think that is very significant.

Mr. MCCORMACK. Thank you very much, Mr. Cronin.

Thank you, Secretary Moskow. Thanks to all of you from HUD. We very much appreciate your testimony. I think we will be working together with you quite a lot in the future. I know we are looking forward to it.

Mr. MOSKOW. Thank you, Mr. Chairman.

Mr. MCCORMACK. The committee is adjourned.

[Whereupon, at 12:10 p.m., the committee adjourned.]

SOLAR ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACT OF 1974

FRIDAY, AUGUST 2, 1974

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON ENERGY,
Washington, D.C.

The subcommittee met, pursuant to recess, at 10:05 a.m., in room 2318, Rayburn House Office Building, Hon. Mike McCormack (chairman of the subcommittee) presiding.

Mr. MCCORMACK. The meeting will come to order.

This is the final meeting in a series this subcommittee has held on legislation involving the long-range aspects of solar energy research, development, and demonstration. The bill that we are considering this morning is H.R. 15612, the Solar Energy Research, Development, and Demonstration Act of 1974.

Our testimony this morning will deal primarily with the administrative and organizational aspects of the creation of a management project to coordinate solar energy research and development in the future.

Our witnesses this morning are Mr. Frank Zarb, Associate Director for Natural Resources, Energy, and Science, Office of Management and Budget, Mr. Raymond Bisplinghoff, Deputy Director for the National Science Foundation, Mr. James Fletcher, Administrator, National Aeronautics and Space Administration, and Hon. Dixy Lee Ray, Chairman, U.S. Atomic Energy Commission.

Mr. Zarb, we want to welcome you here this morning and also Dr. Bill McCormick, who is with you.

[The statement and biographical sketch follows:]

PREPARED STATEMENT OF FRANK G. ZARB, ASSOCIATE DIRECTOR, NATURAL RESOURCES, ENERGY AND SCIENCE

Mr. Chairman and members of the committee, I am pleased to appear before you again to discuss an important aspect of our national energy, research and development program. In this connection, I would like to compliment the Committee on its outstanding record in the energy field, particularly in enhancing public understanding of the important energy problems that face our country and in providing innovative leadership aimed at their solution.

Today, you have requested me to discuss the Solar Energy Research, Development and Demonstration Act of 1974, H.R. 15612, which is now being considered before this Committee. In general, I believe the objectives contained in this bill are laudable ones and ones with which the Administration is in substantive agreement. As you know, the Administration is firmly committed to a broad and vigorous effort in pursuing the exploration and eventual development of solar energy utilization technology. The President's FY 1975 Budget included $50 million for solar energy R&D. This was more than four times the level provided for in FY 1974 and more than ten times the Federal expenditure level of FY 1973. Thus, it is fair to say that Federal research and development activities related to this important future energy source are not only increasing but are increasing dramatically, both with respect to their magnitude and scope. The new activities that have and are being initiated as a result of this increased Federal commitment are in the areas of solar heating and cooling of buildings, central station photothermal conversion, photovoltaics, wind power, ocean thermal-gradients and bio-conversion. Although each of these research areas differs in its state of development and in the direction of its technological programs, all are being pursued, I believe, with the maximum efficient expansion from Federal resources.

I would now like to address several particular aspects of the Federal solar energy research and development program and comment on the proposed legislation before this Committee with respect to program management, level of funding, need for financial incentives and institutional arrangements for conducting the research.

As you know Mr. Chairman, the legislation to create an Energy Research and Development Administration is nearing completion of its legislative journey through the Congress. Thus, we expect that a new independent Federal agency will soon be created which will provide, for the first time, an organizational mechanism capable of formulating, planning and executing an integrated national energy R&D program. Pending creation of ERDA, the National Science Foundation has been acting as lead agency in formulating the detailed aspects of the solar R&D part of the President's Five-Year Energy R&D Program. The Foundation has been working closely with AEC, NASA and other agencies to ensure that there are no undesirable overlaps or omissions in the total Federal R&D effort in this important area.

Mr. Chairman, we recognize that the lead agency approach for coordinating programs residing in several Federal agencies is not an optimal management solution. We feel that the management project proposed in the bill before this Committee can be an effective interim arrangement which could enhance our ability to coordinate and plan our national solar energy research program. Furthermore, we believe the project could be an important vehicle for centralizing planning control prior to and during the transition period to ERDA.

Mr. Chairman, I would now like to turn from consideration of the management of solar research to questions impinging on the effective conduct of such a program. Section 10 of the proposed legislation seems to mandate that a program shall be initiated to design and conduct, in each of the specific solar energy technologies, a demonstration scale facility. If this is intended, I believe it is premature and could be counterproductive to the cause of advancing solar energy as a future contributor to our Nation's energy supplies. It is clear from previous testimony before this Committee and, more generally, from scientists and engineers working in the solar energy field, that the state of development of the various solar technological approaches and the prospects of their eventual technical and economic success are quite varied. Thus, mandating a large demonstration project in each area before technical feasibility has been established could result in needless expenditures of Federal dollars and possibly even unfavorable impact in the commercial sector before each technology has had an adequate opportunity to prove itself. I believe we need to retain the flexibility to move vigorously on attractive demonstration projects but at the same time retain the capability to not pursue unattractive ones in the future.

Permit me now to comment briefly on the proposed Solar Energy Research Institute proposed in Section 12. I believe that an Institute, such as described in this legislation, could be an important instrument in conducting the Federal effort in solar research. However, as I am sure you are aware, an Institute is the only one mechanism for conducting solar research. The most effective research instrument may not be the same for all the different solar energy technological approaches. Thus, I believe it is unwise now to settle on any particular institutional mechanism but rather to provide in this legislation a range of options for conducting solar research so that the new Administrator of ERDA can choose what he believes to be the best research approach.

Mr. Chairman, I would like to comment briefly on the issue of incentives for the private sector conducting solar energy research and development. As you and other members of this Committee have often pointed out, there are a number of barriers, economic, technical and otherwise, which are impeding the early introduction and successful commercial application of solar energy. The proposed legislation would establish a solar energy incentives task force to recommend a program of incentives to accelerate the commercial application of solar energy technology. As the proposed legislation recognizes, it is not clear, at this time, whether such a program of incentives is necessary or, if it is necessary, how it should be structured. Other than lending my support to a study of this matter, I would only add that it is important to consider such a program of incentives in the context of a broader incentives program covering other energy sources as well. In other words, we should be careful not to give undue preferential treatment via an incentives program to solar energy without examining how it might affect the introduction of other energy technologies. In this connection, the President, in his January 23 energy message to the Congress, requested that the Federal Energy Office, now the Federal Energy Administration, initiate a comprehensive study to examine the need for incentives in all energy resource areas and to report its findings to him. Thus, I recommend, Mr. Chairman, that the results of this special incentives study for solar energy be closely coordinated with FEA's study, and that the final decision on whether to move forward on an incentives program awaits the results of FEA's broader incentives analysis.

On a technical matter, I would like to comment on the proposed changes to the NSF and NASA organic acts. Because of the imminent creation of ERDA and its eventual lead role in solar energy, I believe that sufficient authorities now exist for NASA and NSF to conduct vital and significant supporting research for ERDA. Thus, we are not in favor of these amendments.

Finally Mr. Chairman, I would like to say a few words about future Federal levels of funding for solar energy research and development. As I have already mentioned, the Federal expenditure level in this area has increased rapidly over the past several years. It is clear we are dealing with a number of sophisticated new technologies, some of which may prove to be economically feasible and others which may not. It is difficult to predict at this time which of these technologies will become commercially viable and in what precise time period each will be introduced. It is equally difficult to predict which of these technologies will merit full-scale demonstration and what level of Federal, versus private investment, will be necessary to assure this. Consequently, I believe it is not easy to project into the future as to what the level of funding for solar energy should be over the next several years. I think it would be wrong to either artificially limit the level of expenditure or to set an unnecessarily high ceiling. Either course of action could be unproductive. Thus, I favor the normal annual authorization process for determining the levels of funding needed for solar energy—principally, because of the need for continued funding flexibility in these complicated R&D programs but primarily because it seems impossible to project with any precision the appropriate funding levels for the future.

Mr. Chairman, with the exception of the several concerns which I have noted in my testimony, I generally support this proposed legislation. I appreciate the opportunity to present my views to the Committee and I would be delighted to answer any questions either you or the members of the Committee may have.

Thank you.

Biography of Frank G. Zarb

Mr. Zarb is currently Associate Director of the Office of Management and Budget, Executive Office of the President. In this position he provides executive direction and coordination for OMB's activities in Natural Resources, Energy and Science. These activities include responsibility for the Departments of Agriculture, and Interior, the Environmental Protection Agency, the Corps of Engineers, the Atomic Energy Commission, the Federal Energy Office, the National Aeronautics and Space Administration, the National Science Foundation, the National Oceanic and Atmospheric Administration and related agencies.

Prior to assuming his present position, Mr. Zarb was in charge of OMB's Management and Operations activties. This included coordination of a broad range of Federal programs and initiatives, Government reorganization, statistical policy, and OMB field, and intergovernmental relation activities.

Mr. Zarb first joined the Administration in April 1971 as Assistant Secretary of Labor for Administration and Management.

Before coming to the Federal Government, Mr. Zarb was Executive Vice President and Chairman of the Executive Committee of Hayden Stone, Inc., a New York investment and securities firm.

In 1970 he edited The Stock Market Handbook, published by Dow Jones-Irwin, Inc. He has also co-authored "A Stock Broker's Statement of Financial Condition, How to read it—and how to read between the lines." He organized and served as the first Chairman of the Joint-Bank-Securities Industry Committee for Securities Protection and has held membership with the Board of Arbitrators of the National Association of Securities Dealers, and the Board of Advisors of the New York Institute of Finance. He has been a member of the Chicago Board of Trade and the Chicago Mercantile Exchange and an allied member of the New York Stock Exchange as well as the American and Pacific Coast Stock Exchanges. He currently serves on the Board of Trustees of the East Woods School, Oyster Bay, New York.

Mr. Zarb graduated from Hofstra University with a BBA in 1957 and a Master's Degree in 1961. A native of New York, he is married to the former Patricia Koster of Hempstead, New York. They have two children, Krista Ann (14) and Frank, Jr. (12).

STATEMENT OF FRANK G. ZARB, ASSOCIATE DIRECTOR FOR NATURAL RESOURCES, ENERGY AND SCIENCE, OFFICE OF MANAGEMENT AND BUDGET, ACCOMPANIED BY DR. WILLIAM McCORMICK, CHIEF, SCIENCE AND ENERGY TECHNOLOGY BRANCH

Mr. Zarb. First I would like to thank you for allowing us this opportunity to speak to this bill and to this subject at this time.

As I have said several times before, I think the leadership and innovative thinking by you and this committee is to be applauded in this area as well as many other science areas, particularly as they relate to our energy problem.

I am particularly pleased this morning to be able to say that we generally support the bill about which we are here to testify. It is all too frequent that we must come before a microphone and start off by saying we have some grave problems. But we do generally support the bill and its intent and motivation, and certainly the project that it addresses.

The management project which it proposes, it seems to us, is a useful vehicle to prepare the way from now to the time that we are in full swing with the Energy Research and Development Administration which we still hope will become a reality in the near term.

I would, however, in keeping with OMB tradition, ask to raise several points with which we have some concern and would ask you to consider. The chairman of the management project, rather than being identified as one or another specific individual or agency within Government, it seems to us, should be a decision left to the President. In making his judgments at any point concerning organizations within the executive branch, the President is in the best position to say who should have been responsible and been held accountable for the results.

The second area which we would mention briefly is what appears to us to be amendments to the Organic Acts of NASA and NSF. We see all the authorities within the existing acts adequate to do the job and would question changes at this point in time to those acts.

Another area which we have discussed previously relates to the demonstration project mandate. We still, in reviewing the legislation, see or perceive a mandate for demonstration projects. We would urge that you consider along with us the concern that if we demonstrate too early we are not only wasting resources but are doing significant damage to the program. We would hope that demonstration projects are held until the feasibility of the science is sufficiently demonstrated and we thereby will get adequate results and information from such demonstration projects. On the level of funding issue, while remotely addressed by this legislation, we, at this point in time, would urge a continuation of year-to-year funding until we get a better picture as to what longer range programs might be most productive. It seems to us that we ought to keep the flexibility both in the Congress and the executive branch to be able to address the issue each year.

As you know, within the last 3 years the funding within the President's budget has increased significantly as the developments within the solar area have demonstrated their ability to absorb increased funds. I would hope that we can maintain that flexibility.

That ends my formal comments. I certainly will be pleased to answer any questions you may have.

Mr. McCormack. If I may just quickly review the points you have made, under the establishment of a management project, you would recommend that the chairman be appointed by the President rather than specified in the legislation?

Mr. Zarb. Yes, sir.

Mr. McCormack. That could be any individual, including the Administrator of the Federal Energy Administration or anybody else the President might name.

Mr. Zarb. Yes, sir.

Mr. McCormack. May I comment that part of the rationale for the committee's decision to name a specific individual in the bill was to save time.

May I ask, for the record, if the bill were to be written as you suggest, with the chairman to be appointed by the President, do we have your assurance, or can you give us any indication, that this will be done promptly so that the project can get underway quickly?

Mr. Zarb. I can and I will give that assurance, Mr. Chairman. Such a designation will be made promptly.

Mr. McCormack. That is good.

You are objecting also on pages 6 and 7 to the amendment to the National Science Foundation Act and the amendment to the National Aeronautics and Space Act. That is section 6 and section 7.

Mr. Zarb. Yes, sir.

Mr. McCormack. Do I infer from this, then, that you do not have any objection to the specific authorization and directions in the bill for the agencies to participate in the program, but that you do not think it is necessary to amend these acts to do that?

Mr. Zarb. Mr. Chairman, I believe that all the authorities necessary to carry out the intent of the bill are already within these acts and they need no amendment.

Mr. McCormack. Now on section 10, you made the point that you objected to a mandate for demonstration. That is on page 12. If I read you correctly, you are objecting to the word "shall."

Mr. Zarb. Yes, sir.

Mr. McCormack. The word "may" there would be satisfactory, I presume.

Mr. Zarb. Yes, sir, that would do it.

Mr. McCormack. I am sure that we concur with you on that. On reflection, we certainly agree. There was no intention to require a demonstration in every one of these areas.

May I then ask one other question? Under the authorization, the very last section, you are aware that there is a typographical error in some versions of this bill, and that the date should be June 30, 1975 in each instance. In one version it is mistyped and says "76." We meant "75" and will so write the bill. That does not change anything.

Mr. Zarb. All right.

Mr. McCormack. Something that has bothered me does not show up in this bill. We have written this rather standardized transfer of functions section, section 16, which says that within 60 days after the effective date of a law creating an Energy Research and Development Administration, or any other Federal agency with jurisdiction over national energy R. & D. the functions that are established under the authority of this act shall be transferred to the new agency. I am a bit troubled by the possibility that it will take a long time to get an agency such as this organized and working. I am not unaware of the fact that the bulk of the personnel from ERDA, if one is created, will come from the Atomic Energy Commission. It is going to take a great deal of work to reorganize the AEC into a National Energy Commission or whatever it is going to be and an ERDA. There are what seem to be about 6 months of organizational problems involved here.

I am deeply concerned that we do not have those organizational problems getting in the way of the functioning of this solar energy program. We want to keep the program going. I had toyed with the idea of changing that date to 6 months or to sometime in the future at the discretion of the Office of Management and Budget or something of the sort, just to avoid any unnecessary delay in the program that would be caused if the authority in this bill and the authority under the solar energy and cooling bill and the geothermal bill, were more or less forced upon the ERDA Administration while it was still trying to get organized.

The exact method by which we do this is not really important to me, but I am concerned that these programs do not get held up because of that reorganization program. I wonder if you could advise us and give us your perspective on that.

Mr. Zarb. I think that is a legitimate concern which we will have to watch jointly. In my position at OMB I chair a steering group now which is working with all the various elements of the eventual ERDA to anticipate early problems and come to grips with substantive questions. We certainly would support leaving the discretion of OMB in as a provision. We are at the moment and will continue to have some responsibility for insuring that ERDA is launched in some orderly work. We have done a good bit of early work.

The Steering Committee has been in operation for almost 3 months now. Many early questions have been examined. It is our hope that we will be able to separate some of the major organizational issues from the areas that we think can move along and not be interfered by organizational questions not related, for example, to solar. The way to do that is going to be to insure that we have selected the right people to head up these projects, for example, solar, who can work on their own and begin immediately to pull together all the various elements of Government and get this thing launched. But I do agree that we should be sensitive to the problems of an early start of any agency. We certainly would be if you gave us that authority.

Mr. McCormack. I thank you.

Mr. Brown, do you have any questions?

Mr. Brown. Well, I do not think I really have a question. However, I just wanted to discuss briefly with you your comments on page 5 with regard to the Solar Energy Research Institute. You are commenting somewhat negatively on this. I have a little problem in visualizing personally how an institute of this type would work, although I recognize that this a a fairly standard procedure in attacking many problems. We hear of all types of institutes, for example, in the U.S.S.R., for approaching various different kinds of problems. I presume the best comparison here is the way in which we have approached the fusion problem. We have four major centers that are working on fusion in one form or another. Whatever the number is, the basic work is being centralized in an institution, generally under academic control, where the research can be coordinated.

With regard to solar, I think the problem is that there is not the coherence of goal that there is in fusion. In solar, we are talking about some widely different types of activities, such as heating and cooling, as one example, or the conversion of biomass to energy, as another. They are really not suitable to go into the same kind of an institution, it seems to me. I would like to ask you to comment on that.

The kind of thing that is being done in the conversion of biomass is probably best suited to a school of agriculture, whereas that which is involved in, we will say, wind machines should be in a school of engineering.

Is there any real problem in trying to develop some centralized focus, as we are attempting to do with this management project, in which we could coordinate the information with regard to research and development in all these areas while the actual work itself could be done in the institutions best suited to the particular kinds of work?

Mr. Zarb. First let me say that I hope that the comments on page 4 are not interpreted as being negative to an institute. I have tried to say there that the institute is one of several vehicles that should be available to the Administrator in directing this activity and his options to use it or not should be open to him. I think part of the real excitement to a new head of the Energy Research and Development Administration is to come to grips precisely with problems such as that. I spent some time yesterday with members of the scientific community and I have spent some time with the President's science adviser and others on this very issue. We do not have answers. Answers will have to be developed in the management style of the organizational leadership of ERDA. But they must be found and addressed. Our position up until now is let's attempt to keep the tools of availability open to this new leadership so that they can put together the precisely right formula or what appears to be for the moment the precisely right formula to attack the problem.

Mr. Brown. I can agree with this. I do not think we are far enough along to freeze anything at this point. One of the truly fascinating aspects of solar energy is the pervasiveness of it. I can see a solar energy focus, for example, in one of our larger schools which are now devoted to marine biology and resources, because one potential of solar energy is in utilizing temperature differentials in ocean currents and another in more effective conversion of solar energy to organic materials in the ocean.

Research on these applications could become focused in a school devoted to that sort of activity; whereas the sort of thing the Meinels are doing in Arizona in trying to develop a conversion of solar energy and the various kinds of direct applications of energy would not go very well in a school devoted to ocean research, but would need a facility out in the desert.

There are a lot of ways that this could be done, and they need to be explored within the framework of this legislation. If the thrust of your comment is to retain flexibility, I would agree with you. Thank you, Mr. Chairman.

Mr. McCormack. Mr. Cronin?

Mr. Cronin. Mr. Zarb, I am in complete agreement with your comments on the original aspects, and I am very pleased to hear them. I would like to ask a couple of philosophical questions on the administration.

One of them concerns your comment on demonstrating these projects too early and hurting the whole project. You advise holding off until feasibility is proven.

I certainly agree with the concept but it would appear that feasibility has been proven many times, particularly in the area of heating and cooling.

I wonder if you would foresee a situation of getting into demonstration programs very quickly in some areas of solar, such as heating and cooling, or whether you are philosophically looking toward a long-term period of additional feasibility testing before we get into demonstration.

Mr. Zarb. The way you ask that question, Mr. Cronin, directs how I should answer it.

Mr. Cronin. That is the way I hope you will answer it.

Mr. Zarb. I am quite sure we are thinking alike. I surely do not think we should have endless test tube experiments and not get on with the engineering and demonstration as soon as practicable. I agree with you that this is one demonstration that offers the most promise and probably will have some near-term demonstration and feasibility and some near-term demonstration results.

One of the management benefits I see from an ERDA, and I know that ERDA has been argued and there have been pros and cons, but one of the major benefits of having an organization such as ERDA is that it begins to fix responsibility for a result so that someone or some management group now has the responsibility for saying we are here and we want to be here by at certain date; and here are milestones of management objectives in between. Then we really get to the serious business of saying here is where we are going to place a demonstration project because it is going to show us the economics, the technical feasibility, the durability. That is in the critical path and needs to be there to take us to the next stage rather than the sort of fractionation that occurs when the science is so early and we have it splintered throughout Government as is so often the case.

So I see the area of responsibility helping that question. I do think heating and cooling has to be the first area.

Mr. Cronin. You have led me into the second question. Given the structure, we are finally going to be able to hold someone accountable for his actions or lack thereof in bringing about a given result. We then start with ERDA at a point where the fossil fuels have had considerable Government concern over the past years. We have AEC, where we have had massive Federal investments over long-term periods. Now we are talking about the so-called esoteric forms such as solar. Do you think that OMB is going to be receptive to providing some open-ended funding, similar to what they provided to AEC, for these newer sources such as solar and possibly geothermal and some of the other forms of energy, so that the management structure you described so very well can be looking toward a long-term solution of major solar problems and can count on as much money as it can reasonably spend over that period of time?

Mr. Zarb. Let me answer that in two parts. First, I do not believe that we have spent a lot of money in fossil fuel R. & D. over the years. I think we probably have, for reasons which have been stated so often, have really not addressed the advanced state of the art in, for example, coal imperfection or coal gasification.

We just never envisioned an embargo and cartels and other problems that lead us to look at a Project Independence type situation. Be that as it may, we now need to address that issue as well. In making funds available in the amounts needed by, take, for example, solar research and development, I guess it really depends on how you define "reasonable." Our continuing function is to ask questions and to be sure that there is a plan and that progress is being made toward the achievement of the results at the end of that program and to challenge the spending of money which may not lead ultimately to that conclusion.

Within the constraint of good management and that kind of oversight, I would say that solar will get all of the funding required to bring it on line as soon as practicable. I do not mean to be hedging but so frequently the advocates of a program believe that the program can be be advanced by burying it in money while it is clear that it is really not so.

Mr. Cronin. That is not what I was getting at. Really the philosophical division is either line-by-line appropriation or, in effect, an open-ended authorization that is going to allow them to spend as much as someone who is going to held them accountable thinks can reasonably be spent in an effective manner. I think that is the basic split. That is what I am trying to get at. We have heard the discussion over the last few weeks to the effect that the outcome of certain major questions in the country depends upon the point from which you start. Do you start from the point where all solar projects have to be proven effective before appropriation is made or just reverse of that, that an appropriation will be made for anything that has some promise and can be absorbed within the technological capacities of the engineering, scientific, and industrial communities?

Mr. ZARB. From a philosophical point of view I would say probably some of the best R. & D. accomplishments come out of what I call bootleg R. & D.

Mr. CRONIN. Right; particularly in solar.

Mr. ZARB. Having said that, I do not think that any effort, even one such as this one, cannot benefit from some management direction and constraint. For that reason, I would have the people responsible for developing this program at least annually for the next 2 or 3 years until the state of the art takes on a little more substance, just tell us where they are and where they are going and how much it will cost over the next 12 months to take them there and treat that rather reasonably.

Mr. CRONIN. Thank you very much. I have no further questions.

Mr. MCCORMACK. As you know, I serve in the Joint Committee on Atomic Energy. The law says that the AEC will keep the committee and the Congress currently informed. That is in the title. This works very well, by the way.

It strikes me that every year might not be often enough. I wonder what your thought might be on having any energy agency reporting more frequently to the Congress, so that we would be more deeply involved and could prevent situation that would cause subsequent problems because of lack of information.

Would you think that sort of provision in the bill would be an acceptable one? We could say, "fully informed," or "quarterly reviews," or something like this?

Mr. ZARB. The quarterly type of thing would trouble me some because there are just too many parts of government right now that spend too much time preparing paper and then its quality is really weighed in terms of pounds and the resources are wasted, I think. I certainly would have no objection to an annual type of event which I think could recap and summarize where we have been during the year. I think that would be very healthy. I think further than that there is a lot more gained in the kind of informal consultation that can continue throughout the year as it has between you, Mr. Chairman, and all elements of this particular area and my office, where we share our problems and our plans as we go through the year. I think that is terribly productive.

I would think an annual rack-up to show what good we did with the funds that you, the Congress, gave us is really a good exercise.

Mr. MCCORMACK. Thank you.

Mr. Pickle, do you have any questions?

Mr. PICKLE. Thank you, Mr. Chairman.

I am wondering if we should incorporate in this legislation some kind of a study to attempt to remove some of the nontechnical barriers we have in the solar energy field. We do have some research and development for commercial utilization which is aimed at improving that situation as quickly as possible. But assuming the rapid development of solar energy, and we can hope that the development will be rapid, no matter how quickly it comes—1 year or 5 years—we are going to be faced with a problem of who can afford it. This will be especially true if solar energy is determined feasible for homes.

Now, it seems to me that we ought to be giving some specific study to fostering interest in initial capital investment, because it is going to be out of reach of everybody. We may have this great potential energy source, and yet not many people will be using it. What is the answer? How would OMB feel about funds that would help in this capital investment program? How do you make it obtainable by the individual?

Mr. Zarb. You have asked two questions, Mr. Pickle. I think the first is answered by saying it seems to us that the bill provides the development of that kind of study in its statement that the chairman of the project shall establish a solar energy incentive test for such individuals as he feels may carry out the functions and report to the Congress within 120 days. That seems to broadly embrace many of the things you just described.

On the issue of incentives, that is terribly argumentative. I will not lead you to believe I have all of that answer. I think a lot will depend on what we learn from this kind of a study. There is no denying, however, that one of the key breakthroughs that needs still to happen in this area is in the area of economic feasibility and the extent that this kind of energy source can be made competitive with other energy sources that may be available to us. That will be the driving force that will talk to the point of incentive size and length and scope.

Clearly we could not be in a position of subsidizing every homeowner in the Nation for 50 years so that he could join in the solar energy program because that would just be economically infeasible. We would not be able to afford it as a Nation. But that is not to say that there should not be at the right place in time and at the right moment some consideration of certain incentives to get through a critical point that needs to be addressed with an incentive type of tool.

Mr. Pickle. I will look at your views on the utilization of technology. Perhaps this task force incentive approach might be what we had in mind. I do not have a copy of the bill before me at the moment. I did not think it was that broad at all.

I think this is one of the biggest problems we have. The big problems, of course, is to establish the energy. If we do not make it available to the individual, however, what do we gain, really?

Thank you, Mr. Chairman.

Mr. McCormack. Thank you, Mr. Pickle.

I want to thank you, Mr. Zarb, for being here today. I want to comment that you have your son with you here today. We are very proud to have him with us and have him watch his father testify. It is very good to have you with us today, Frank, Jr.

At this time we are going to have a film by the National Science Foundation that will precede their testimony. After the film we will have Dr. Bisplinghoff, Dr. Fletcher, and Chairman Ray all come up to testify together.

Thank you very much, Mr. Zarb, and Mr. McCormack.

[At this time the film was shown.]

Mr. McCormack. Our next witness is Dr. Raymond Bisplinghoff, Deputy Director of the National Science Foundation.

STATEMENT OF DR. RAYMOND L. BISPLINGHOFF, DEPUTY DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. McCormack. I want first of all to congratulate you and the National Science Foundation on that film. That is certainly excellent. I am sure it will do a great deal to help the general public understand. I hope you are getting it out to all the schools in the country.

Dr. Bisplinghoff. Yes, sir, we are attempting to do that.

Mr. Pickle. Mr. Chairman, I was going to inquire of the staff, but while Dr. Bisplinghoff is here, may I ask him if it will be available through your offices? Can we make a request for it?

Dr. Bisplinghoff. Yes, sir.

Mr. Pickle. Will you give us the data that you have?

Dr. Bisplinghoff. Yes, sir.

We are now securing more copies. I cannot tell you how many are available, but you may request them from our office and we will give you prompt service.

Mr. Pickle. Good. Thank you.

Mr. McCormack. Dr. Bisplinghoff, you may proceed.

Dr. Bisplinghoff. Mr. Chairman and members of the subcommittee, I am happy to present the National Science Foundation's views on H.R. 15612, the Solar Energy Research, Development, and Demonstration Act of 1974.

This subcommittee has made an extensive review of the need for a national commitment to the development of solar energy technologies. The National Science Foundation shares your desire to see rapid commercial application of these technologies to help meet the growing energy demands of the Nation, and your subcommittee is to be commended for the fine work that it has done in calling attention to the importance of developing solar energy technologies and in developing legislation that is designed to achieve them.

Mr. Chairman, as you know, the national solar energy program already in progress under NSF leadership and with the strong participation of the National Aeronautics and Space Administration, Atomic Energy Commission, Department of Housing and Urban Development, General Services Administration, Federal Energy Administration, and other Federal agencies, is moving ahead rapidly. The pace of this program is reflected in the funding trend which has grown from a little over one million dollars in fiscal year 1971 to 50 million in fiscal year 1975.

I will give a few highlights of the progress being made under this program later in my statement, and amplify some of the points in the experiments in the solar heating of school buildings. But first, Mr. Chairman, let me comment briefly on specific provisions of H.R. 15612.

The bill would establish a solar energy coordination and management project with broad authority to develop, manage, and coordinate a national solar energy research, development and demonstration program. The responsibilities given to the project range from determining the Nation's solar energy resource base to the designs, construction, and operation of facilities or powerplants to demonstrate the technical and economic feasibility of utilizing various forms of solar energy.

The responsibilities assigned to the project fall within the range of those activities that are provided for in the legislation now before the Congress establishing the Energy Research and Development Administration. The foundation appreciates the desire of the committee for the Nation to move as rapidly as possible on the development, demonstration and utilization of solar energy during the interim period while ERDA is being organized.

As you know, Federal wide coordination of the Nation's solar energy research program is currently the responsibility of NSF. Much of the coordination now being accomplished is through the Interagency Panel on the Terrestrial Applications of Solar Energy, which is chaired by NSF. The panel consists of representatives of 15 Federal agencies and includes all of the agencies whose representatives would constitute the coordination project recommended in the proposed legislation.

Recently, at the request of FEA, the panel appointed a solar energy task force to develop analyses and data needed for an integrated national energy program. The task force, also chaired by NSF, was made up of more than 60 outstanding scientists, engineers, and other professionals from Federal agencies, industry, and universities. It is in the process of preparing a report.

The draft of the task force report is now being reviewed and revised, and we will be happy to provide the committee with copies of the final report when it is available. I believe Mr. Sawhill mentioned the report in his statement. It includes an initial analysis of the utilization goals for each of the major solar energy technology areas—heating and cooling of buildings, wind energy conversion, solar thermal conversion, bioconversion to clean fuels, ocean thermal, and photovoltaic conversion, which parallel the technology areas listed in section 9 of the proposed legislation. The report contains an assessment of the state of the art in each of these areas, the factors impeding their development, and detailed program plans for implementation, including project milestones for developing each of the technologies. Manpower requirements and a discussion of possible incentives that might be appropriate are also discussed.

The extensive involvement of Federal agencies in the development, shaping, and conduct of the national solar energy program now in progress and the steps already being taken to establish effective coordination of the program will facilitate a smooth transition to ERDA. In our view, solar energy should occupy a strong and important position among the various energy sources such as coal, geothermal, nuclear and others. We believe that resources and priorities for energy sources should be evaluated as part of a comprehensive overall Federal energy program and the work of NSF is directed to this purpose while ERDA is becoming operational.

The foundation has borad authority to support basic and applied solar energy research and technology efforts. We believe that major development and demonstration programs would more properly be handled by ERDA. With regard to funding, major development and demonstration projects should be funded by ERDA and in the meantime, pending the establishment of that agency this responsibility should be borne by the mission agency involved rather than by NSF.

The bill authorizes the foundation to support a range of solar energy research and science education programs for which the foundation already has legislative authority. This duplication of authority is a matter of concern to us because responsibilities given to NSF in the bill are to be transferred to ERDA. If the bill were interpreted literally, existing authority contained in our basic enabling legislation for the conduct of portions of the broad-based research and science education programs of NSF would have to be transferred to ERDA. We believe the bill should be modified to allow for judgment in the selection of functions that should be transferred. Mr. Chairman, the foundation feels very strongly that adding to our organic act specific subject matter authorizations and directions is undesirable and we strongly urge that the provisions of the bill that provide for these changes be deleted.

I know that this subcommittee fully appreciates the need for the National Science Foundation to provide a strong base of research support in solar energy related areas just as it does for all other fields of science. This is an appropriate role for NSF, Mr. Chairman, and one which we believe will contribute to the accomplishment of the ERDA solar energy mission and the mission assigned to the coordination project should it be established.

Section 10 of the bill states that the project will provide for the design and construction of facilities or powerplants needed to demonstrate the feasibility of each of the specific solar energy technologies named in the bill. We believe that the interest being shown by industry in the development of solar energy technologies dictates that legislative provisions for demonstration projects include wide flexibility for industry involvement.

With respect to incentives, experience shows that while stimulation of one component of a technology delivery system may help to advance the technology, it does not insure that the technology will be carried through to the marketplace. Therefore, in considering incentives, it is important to remember that no matter how good or effective a particular incentive might be in stimulating one element of the process, such as obtaining risk capital or inducing equipment manufacturers to make a certain product, the incentives effort may be totally wasted unless you provide for appropriate incentives at key points throughout the delivery system.

For example, in the case of heating and cooling of buildings, the technology delivery system involves architectural engineering companies, equipment manufacturers, homebuilders, lending institutions, labor organizations, State and local government codes and regulations, and a host of other factors. Appropriate incentives may have to be applied to each of these elements. There could be a technology blockage within any one or all of them, so it is important to consider the entire delivery system in the development of incentives strategies.

Mr. Chairman, sections 12 and 13 of the bill recommend a number of organizational arrangements, mechanisms, and procedures for carrying out the functions of the bill. These include a Solar Energy Research Institute, a solar energy information data base, a Solar Energy Incentives Task Force, and sweeping requirements for coordinating technology utilization efforts. While we believe that these elements could be useful, it is our view that the Administrator of

ERDA and the chairman of the proposed coordination project should be allowed discretion in the way in which they set about to achieve solar energy objectives.

In this connection, Mr. Chairman, we believe it would not be wise to require the coordination project to mount major demonstration projects in each of the solar energy technology areas as now proposed in the bill, since this approach may not be cost-effective in all cases.

I should point out that the solar energy program currently in progress under NSF leadership is taking full advantage of the high technology agencies such as NASA, AEC, NBS, and others, and it provides for important participation of industry in the planning, development, and operational phases. Using the combined resources of Government, industry, and universities, the Foundation has equipped four schools in different sections of the country with experimental solar systems for augmenting heating. You will see these systems in operation in the film I am about to show.

Experimental solar heated and cooled homes have been completed with NSF funding in Colorado Springs and Fort Collins, Colo. A school near Atlanta, Ga., is being considered for a heating and air-conditioning system for year-round use. Major studies of the potential for solar heating and cooling have been concluded under contracts with three companies—General Electric, Westinghouse, and TRW systems. Other projects are being developed including a fruit and crop-drying experiment in California. Through these and other investigations, we are moving expeditiously toward proof-of-concept experiments.

We have also completed a transportable solar laboratory which will be gathering solar energy resource data from all parts of the Nation in the coming months.

The solar energy program proposed in the draft report to the FEA is directed at achieving systems that will be cost-competitive in the marketplace at the earliest practicable time.

Other aspects of solar energy—primarily for generating electricity, but also to produce gas and liquid fuels—will take considerably longer to bring to the same level of technological development that has been reached on solar heating systems for buildings, but we are hard at work on them.

In summary, Mr. Chairman, the Foundation is in agreement with the importance of moving expeditiously toward the achievement of the objective of attaining widespread application of solar energy. The only question to be resolved is how best to proceed; and as I have stated, it is our belief that the establishment of the Energy Research and Development Administration is of critical importance to the achievement of this objective. This concludes my formal statement, Mr. Chairman. Now, with your permission, I would like to show the film.

Mr. McCormack. May we have a copy of that task force report?

Dr. Bisplinghoff. The draft of the task force report is now being reviewed and revised, and we will be happy to provide the committee with copies of the final report when it is available. I believe Mr. Sawhill mentioned the report in his statement. Insofar as I know, as soon as that revision and review is completed, we will be able to supply you with copies of it.

Mr. McCormack. Thank you.

Dr. Bisplinghoff. Let me go now to the bill itself. The bill under consideration this morning authorizes the Foundation to support a range of solar energy research and science education programs for which the Foundation already has legislative authority. This duplication of authority would be a matter of concern to us because responsibilities given to NSF in the bill are to be transferred to ERDA. If the bill were interpreted literally, existing authority contained in our basic enabling legislation for the conduct of a portion of the broad-based research in science programs in NSF would have to be transferred to ERDA.

We believe the bill should be modified to allow for judgment in the selection of functions that should be transferred. Mr. Chairman, the Foundation feels very strongly that adding to our Organic Act specific subject matter authorizations and directions is undesirable, and we strongly urge that the provisions of the bill that provide for these changes be deleted.

I know that this subcommittee fully appreciates the need for the National Science Foundation to provide a strong base of research support in solar energy related areas, just as it does for all other fields of science. This is an appropriate role for NSF, Mr. Chairman, and one which we believe will contribute to the accomplishment of the ERDA solar energy mission and the mission assigned to the Coordination project should it be established.

Section 10 of the bill states that the project will provide for the design and construction of facilities or powerplants needed to demonstrate the feasibility of each of the specific solar energy technologies named in the bill. We believe that the interest being shown by industry in the development of solar energy technologies dictates that legislative provisions for demonstration projects include wide flexibility for industry involvement.

I cannot overemphasize that point, Mr. Chairman, since in our own NSF planning we have invariably tried to bring industry into the planning and execution of our programs right from the very beginning. The film which you just saw is an illustration of what four industries could do very quickly in bringing these technologies to bear in specific applications.

With respect to incentives, experience shows that while stimulation of one component of a technology delivery system may help to advance the technology, it does not insure that the technology will be carried through to the marketplace. Therefore, in considering incentives, it is important to remember that, no matter how good or effective a particular incentive might be in stimulating one element of the process, such as obtaining risk capital or inducing equipment manufacturers to make a certain product, the incentives effort may be totally wasted unless you provide for appropriate incentives at key points throughout the delivery system.

For example, in the case of heating and cooling of buildings, the technology delivery system involves architectural engineering companies, equipment manufacturers, homebuilders, lending institutions, labor organizations, State and local government codes and regulations, and a host of other factors. Appropriate incentives may have to be applied to each of these elements. There could be a technology blockage within any one or all of them, so it is important to consider the entire delivery system in the development of incentives strategies.

We are very much in agreement with your desire to study this total system as a system to look at where the blockages might be.

Mr. Chairman, sections 12 and 13 of the bill recommend a number of organizational arrangements, mechanisms, and procedures for carrying out the functions of the bill. These include a Solar Energy Research Institute, a Solar Energy Information Data Base, a Solar Energy Incentives Task Force, and sweeping requirements for coordinating technology utilization efforts. While we believe that these elements could be useful, it is our view that the Administrator of ERDA and, if the bill is passed, the chairman of the proposed Coordination project should be allowed discretion in the way in which they set about to achieve solar energy objectives.

In this connection, Mr. Chairman, we believe it would not be wise to require the Coordination project to mount major demonstration projects in each of the solar energy technology areas as now proposed in the bill since this approach may not be cost effective in all cases.

Other aspects of solar energy—primarily for generating electricity, but also to produce gas and liquid fuels—will take considerably longer to bring to the same level of technological development that has been reached on solar heating systems for buildings, but we are hard at work on them.

In summary, Mr. Chairman, the foundation is in agreement with the importance of moving expeditiously toward the achievement of the objective of attaining widespread application of solar energy. The only question to be resolved is how best to proceed, and as I have stated, it is our belief that the establishment of the Energy Research and Development Administration is of critical importance to the achievement of this objective.

I would be happy to answer questions.

Mr. McCormack. Thank you, Dr. Bisplinghoff.

Before we have any questions we are going to hear from our other two witnesses. Otherwise, we are going to run out of time. The House is already in session. I would like to invite Chairman Dixy Ray and Administrator Jim Fletcher to come up and join us now at the witness table. We will have your testimony at this time. Then we will ask questions of all three of you at once.

I am sure that everyone here is already acquainted with everybody at the table, so I won't take any time with introductions.

STATEMENT OF HON. DIXY LEE RAY, CHAIRMAN, U.S. ATOMIC ENERGY COMMISSION

Dr. Ray. Perhaps in the interest of saving time I might, as you suggest, submit the whole statement but touch upon a number of points in a summarizing manner.

Mr. McCormack. Thank you. Well, without objection, insert your formal statement in the record at this point.

[The statement follows:]

STATEMENT OF DR. DIXY LEE RAY, CHAIRMAN, U.S. ATOMIC ENERGY COMMISSION, BEFORE THE HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS, SUBCOMMITTEE ON ENERGY, ON H.R. 15612, "SOLAR ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACT OF 1974"

AUGUST 2, 1974

MR. CHAIRMAN, THANK YOU FOR THE OPPORTUNITY TO BE HERE TODAY TO PRESENT TESTIMONY ON H.R. 15612, THE SOLAR ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION ACT OF 1974.

IT IS ENCOURAGING INDEED THAT THIS COMMITTEE RECOGNIZES THAT THE ENERGY PROBLEM IS STILL WITH US, DESPITE THE LACK OF ATTENTION FROM THE PRESS AND THE WIDE AVAILABILITY OF GASOLINE, ALBEIT AT HIGHER PRICES. INDEED, THE INFLATION THAT WE ARE NOW EXPERIENCING MAY BE ASCRIBED, IN PART, TO ENORMOUS INCREASES IN THE PRICE OF OIL, THE NATION'S MAJOR SOURCE OF ENERGY.

IN THE PROPOSED LEGISLATION YOU HAVE FOCUSED ON A SOURCE OF ENERGY THAT, IN TIME, MAY HELP SIGNIFICANTLY TO ALLEVIATE OUR ENERGY PROBLEMS. SOME HAVE SAID THAT THE FEDERAL GOVERNMENT SHOULD HAVE SUPPORTED THE DEVELOPMENT OF SOLAR ENERGY LONG AGO. PERHAPS THAT IS SO. BUT UNTIL RECENT MONTHS, FEW REALLY FORESAW THE NEED FOR SOLAR ENERGY. AND BECAUSE FOSSIL FUELS WERE READILY AVAILABLE AT REASONABLE PRICES, INDUSTRIAL AND COMMERCIAL DEVELOPMENT DID NOT OCCUR. NOW THE NEED IS EVIDENT AND THE FEDERAL GOVERNMENT HAS BECOME INVOLVED. IN FY 1974, TOTAL FEDERAL FUNDING FOR SOLAR RESEARCH AND DEVELOPMENT EXCEEDED $13 MILLION AND IN FY 1975 FUNDING HAS INCREASED TO MORE THAN $50 MILLION.

Solar energy, if it can be economically applied, is virtually inexhaustible and is inherently clean. Knowledgeable scientists have testified that successful research and development could ultimately lead to the capability to reduce by as much as 30% the Nation's demand for fuels to produce the power to heat and cool homes and commercial buildings. As the members of this Committee know, there are several functional areas of solar energy -- heating and cooling of buildings; indirect production of electricity through heat engines; direct production of electricity through use of solar cells; using the energy of winds to generate electricity; using the temperature differences between surface and deep water in the oceans; applying various known photochemical processes to production of hydrogen; and using living organisms to produce hydrogen or various organic compounds. Most of these applications require extensive use of land areas. They are at different stages of development and thus, at the present time, they require different levels of funding.

Despite the very great potential of these possibilities for using solar energy, and the obvious need to accelerate research and development on them, we have to accept the fact that solar energy is not readily commercially available today. Of all of the applications, space heating and cooling is probably the closest to commercial realization. Currently, the National

Science Foundation is funding two general types of proof-of-concept experiments in this area. One type deals with the heating and cooling of five public schools in Minneapolis; Warrenton, Virginia; Atlanta, Georgia; Baltimore, and Boston. These activities are funded at approximately $2 million. In the second type of project, NSF is investigating two residential houses, one in Colorado Springs, Colorado, and the other at Colorado State University. Total two year program costs are $363,000. Together these FY 1974 figures represent almost $2.5 million of the almost $14 million Federal solar budget. In addition to these NSF projects, several other agencies have assessment studies of the importance and possible use of solar energy in their areas of responsibility.

As I noted in the December 1 Report to the President on "The Nation's Energy Future", the development of practical solar systems for heating and cooling buildings should not require high technology. The research and development costs should be small in relation to the energy saved. But Federal involvement should continue because capital investment in such solar systems is high and the manufacturing problems are far from solved. This situation must be changed before the public can be served.

There is no question about the need to develop solar energy. The question is how best to do it. H.R. 15612 is one approach to the problem. First, let me state that I thoroughly agree

WITH THE OBJECTIVES OF THE BILL. A VIGOROUS "PROGRAM OF RESOURCE ASSESSMENT, RESEARCH AND DEVELOPMENT AND DEMONSTRATIONS" WOULD PROVIDE INFORMATION WHICH WOULD ENABLE US TO PREDICT THE BENEFICIAL EFFECTS AND THE EXTENT OF APPLICATION AND USE OF SOLAR ENERGY. INDEED, THIS IS ONE OF THE GOALS OF THE SOLAR RESEARCH AND DEVELOPMENT THAT WE HAVE LONG RECOMMENDED. (SEE "THE NATION'S ENERGY FUTURE.")

H.R. 15612 CREATES A MANAGEMENT PROJECT HAVING "OVERALL RESPONSIBILITY FOR THE PROVISION OF EFFECTIVE MANAGEMENT AND COORDINATION" OF THE NATIONAL SOLAR PROGRAM. THE PROJECT WOULD BE COMPOSED OF SIX MEMBERS: THE ADMINISTRATOR OF THE FEDERAL ENERGY ADMINISTRATION, AN ASSISTANT DIRECTOR OF THE NATIONAL SCIENCE FOUNDATION, AN ASSISTANT SECRETARY OF HOUSING AND URBAN DEVELOPMENT, A MEMBER OF THE FEDERAL POWER COMMISSION, AN ASSOCIATE ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, AND THE GENERAL MANAGER OF THE ATOMIC ENERGY COMMISSION.

WITH REGARD TO THE STRUCTURE OF THE PROJECT, I MIGHT NOTE THAT THE PROJECT MEMBERS ARE GIVEN RESPONSIBILITIES IN CERTAIN AREAS, WHILE IN OTHERS THE CHAIRMAN OF THE PROJECT IS DESIGNATED AS THE SOLE AUTHORITY. IN THE CASE OF THE DATA BANK (SEC. 13) AND PROGRAM DEFINITION (SEC. 18), THE CHAIRMAN OF THE PROJECT IS TO WORK WITH MEMBER AGENCIES AND OTHER APPROPRIATE GOVERNMENTAL AND PRIVATE ORGANIZATIONS. IN THESE AREAS THE ROLE OF THE OTHER PROJECT MEMBERS IS NOT CLEAR.

With regard to the data bank, I would like to note that the Atomic Energy Commission is already developing an integrated data file at the Technical Information Center at Oak Ridge. The file will cover bibliographic references to research and development in ALL energy areas and is expected to be largely up to date and available for use within six months.

We have given a high priority to collecting information on solar research and development. When completed this file will contain bibliographic references on world-wide research and development covering conversion of solar radiation to useful amounts of electric energy. It will also cover research results in the use of solar energy for heating and cooling, or any other use of solar energy that might contribute to the total energy budget. We are cooperating in this effort with NASA, the National Science Foundation, Engineering Index, and other organizations that have an interest in the collection and distribution of the results of solar energy research. It appears that the total solar energy data file initially will contain more than 5,000 research citations. This is expected to grow rapidly as greater emphasis is placed on research and development in this field. We plan to make this bibliographic data file available to anyone who wants to use it.

SUPPLEMENTARY INFORMATION ON ENERGY DATA FILE

In developing the energy data file at Oak Ridge, we have a two-fold objective:

1. To bring together and make available existing energy bibliographic resources in their present form for use by research and development and planning people, and
2. To develop an integrated data bank of documentation information to facilitate timely, economical, and thorough literature search services in the "core" fields of energy research and development.

In light of these goals, one of the first steps has been to pull together the information which now exists in separate data bases for use in providing information services until the integrated file becomes available. This information will also serve as raw material for the construction of the integrated file.

Other priority areas in the early phase of the data base compilation will cover storage of electrical energy, energy transmission, superconductivity, geothermal energy, and the literature of energy policy analysis. The contents of these data sources consist of bibliographic information, document citations, abstracts, and subject indexing. Wherever possible the information has been drawn from existing sources -- government publications and data files and services issued by professional societies and other private organizations both here and abroad. Our people will do their own abstracting and indexing only when the needed information is not readily available from some other source.

In assembling abstracting materials from such diverse sources, it is recognized that the data file must be further refined to be most useful. Formats must be harmonized, missing data elements must be supplied, and indexing schemes must be made consistent.

We also are accelerating our efforts in the compilation of stores of non-bibliographic data in various energy fields: numerical data on physical constants and the like, qualitative data describing in a standardized fashion the location and attributes of energy-related phenomena. This work is being done at information centers in our National Laboratories, in collaboration with specialists from other organizations as appropriate. For example, we are now working closely with the U.S. Geological Survey, the State of California, and others to develop a sophisticated data base on geothermal energy at the Lawrence Berkeley Laboratory.

Our intention, of course, in assembling these data stores is to provide needed information support to AEC energy-related programs from the management level to the laboratory bench. For example, the geothermal data base is being assembled in support of geothermal energy programs at the Lawrence Berkeley Laboratory, Lawrence Livermore Laboratory, Los Alamos Scientific

Laboratory and the Pacific Northwest Laboratory, as well as programs supported by other agencies. The data stores will also be made freely available to all who need them outside the AEC program, subject only to proprietary restrictions imposed by the suppliers of some of the information. We are being most careful not to offer competition to old or new services provided by the private sector.

Returning to my comments on the Proposed Management Project, it is my judgment that this arrangement might make a convivial group, but may not be a good structure for effective management. I believe in a single manager for any large enterprise in order to fix responsibility. Coordination is another matter, however, and whether legislation is an effective way to achieve that is questionable. In the solar energy Federal program as it now stands, there does exist an informal system of agency consultation. The AEC cooperates actively with the National Science Foundation and other Federal agencies in the development of national plans for solar energy research and development. AEC is now participating with NSF to help better define the five-year program and the Federal Energy Administration to evaluate solar energy's role in Project Independence. In addition, our solar energy program has been closely coordinated with the NSF to ensure an integrated national solar energy research and development program.

There are two other aspects of the Bill which should be noted. First, there is a need for the kind of information that would be developed by the Solar Energy Incentives Task Force. Clearly, incentive programs "to accelerate the commercial application of solar energy technology" should be given careful consideration. The second aspect is contained in Section 11 which encourages programs to provide the "necessary trained personnel to perform required solar energy research and

DEVELOPMENT, AND DEMONSTRATION ACTIVITIES." Manpower shortages could be a major obstacle to the development of several energy sources. In "The Nation's Energy Future" I proposed that manpower development receive $50 million in funds from FY 1975-79 for redistributing, reorienting, and retraining the necessary work force. This should continue to be a priority item.

I have one other comment on this Bill, specifically regarding the proposed Solar Energy Institute. I believe that the institution of any new energy facilities or organizations should not be done prior to the establishment of the proposed ERDA. The Administrator of ERDA should have the flexibility to propose any new facilities after all existing resources have been inventoried.

Having made these brief comments, let me turn to a discussion of AEC's interest and involvement in this area. The personnel of AEC's national laboratories are well suited to participate in the conduct of solar energy research. They are expert in solving a broad spectrum of problems, including basic materials questions, complex chemical processes, etc. With broad experience in all disciplines of science, the AEC laboratories, with their diversity of scientific and technical resources, represent national assets of enormous importance.

Approximately 85,000 employees work at the five types of government-owned contractor-operated facilities: the multi-program laboratories, the engineering development laboratories,

THE SPECIALIZED PHYSICAL RESEARCH AND SPECIALIZED BIOMEDICAL LABORATORIES, AND THE PRODUCTION DEVELOPMENT AND FABRICATION FACILITIES. ABOUT 25,000 OF THESE EMPLOYEES ARE SCIENTISTS AND ENGINEERS REPRESENTING NEARLY ALL TECHNICAL SKILLS. THE RESEARCH AND DEVELOPMENT LABORATORIES EMPLOY 8,269 ENGINEERS, 1,036 COMPUTER SCIENTISTS AND MATHEMATICIANS, 1,337 LIFE SCIENTISTS, 5,698 PHYSICAL SCIENTISTS, AND 10,032 TECHNICIANS. AN UNUSUALLY HIGH PERCENTAGE OF THESE PEOPLE HAVE ADVANCED DEGREES. SIXTY-ONE PERCENT OF THE SCIENTISTS AND ENGINEERS AT NINE MAJOR LABORATORIES INCLUDED IN A RECENT SURVEY HAD M.S., M.D., OR PH.D. DEGREES. THESE EMPLOYEES WORK NOT ONLY ON AEC PROJECTS BUT ON SOME 300 PROJECTS FUNDED BY MORE THAN A DOZEN OTHER FEDERAL AGENCIES. I WOULD LIKE TO SUBMIT FOR THE COMMITTEE'S INFORMATION A COPY OF AN AEC PUBLICATION ENTITLED "ATOMIC ENERGY COMMISSION RESEARCH AND DEVELOPMENT LABORATORIES." IT PROVIDES A MORE DETAILED DESCRIPTION OF THE FACILITIES, STAFFING, AND FUNDING OF THE LABORATORIES.

OVER THE YEARS PERSONNEL AT THE AEC LABORATORIES HAVE CONDUCTED MUCH BASIC RESEARCH THAT IS APPLICABLE TO SOLAR RESEARCH AND DEVELOPMENT. AS PART OF THE ACCELERATED NATIONAL SOLAR PROGRAM, THE AEC SPENT $600,000 ON SOLAR ENERGY RESEARCH IN FY 1974 AND WILL SPEND $1.2 MILLION IN FY 1975. WHILE THIS IS A RELATIVELY SMALL AMOUNT WHEN COMPARED TO NSF'S $13.2 MILLION IN FY 1974 AND $50 MILLION IN FY 1975, THE AEC PROJECTS ARE SIGNIFICANT. LET ME DESCRIBE OUR FY 74 PROGRAM BRIEFLY.

AT SANDIA LABORATORY, $400,000 WAS USED TO ESTABLISH A PILOT PROJECT TO TEST A NEW SOLAR COMMUNITY CONCEPT. THE PILOT PROJECT IS DESIGNED TO PROVIDE ELECTRICITY, SPACE HEATING, AIR CONDITIONING AND HOT WATER FOR A 12,000 SQUARE FOOT BUILDING AT SANDIA LABORATORY BY JUNE 1975. THE BASIC EQUIPMENT WILL INCLUDE SOLAR HEAT COLLECTORS, INSULATED STORAGE TANKS, A TURBO-GENERATOR AND AN ABSORPTION AIR CONDITIONER. THIS RESEARCH WORK ALSO IS EXPECTED TO GIVE SCIENTISTS AND ENGINEERS GOOD DATA ON THE STRENGTHS AND WEAKNESSES OF THE SYSTEM AND TO PERMIT TESTING OF COMPONENTS AND SUBSYSTEMS DEVELOPED BY SOLAR ENERGY RESEARCHERS OUTSIDE SANDIA LABORATORY. THE LARGER SOLAR COMMUNITY CONCEPT TO FOLLOW WOULD INVOLVE THE CENTRAL COLLECTION AND STORAGE OF SOLAR ENERGY AND ITS DISTRIBUTION TO INDIVIDUAL HOMES AND BUSINESSES.

THE ARGONNE NATIONAL LABORATORY PROJECT, WITH FUNDING OF $140,000, IS DEVELOPING A DEVICE WHICH HOLDS PROMISE AS AN EXTREMELY EFFICIENT CONCENTRATOR OF THE SUN'S RAYS. THIS TROUGH-SHAPED DEVICE HAS THE POTENTIAL FOR GATHERING THE SUN'S RAYS TO PROVIDE ELECTRICITY FROM A CENTRAL STEAM POWER STATION OR THROUGH THE PHOTOVOLTAIC PROCESS, WHICH CONVERTS THE SUNLIGHT DIRECTLY TO ELECTRICITY, AND FOR PROVIDING ENERGY FOR HEATING AND COOLING OF ALL SIZES OF BUILDINGS, INCLUDING HOMES.

AT LOS ALAMOS SCIENTIFIC LABORATORY, SCIENTISTS BEGAN WORKING WITH A FUNDING OF $60,000 TO PERFECT AN ADVANCED FLAT-PLATE SOLAR COLLECTOR THAT EVENTUALLY CAN BE BUILT AS PART OF THE ROOF STRUCTURE OF HOMES AND BUILDINGS. AN INDUSTRIAL

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PARTNER WILL BE SELECTED SOON TO PROVIDE HIGH VOLUME MANUFACTURING EXPERIENCE NECESSARY FOR THE SUCCESSFUL TRANSFER OF THIS TECHNOLOGY TO THE PRIVATE SECTOR. THE COLLECTOR-ROOF STRUCTURE WILL BE DESIGNED SO IT CAN BE BUILT ON AN ASSEMBLY-LINE BASIS AS A UNIT SUITABLE FOR SITE INSTALLATION ON A WIDE VARIETY OF RESIDENTIAL AND COMMERCIAL STRUCTURES. IT WOULD BE AN INSULATED, WEATHER-TIGHT BARRIER AGAINST THE ELEMENTS AND A COMPATIBLE ARCHITECTURAL FEATURE OF THE BUILDING.

AT SEVERAL POINTS IN THIS TESTIMONY, I HAVE REFERRED TO THE DECEMBER 1 REPORT TO THE PRESIDENT ON "THE NATION'S ENERGY FUTURE" AND ITS RECOMMENDATIONS ON SOLAR ENERGY. LET ME TAKE A FEW MOMENTS NOW TO COMMENT ON IT. AT THE PRESIDENT'S DIRECTION, THE REPORT RECOMMENDED AN INTEGRATED FIVE-YEAR $10 BILLION RESEARCH AND DEVELOPMENT PROGRAM FOR THE NATION. THE REPORT WAS BASED ON SEVERAL MAJOR AND SOMEWHAT INDEPENDENT EFFORTS. THE PRELIMINARY REPORTS PREPARED BY THE GROUPS INVOLVED HAVE BEEN AVAILABLE FOR PUBLIC INSPECTION IN THE AEC'S PUBLIC DOCUMENT ROOM SINCE EARLY JANUARY. ONE OF THESE WAS A GROUP OF ENERGY WORKSHOPS ORGANIZED BY CORNELL UNIVERSITY TO CONSIDER THE MAJOR DIRECTIONS OF A NATIONAL PROGRAM. A SECOND EFFORT WAS THAT OF THE 16 TECHNICAL REVIEW PANELS THAT WERE ESTABLISHED TO REVIEW THE 1,100 RESEARCH AND DEVELOPMENT PROPOSALS THAT WERE RECEIVED. THESE PANELS, ONE OF WHICH WAS SOLAR ENERGY PANEL IX, CHAIRED BY ALFRED J. EGGERS, JR., OF NSF, WERE MADE UP OF 121 FEDERAL EMPLOYEES FROM OVER 30 DEPARTMENTS AND AGENCIES ASSISTED by 282 consultants. Finally, an Overview Panel was established to review the results of the workshops and Panels and present specific recommendations to me on the composition of the five-year $10 billion program. The members of the Overview Panel were:

Mr. Stephen A. Wakefield, Assistant Secretary for Energy and Minerals, Department of the Interior

Mr. William E. Simon, now Secretary of the Treasury

Dr. Beatrice E. Willard, Member, Council of Environmental Quality

Dr. Betsy Ancker-Johnson, Assistant Secretary for Science and Technology, Department of Commerce

Dr. Stanley M. Greenfield, then Assistant Administrator for Research and Development, Environmental Protection Agency

Mr. William A. Anders, Commissioner, Atomic Energy Commission

Mr. Bruce T. Lundin, Director, Lewis Research Center, National Aeronautics and Space Administration

Mr. John P. Abbadessa, Controller, Atomic Energy Commission

The judgments of this Overview Panel were particularly valuable and necessary because all of the panels, including the Solar Energy Panel, were developing plans and recommendations without budgetary constraints. (I am sure that members of Congress recognize this kind of problem!) All panels requested a

CONSIDERABLY HIGHER FUNDING LEVEL THAN COULD BE RECOMMENDED GIVEN THE $10 BILLION CONSTRAINT. THE MEMBERS OF THIS COMMITTEE MIGHT BE INTERESTED IN THE OVERVIEW PANEL'S RANGE OF RECOMMENDATIONS ON SOLAR ENERGY. THE INITIAL RECOMMENDATIONS OF THE MEMBERS OF THIS GROUP -- AFTER REVIEW OF SUBPANEL IX REPORT -- RANGED FROM $150-500 MILLION FOR FY 1975-79. FOUR OF THE RECOMMENDATIONS WERE FOR $150 MILLION WITH ONE EACH FOR $240, $300, $350, AND $500. AFTER FURTHER DISCUSSION OF BOTH THE TECHNICAL AND BUDGETARY CONSTRAINTS, THE PANEL REACHED A CONSENSUS OF $200 MILLION. I CONCURRED IN THAT RECOMMENDATION IN MY FINAL REPORT. OF $200 MILLION, $32.5 MILLION WAS RECOMMENDED FOR FUNDING IN FY 1975. AS IT TURNS OUT, THE FY 75 BUDGET CONTAINS $50 MILLION FOR RESEARCH AND DEVELOPMENT IN SOLAR ENERGY.

THE UNITED STATES CAN ILL AFFORD TO LEAVE UNTAPPED ANY POTENTIAL ENERGY RESOURCE. SOLAR ENERGY IS ESPECIALLY ATTRACTIVE BECAUSE OF ITS PROBABLE LIMITED EFFECTS ON THE ENVIRONMENT, BECAUSE IT IS ADAPTABLE FOR USE IN SMALL PACKAGES INDEPENDENT OF CENTRALLY LOCATED GENERATING STATIONS, AND BECAUSE THE RESOURCE EXISTS AND THE TECHNOLOGY BASE TO PUT IT TO USE CAN BE DEVELOPED. WITH RESEARCH AND DEVELOPMENT EFFORT ON THE PART OF THE FEDERAL GOVERNMENT AND INDUSTRY SOLAR ENERGY SYSTEMS SHOULD BECOME COMMERCIALLY COMPETITIVE AND CONTRIBUTE TO OUR NATIONAL ENERGY BASE.

Mr. McCormack. Proceed as you like to summarize.

Dr. Ray. Let me take a moment at the beginning to recognize that this committee is absolutely on the right track in recognizing that the energy problem is still with us despite the fact that we are able to get gasoline, albeit at high prices, and despite the fact that press attention is not nearly as great as it was a month ago. Nevertheless, the energy problems have by no means been resolved in the longer term.

The actions of the Congress, particularly action such as indicated in this bill, are extremely important.

The area of solar research has been, as everyone recognizes, a neglected area of research. While we can take a lot of time trying to understand why that is so, the fact is that until recently very few people saw clearly the need for Federal involvement in this area of energy resource development.

We recognize now that the Nation cannot afford to overlook any energy source and that the Federal effort should involve all potential areas. In this respect we have seen some recent improvement in this field; in fiscal year 1974 the budget for R. & D. in solar energy was in excess of $13 million, about $13.8 million. For 1975 it is approximately $50 million. That is an encouraging step forward.

A great deal has been said already about the areas in which solar energy can be effectively developed. I do not consider myself an expert in this area, so I will move along to comment first of all on the objectives of the bill, H.R. 15612. Let me say that I am very much in sympathy and support thoroughly the objectives of the bill.

With regard to the structure of the management project, I might note that the members of the project are given responsibilities in certain areas and in other areas the chairman of the project is designated as sole authority. In the case of the data bank this is rather clear. The chairman of the project is to work with member agencies and other appropriate government and private organizations; the role of the other project managers is not clear. I specifically identified this item because the AEC has an active interest in data gathering.

As you know, Mr. Chairman, the AEC has a technical information center at Oak Ridge, Tenn., and there we keep files and bibliographic references on a wide variety of areas of basic research and technology. Recently we have developed a special section for adding to that data with respect to solar energy. I would like to submit a supplement to the information contained in my formal statement. This supplement describes in further detail what the AEC is doing to contribute to the accumulation of information in this field.

Mr. McCormack. If there is no objection, it will be inserted in the record.

I would like to interrupt with a question on this point. Has the AEC had general authority to do solar R. & D. in the past?

Dr. Ray. In a specific sense, no, sir. In a general sense, yes. Since 1971, when the Congress passed an amendment to the Atomic Energy Act, the AEC has had the authority to conduct research in a broad area of energy, irrespective of its origin. We have not, however, experienced a high level of success in getting projects approved and funding provided for these efforts. Nevertheless, we do have underway a few projects which, much the same as other Federal agencies, are coordinated with the National Science Foundation, and I do have with my testimony a description of the specific areas of solar energy research the Atomic Energy Commission has undertaken.

Mr. McCormack. You have had authority since 1971?

Dr. Ray. Yes, sir.

Mr. McCormack. You have to some extent been bootlegging some work in this area, I take it, within the latitude allowed in contractual relationships?

Dr. Ray. Insofar as many areas of research overlap in basic studies; studies of materials development components, basic chemical processes, and so on, are fundamental and applicable to a number of areas of research. For example, research on energy storage through the development of better and more efficient batteries is applicable and very useful in solar energy activity, as it is in the utilization of other energy. In this sense, AEC has a fairly broad, basic involvement.

Mr. McCormack. You have not been suppressing any information, have you?

Dr. Ray. No, sir.

Mr. McCormack. Thank you.

Dr. Ray. With respect to the data bank, we do have a high priority on collecting information in solar research and development. When completed this file will contain bibliographic references on worldwide research and development activities including the conversion of solar radiation to useful amounts of electric energy. It will also cover research results on the use of solar energy for heating and cooling, and any other use of solar energy that might contribute to the total energy budget. We are cooperating in this effort with NASA, the National Science Foundation, Engineering Index, and other organizations that have an interest in the collection and distribution of the results of solar energy research. It appears that the total solar energy data file initially will contain more than 5,000 research citations. This is expected to grow rapidly as greater emphasis is placed on research and development in this field. We plan to make this bibliographic data file available to anyone who wants to use it.

Mr. McCormack. How soon?

Dr. Ray. The file is expected to be up to date and available for use within 6 months.

Mr. McCormack. This year?

Dr. Ray. Yes, sir.

There is another item in the bill that deserves mention. Section II encourages programs to provide the necessary trained personnel to perform required solar energy research and development, and demonstration activities. We believe that manpower shortages can be a major obstacle in the development of future energy sources, and we believe that this provision is a very important one and must continue to receive a very high priority.

In general, then, with respect to the bill itself, those are my main comments. If you like, I will take a moment to comment on AEC's interest and involvement in the area of solar research.

I would like to recall to the committee that the AEC has a wide range of operating laboratories located in various sections of the country. These range all the way from very large multidiscipline national laboratories involving a broad spectrum of problems to specific facilities investigating a more narrow range of technological problems.

Spread throughout this system there is broad experience in all disciplines of science; this diversity of scientific and technical resources represents a national asset of really great importance. Approximately 85,000 employees work at several types of Government-owned, contractor-operated facilities: the multiprogram, the engineering development, specialized physical research and specialized biomedical labs.

About 25,000 of these employees are scientists and engineers representing nearly all technical skills. The research and development laboratories employ 8,269 engineers, 1,036 computer scientists and mathematicians, 1,337 life scientists, 5,698 physicial scientists, and 10,032 technicians. An unusually high percentage of these people have advanced degrees. Sixty-one percent of the scientists and engineers at nine major laboratories included in a recent survey had M.S., M.D., or Ph. D. degrees. These employees work not only on AEC projects but on some 300 projects funded by more than a dozen other Federal agencies.

I would like to submit for the committee's information a copy of an AEC publication entitled "Atomic Energy Commission Research and Development Laboratories." It provides a more detailed description of the facilities, staffing, and funding of the laboratories. This is a recent brochure which brings together information on the expertise and the types of projects and capability to perform them in the AEC National Laboratory System.

Mr. McCormack. May we have a copy for the record?

Dr. Ray. Yes, sir.

Mr. McCormack. Without objection, it will be included in the record at this point.

[Material referred to follows:]

TID-26400

Atomic Energy Commission Research and Development Laboratories

A National Resource

September 1973

U. S. Atomic Energy Commission
Office of Information Services
Technical Information Center

Introduction

In his energy statement of June 29, 1973, President Nixon proposed the establishment of a new independent Energy Research and Development Administration (ERDA). The President stated that "the creation of ERDA contemplates building upon the scientific and technical base of the Atomic Energy Commission and making use of the laboratories and technical management capabilities now located in that agency."

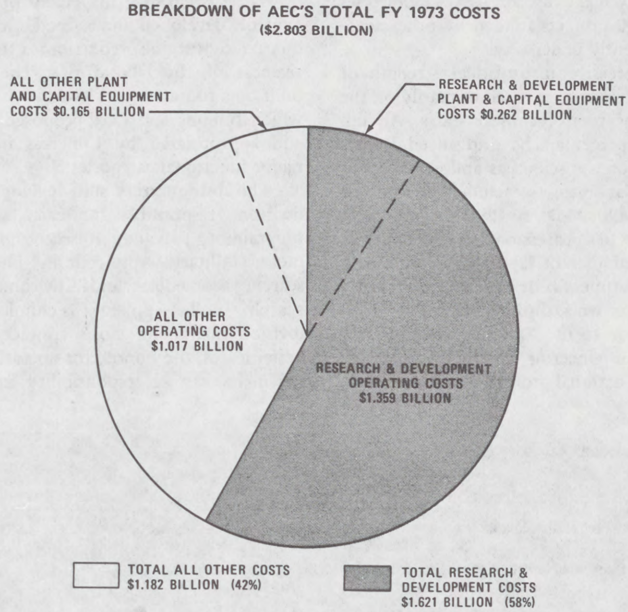
This report describes the full range of AEC research, development, and testing capabilities including very brief descriptions of individual AEC plants and laboratories which represent a cumulative capital investment of $9.5 billion. The work of some 91,000 AEC and contractor employees is summarized within the framework of the AEC management concept, which places prime responsibility for facility operations on the skills of U. S. private industry and major universities.

AEC facilities are located in all regions of the United States. The versatility and diverse scope of these facilities provides, in total, a cohesive entity with a record of success in varying program objectives in both military and civilian applications of atomic energy. These facilities are also capable of undertaking additional research and development tasks on energy problems and are particularly adaptable to new programs appropriate to the proposed Energy Research and Development Administration.

AEC Management of Research and Development Activities

In contrast to other Federal agencies with major energy research and development programs, the Atomic Energy Commission oversees a system of government-owned laboratories operated by contractor organizations representing universities, other non-profit organizations, and private industry. Two smaller laboratories are staffed by Federal employees. Many individual contracts are also entered into with industrial and non-profit concerns, and with universities.

A comparatively small staff located at AEC Headquarters, Washington, D. C., formulates and administers the programs (including allocating funds). Apart from the staff associated with the regulatory functions of the



The right side of the chart shows the portion of these costs devoted to research and development; the left side shows all the other costs including production of nuclear materials, weapons manufacture and testing, etc. Note that research and development represents the larger portion of the 58%-42% split.

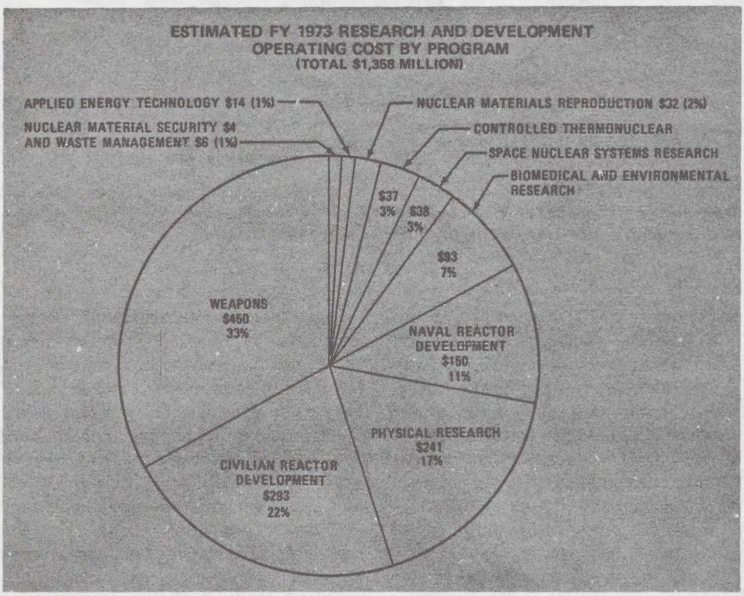
AEC, approximately 2,100 persons are involved in program management. Contract administration, management review, and contractor appraisal are carried out by the AEC's field offices, where the employment totals approximately 3,900. Major research, development, and production activities are carried out by contractor employees, for the greatest part in Federal facilities built specifically for AEC purposes, but extensive use is also made of facilities owned by industry, universities, and non-profit corporations. Approximately 85,000 employees work at the government-owned contractor-operated facilities funded by the AEC.

Laboratory management, composed largely of experienced scientists and engineers, provides a substantive share of program formulation by proposing projects designed to implement general AEC program guidance. Final decisions on program emphasis, balance, and levels of effort are made at AEC Headquarters. The AEC and its laboratories employ approximately 25,000 scientists and engineers representing nearly all technical skills and including large numbers of chemists, physicists, mathematicians, biomedical, and environmental specialists, and chemical, mechanical, civil, electrical, and nuclear engineers. More than a dozen other Federal agencies also make use of AEC laboratories and over 300 projects funded by other agencies are currently under way.

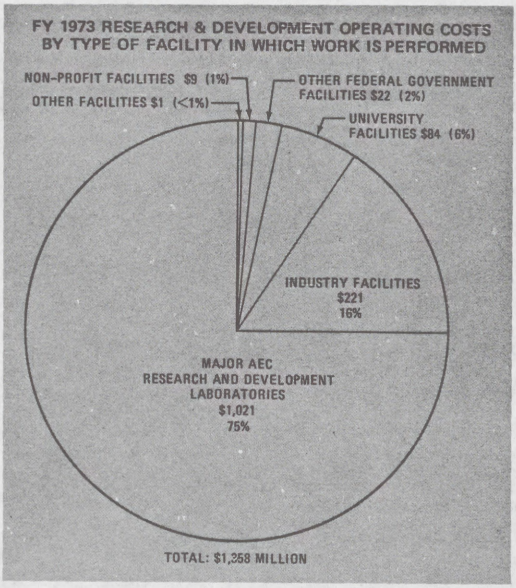
The impressive institutional strength of the AEC laboratories is based primarily on the excellence of their technical staffs. An unusually high percentage have advanced degrees (61 percent of the scientists and engineers at nine major laboratories included in a recent survey had M.S., M.D., or Ph.D. degrees) and many years of professional experience. A substantial number of laboratory employees, as shown in Appendix 1, have received recognition for their work through receipt of Nobel prizes, election to the National Academies of Science and Engineering, and receipt of major awards from national professional societies.

The system of management practices and controls developed and refined during the last quarter century also contributes to the effectiveness of the laboratories. The system is built on a foundation of program budgeting in which funding levels are proposed, defended, and appropriated by Congress in terms of major functional categories.

The Headquarters' staff includes operating divisions responsible for each category or program; e.g., Reactor Research and Development, Military Applications, Physical Research, Biomedical and Environmental Research, and Applied Technology. Each division maintains close contact with the activities of the contractor-operating personnel in its area of responsibility, arranges for



Out of each operating dollar considered here, 29¢ was spent by the AEC on programs classified as energy research and development in the "Special Analyses, Budget of the U. S. Government", issued by the Office of Management and Budget.

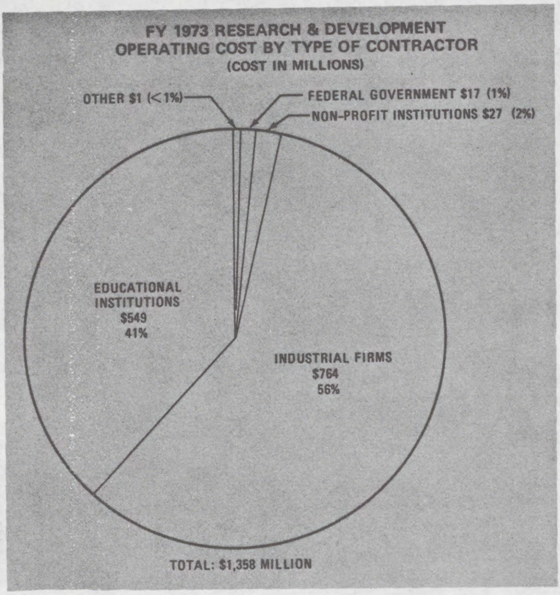


The nature of the performers of the research and development funded by the AEC. This chart shows that 75% of these efforts are carried out at 19 major AEC laboratories. These laboratories are: Ames Laboratory, Argonne National Laboratory, Bettis Atomic Power Laboratory, Brookhaven National Laboratory, Hanford Engineering Development Laboratory, Knolls Atomic Power Laboratory, Lawrence Berkeley Laboratory, Lawrence Livermore Laboratory, Los Alamos Scientific Laboratory, Mound Laboratory, National Accelerator Laboratory, National Reactor Testing Station, Oak Ridge Associated Universities, Oak Ridge National Laboratory, Pacific Northwest Laboratory,. Princeton Plasma Physics Laboratory, Sandia Laboratories, Savannah River Ecology Laboratory, and Stanford Linear Accelerator Center.

discussions of problems as they arise, and provides technical guidance. The Headquarters' staff works with the AEC field offices, which have the primary responsibility for contract administration.

Laboratory management hires and assigns personnel. Frequently, laboratory management formulates and executes specific projects with broadly defined program areas. It provides extensive formal and informal input for program planning, including specific budgetary proposals developed on a laboratory-wide basis which are submitted annually through the appropriate AEC field office.

The management system was developed to serve efforts covering the full spectrum of research and development. It applies to pioneering experiments conceived by individual investigators at major accelerator centers and, at the same time, is applied to the engineering



Nearly all the research and development is performed by contractor employees and the distribution of these costs by type of management is shown here. Only about 1% of the research and development is performed at installations staffed by Federal employees.

development of reactor systems requiring day-to-day coordination between the Headquarters' staff and many contractors. The system has proved its effectiveness and is properly viewed as an integral and important part of the capabilities of the AEC laboratory complex.

Laboratory and Other Facilities

A central factor of the AEC laboratories' institutional strength is the excellence of their physical facilities. The laboratories are equipped to perform experiments covering most aspects of the physical and life sciences. Much of the specialized instrumentation has been developed by the individual researchers and, in many instances, they are one-of-a-kind items. Large engineering facilities are available to many of the laboratories. The research and engineering staffs at each of the major laboratories have at their disposal highly competent machine and electronics shops and computer centers. Environmental and ecological studies have benefited from setting aside protected environmental research areas at selected AEC sites.

Although the AEC laboratories have a number of features in common, the focus and character of each are distinctive, ranging from small research centers closely integrated with university campuses and carrying out work of a clearly academic nature to large isolated engineering development and test stations.

In this report, AEC research and development installations are grouped into five categories:

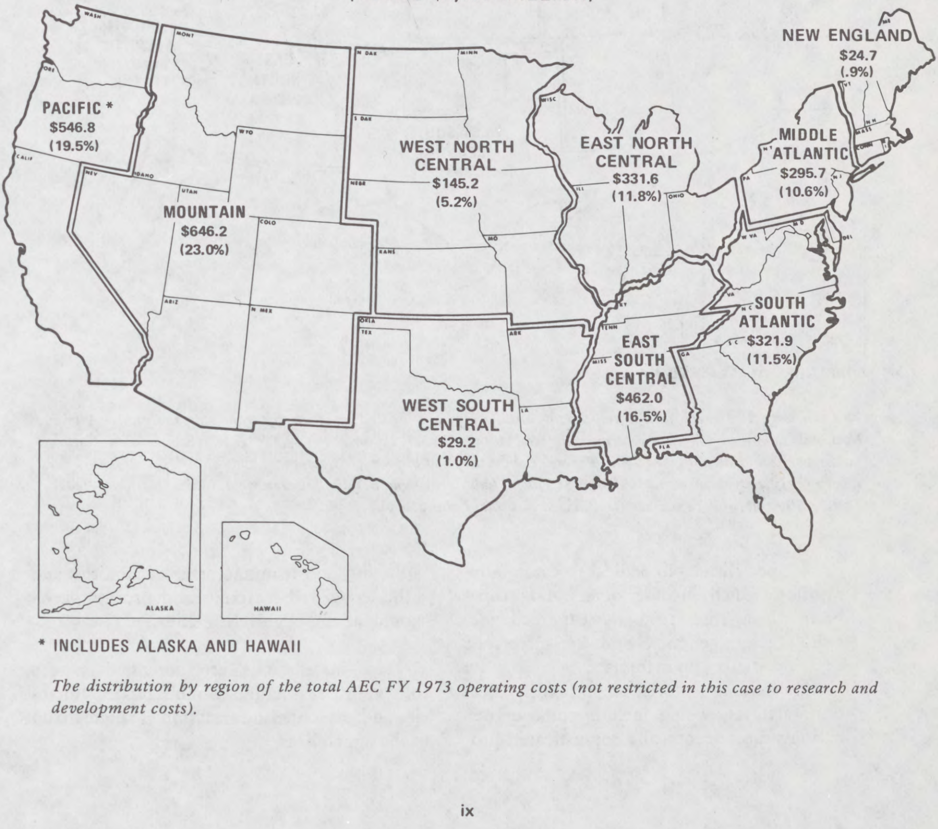
1. Multiprogram national laboratories, each of which has broad capabilities in both physical and life sciences, as well as in nuclear systems, electrical, mechanical, and other branches of engineering.

2. Major engineering development laboratories, whose capabilities include all stages from conceptual design through construction and test of prototypes.

3. Specialized physical research laboratories, whose workers probe deeply into one or more physical science disciplines.

ESTIMATED TOTAL FY 1973 COSTS BY GEOGRAPHIC REGION

(TOTAL $2,803 MILLION)

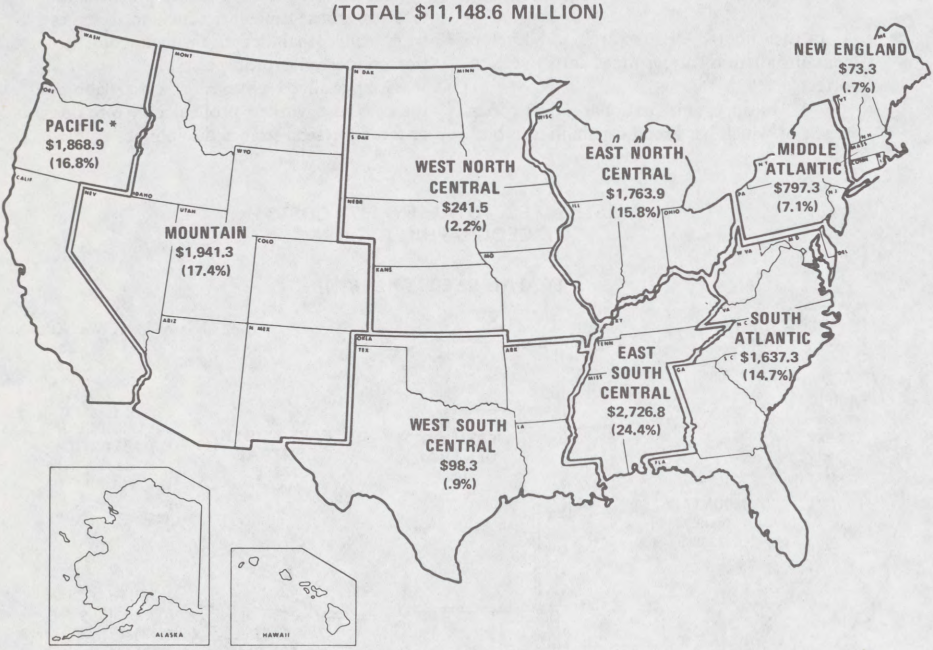


* INCLUDES ALASKA AND HAWAII

The distribution by region of the total AEC FY 1973 operating costs (not restricted in this case to research and development costs).

CAPITAL FACILITIES AND EQUIPMENT INVESTMENT AUTHORIZED THROUGH FY 1973 BY GEOGRAPHIC REGION

(TOTAL $11,148.6 MILLION)



* INCLUDES ALASKA AND HAWAII

The ten largest research and development installations are located in seven different states: Illinois (Argonne National Laboratory), Pennsylvania (Bettis Atomic Power Laboratory), New York (Brookhaven National Laboratory and Knolls Atomic Power Laboratory), California (Lawrence Laboratories—Berkeley and Livermore), New Mexico (Los Alamos Scientific Laboratory and Sandia Laboratories), Idaho (National Reactor Testing Station), and Tennessee (Oak Ridge National Laboratory).

4. Specialized biomedical research laboratories, which include outstanding capabilities for studies in nuclear medicine, radiobiology, genetics, and the effects of toxic substances on mammals.

5. Production development and fabrication facilities, which include some of our nation's most technically sophisticated production and manufacturing capabilities and the associated materials and process development and engineering skills.

The installations are described in the following five sections of this report. Financial and personnel information is summarized in the appendices.

I MULTIPROGRAM LABORATORIES

SUMMARY

Seven multiprogram laboratories form the backbone of the AEC's research, development and engineering capabilities:

Argonne National Laboratory, Argonne, Illinois
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Lawrence Livermore Laboratory, Livermore, California
Lawrence Berkeley Laboratory, Berkeley, California
Brookhaven National Laboratory, Upton, New York
Pacific Northwest Laboratory, Richland, Washington
Los Alamos Scientific Laboratory, Los Alamos, New Mexico

Programs carried out in these laboratories range from the most fundamental research programs in the physical and life sciences to the most advanced goal-oriented design and development programs in nuclear reactors and nuclear weapons. The laboratories have built up an unusual diversity in scientific and technical resources, manpower and plant facilities that represent national assets of enormous importance.

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Geographically the laboratories embrace every major region of the nation, and maintain excellent cooperative arrangements with each other and with the major universities, especially in the region of their location.

One measure of their size is the operating cost for each of the laboratories in FY 1973:

	AEC Funds	Work for Others (Primarily Other Gov't Agencies)
	(In Millions)	
Argonne National Laboratory	$ 89	$ 4
Oak Ridge National Laboratory	83	17
Lawrence Livermore Laboratory	124	12
Lawrence Berkeley Laboratory	34	2
Brookhaven National Laboratory	50	3
Pacific Northwest Laboratory	22	16
Los Alamos Scientific Laboratory	108	12
Total	$510	$66

Nearly one-eighth of the work performed in FY 1973 was for others—primarily for government agencies but also for industry and private institutions.

Another measure of laboratory capability is that of total plant investment. Through FY 1973, authorized investment in plant and capital equipment was as follows:

	(In Millions)
Argonne National Laboratory	$ 465
Oak Ridge National Laboratory	356
Lawrence Livermore Laboratory	278
Lawrence Berkeley Laboratory	156
Brookhaven National Laboratory	329
Pacific Northwest Laboratory	58
Los Alamos Scientific Laboratory	491
Total	$2,133

These facilities include specialized and general laboratory space of all types, major machine shops and services, advanced computing capability, sophisticated instrumentation serving such diverse programs as biology, physics, chemistry, medical and environmental research, and engineering, as well as reactor and weapons design and development.

The extensive staff of professional and technical personnel of these laboratories is a most important national resource.

The FY 1973 staffing of these laboratories was:

	Scientists & Engineers	Technicians	Others	Total
Argonne National Laboratory	1,580	765	1,637	3,982
Oak Ridge National Laboratory	1,490	598	1,849	3,937
Lawrence Livermore Laboratory	1,771	1,384	2,198	5,353
Lawrence Berkeley Laboratory	645	693	797	2,135
Brookhaven National Laboratory	750	466	1,221	2,437
Pacific Northwest Laboratory	516	288	663	1,467
Los Alamos Scientific Laboratory	1,718	1,308	1,453	4,479
Total	8,470	5,502	9,818	23,790

Although each of these laboratories is multidisciplinary, each has its own peculiar expertise or specialty. Details on each of the above laboratories follow.

Argonne National Laboratory (ANL)

Argonne, Illinois

Argonne National Laboratory, operated by the University of Chicago and Argonne Universities Association, is located on a 1700-acre site near Chicago, Illinois (population 3,520,000). The major reactor facilities are located at the National Reactor Testing Station near Idaho Falls, Idaho (population 35,776).

Program Funding

ANL's operating budget in FY 1973 was $93 million, of which about $3.8 million was for non-AEC work, primarily for other Federal agencies. By June 1973, Laboratory employment was approximately 4,000, down from around 5,600 employees in mid-1968. The major programs in FY 1973 were the following:

AEC	FY 1973 Operating Funds (In Millions)
Reactor Development	$42
Physical Research	34
Biomedical and Environmental Research	9
Regulation (support)	2
National Laboratory-University Cooperation	1
Division of Applied Technology	0.6
Other AEC	0.6
Total	$89.2

Other Sources*	
Environmental Protection Agency	$0.7
National Science Foundation	1.2
Illinois Institute for Environmental Quality	0.5
Other	1.3
Total	$3.7

*These funds are primarily for environmental research and studies related to the production and storage of energy.

Facilities

The authorized investment in plant and equipment at ANL (including Idaho) in

FY 1973 was $465 million. Located in Idaho are the Experimental Breeder Reactor II (EBR-II), the only operating breeder reactor in the U. S.; a Zero Power Plutonium Reactor (ZPPR), a unique device that provides reactor physics data on full-size liquid metal fast breeder reactor (LMFBR) demonstration plant cores; and the High Flux Experimental Facility (HFEF), a large shielded facility used to examine and analyze highly radioactive reactor fuels and materials.

The two research reactors located in Illinois are used for studies in nuclear physics, materials science, and life sciences. The Zero Gradient Synchrotron (ZGS) and associated facilities are designed to perform a large number and variety of experiments in high-energy physics. The 12-foot liquid hydrogen-deuterium bubble chamber is the first of a new generation and the only one of this generation now in routine operation. An 8.5 million volt (MV) tandem Van de Graaff, a 4 MV dynamitron, a fast-neutron generator, a 60-inch synchrocyclotron, and other smaller high-voltage accelerators are available for research in chemistry, physics, and materials science.

The reactor TREAT, designed by ANL, can deliver a high-intensity, short-duration surge of nuclear energy without damage to the facility itself. The surge is useful in simulating abnormal reactor operating conditions, permitting reactor designers to observe on a small scale the effect of such conditions on prototype fuel elements planned for fast reactors.

The Zero Power Reactor Building houses ZPR-6 (the Argonne Fast Critical Facility) and ZPR-9 (the Coupled Fast-Thermal Critical Facility). These facilities are used to check experimentally the accuracy of theoretical calculations on fundamental fast reactor design. Mock-ups of various fast reactor cores have been made and the characteristics and behavior measured.

Extensive programs in life sciences research are carried out with the aid of extremely sensitive radiation detection devices, specialized air and water sampling and analysis equipment, an advanced meteorological laboratory; and an animal care facility housing 500 dogs and 50,000 mice is employed in life sciences research. General facilities include extensive chemical laboratories, sophisticated radiochemical analysis equipment, a 360/195 computer system, engineering development and test laboratories, and large shops capable of specialized research and development fabrication. These examples are representative of, but do not exhaustively describe, the $450 million investment at ANL.

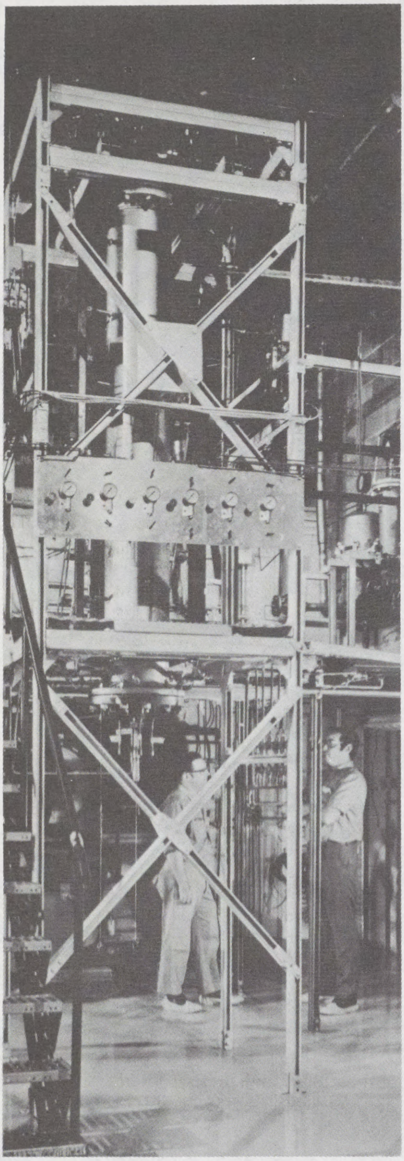
Personnel Information

The ANL staff is composed of the following:

Highest Degree Attained	Number of Individuals
Ph.D.	550
M.S.	325
B.S.	650
Total	1,525

Occupation	Permanent Employees
Engineers	720
Computer Scientists/ Mathematicians	60
Life Scientists	150
Physical Scientists	650
Technicians	765
Other	1,637
Total	3,982

The temporary employees are faculty, postdoctoral, and thesis appointees. In addition, an average of 550 faculty and students,



not paid by ANL, work at ZGS and other Divisions during the year.

Current Activities and Mission

Development of the liquid metal fast breeder reactor is the largest program at ANL and comprises a number of coordinated efforts. The Experimental Breeder Reactor II is used for irradiation testing of fuels and other reactor components and provides breeder operation and maintenance experience. Examination of test components and fuels irradiated in EBR-II is conducted in the new High Flux Experimental Facility.

A large effort on LMFBR safety encompasses the effects of fuel failures, interaction of molten fuel and coolant, effects of fission-gas release, and computer modeling for safety analysis. The reactor physics program develops basic neutronic information and design techniques for improvement of reactor designs, performance, safety, and economics. Methods to reduce radiation-induced swelling of stainless steel and possible interaction between fuel and cladding are two of the goals of the materials program. In addition to these programs, there are essential efforts on reactor instrumentation, component technology, sodium behavior, impact of the LMFBR on the environment, and management of gaseous fission products.

The Zero Gradient Synchrotron, used in a major proton physics program, offers exceptional experimental opportunities to scientists, especially to younger members of the academic community. The liquid hydrogen-deuterium bubble chamber is producing the first direct information on the interactions of neutrinos and hydrogen. Research in the fields of medium- and low-energy physics, chemistry, solid-state, and materials science is among the most actively pursued fundamental

A device for low-pollution burning of coal at the Argonne National Laboratory.

investigations currently under way. A prototype of a new heavy-ion accelerator has been successfully tested at Argonne. The new device, a particle accelerator in the form of a superconducting coil, is designed to accelerate atoms of heavy elements, such as uranium, to very high velocities. This research is conducted in order to better understand the nature of matter.

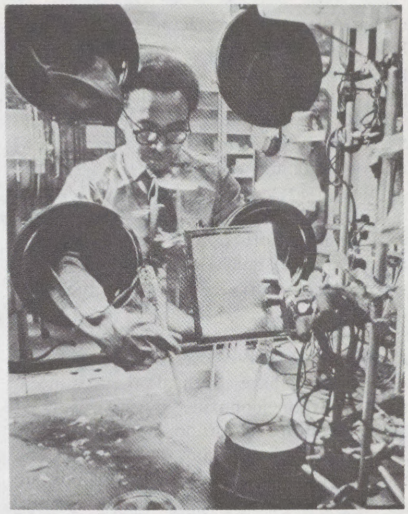
Of the environmental and general energy programs now under way, one of the largest efforts, supported jointly by the National Science Foundation (NSF) and AEC, is the development of a rechargeable lithium/sulfur battery for cars and for electrical power load-leveling in utility power systems. This may result in a 5-fold increase in energy storage above that achieved by lead-acid batteries.

The Environmental Protection Agency (EPA) is sponsoring at ANL, Westinghouse, and Esso Research and Engineering the development of a low-polluting process that burns coal in a fluidized bed of limestone. This process would allow high-sulfur coal to be used. The goal is improved energy conversion efficiency and reduction of air pollutants.

In a program funded by the Office of Naval Research, ANL is investigating a magnetohydrodynamic (MHD) generator that might be used in central-station generation of electrical power.

A controlled thermonuclear research program is concerned with the identification, evaluation, and solution of critical material and engineering problems expected to come from the development of fusion power.

The Argonne Center for Environmental Studies makes evaluations and analyses of the costs and benefits of alternative methods for electrical generation, strip mine reclamation, thermal effects in Lake Michigan caused by electrical generation, land use, and transportation programs, etc. In the biomedical and environmental sciences there is active pursuit of aquatic, atmospheric, and terrestrial ecological studies dealing with thermal and radioactive effluents from nuclear and fossil-fueled power plants, and related studies on carcinogenesis, genetics, radiation toxicity, and biochemistry. Information of this kind is necessary in order to understand the environmental impact of civilian electrical power production. Studies of atmospheric pollutants are also being pursued.



A series of lithium/sulfur storage cells are connected for testing at the Argonne National Laboratory. The tests are conducted in a sealed enclosure to exclude oxygen that would react with the cell components.

Significant Accomplishments

1. The design and fabrication of the first power-generating nuclear reactor in the world.

2. The design and fabrication of the EBR-II, which is used to test materials for the LMFBR program.

3. The conception and initial development of both boiling-water reactors (BWR)

and pressurized-water reactors (PWR). (The PWR concept led to reactors for naval propulsion as well as for central-station generation of electrical power.)

4. Conceptual design of the versatile Savannah River Plant reactors for production of plutonium and tritium.

Important contributions of ANL in all of the above reactor programs were (1) the choice and construction of nuclear fuels and targets and (2) much of the technology for reprocessing of irradiated reactor fuels and targets.

It was first definitely demonstrated at Argonne that noble gases react chemically. ANL chemists have also made the first inventory of carbon monoxide; this revealed that 10 times as much carbon monoxide comes from decaying vegetation as from autos and power plants. ANL developments of substantial social benefit are (1) an inexpensive artificial kidney and (2) a magnetic tape system that produces Braille editions of books and other written material.

More than 1,000 living persons whose bodies contain significant amounts of radium-226 have been located by the Center for Human Radiobiology. Information from the study of this population is valuable in setting exposure limits for other alpha-emitting, bone-seeking radioelements such as plutonium.

Adaptability to New Programs and Problems

ANL's equipment for coal combustion with efficient sulfur removal together with its evaluations of coal gasification for EPA provide a base for extending its work into coal technology. The lithium/sulfur battery program indicates a promising direction for reduction of pollution from automobiles and dependence on scarce petroleum fuels.

Strongly interactive research on materials properties and systems modeling at Argonne will provide essential guidance in materials identification and component development for energy conversion systems; e.g., superconducting systems and MHD generators. Research effort now under way on the chemical physics of energy systems will yield information on the fundamentals of energy transfer, chemistry of controlled fusion, chemical physics of reactor materials and reactions, and energy conversion and storage.

These specific programs in environmentally compatible energy generation are supported by many types of expert personnel and related equipment, and programs including computerized systems analysis, materials research and development, general and analytical chemistry, chemical engineering, and biomedical research. A wide variety of experience and expertise exists for evaluating the effects of energy generation on the well-being of man and his environment. Efforts in this area presently channeled toward preparation of environmental impact statements for nuclear power stations can be applied more broadly to assess the environmental influences of other energy conversion schemes and fuel conversion processes.

CURRENT ACTIVITIES AND MISSION OF ANL

Reactor Development	Breeder development Reactor physics Materials evaluation Instrumentation Component technology Sodium behavior Environmental impact Management of gaseous fission products
Physical Research	Proton physics Medium energy physics Low energy physics Solid state physics Chemistry Materials science
Energy Development	Lithium/sulfur batteries Low pollution coal-burning process Magnetohydrodynamic generation Identification of controlled thermonuclear research materials and engineering problems
Environmental Studies	Alternative electricity generation Strip mine reclamation Thermal effects of power plants Land use planning Chemistry of air pollution Ecological effects of radioactive effluents from nuclear power plants
Biomedical Studies	Toxicity of ionizing radiation Carcinogenesis Aging Radiobiology of mammalian cells Structure of biologically important macromolecules Metabolism and therapy of plutonium in animals

Oak Ridge National Laboratory (ORNL)

Oak Ridge, Tennessee

Oak Ridge National Laboratory (ORNL), operated by Union Carbide Corporation, is near Oak Ridge (population 28,000) in eastern Tennessee. The nearest urban center is Knoxville (population 175,000), thirty miles away, which contains the main campus of the University of Tennessee and the central administrative offices for the Tennessee Valley Authority.

ORNL is part of a three-plant complex in Oak Ridge operated by Union Carbide Corporation for the AEC. The others are the Oak Ridge Y-12 plant, an engineering development and fabrication organization engaged primarily in national defense work, and the Oak Ridge Gaseous Diffusion Plant, one of the three U. S. plants for enriching uranium.

Program Funding

In FY 1973, ORNL's operating budget was about $100 million. About 80 percent was for the AEC, and the remainder was work primarily for other Federal agencies. At fiscal year-end Laboratory employment was about 4,100, down from a level of about 5,000 in FY 1969. Major operating programs in FY 1973 included:

AEC	FY 1973 Operating Funds (In Millions)
Reactor Development	$27
Physical Research	32
Biomedical and Environmental Research	14
Support for Regulation of Commercial Power Facilities	4
Total	$77

Other Federal Agencies	
National Institutes of Health	$ 5.2
National Science Foundation	4.8
Department of Defense and National Aeronautics and Space Administration	4.2
Department of the Interior	1.3
Department of Housing and Urban Development	0.7
Total	$16.2

Almost half of the NIH funding was from the National Cancer Institute. The NSF funds are primarily for environmental research and studies related to the use and conservation of energy; the DOD and NASA support is primarily for radiation and nuclear shielding research, chemical analysis and computer services; the Interior funds are for desalting research and development; and the HUD support is for studies of integrated utility systems and urban growth patterns.

Facilities

The authorized investment in plant and equipment in FY 1973 was $356 million. Special facilities include:

1. An assortment of nuclear reactors ranging from the High Flux Isotope Reactor (HFIR), which produces the world's highest neutron flux, to the Tower Shielding Facility, a reactor that can be suspended in the air for shielding studies.
2. Several particle accelerators, including an advanced electron linear accelerator (ORELA), and the isochronous cyclotron (ORIC), which has special capability for accelerating heavy ions.
3. A variety of chemical processing development facilities, including the Transuranium Processing Plant for separating californium and other heavy elements and the Thorium–Uranium Recycle Facility for remotely processing reactor fuels.
4. An extensive and varied biological laboratory complex, including a Small Animal Facility that can house an experimental animal population of about 330,000.
5. The Aquatic Facility for studying the effect of water temperature on fish and other aquatic life.
6. Extensive materials development facilities, including large laboratory-scale capabilities for purifying, casting, forming, and testing both metals and ceramics.
7. Extensive and varied chemical laboratories and chemical analysis facilities.
8. A variety of engineering development and test facilities.
9. A large diversified research fabrication and shop capability for the three-plant complex.
10. An extensive three-plant computer facility.

Personnel Information

The ORNL staff includes the following:

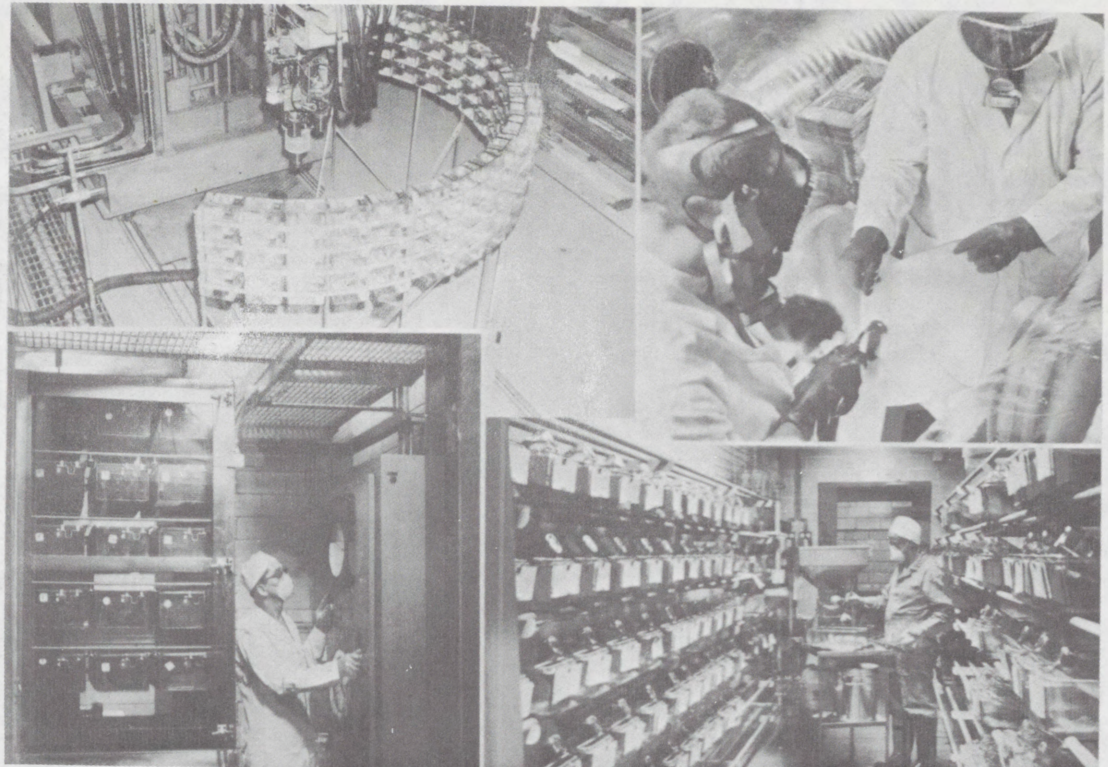
Highest Degree Attained	No. of Individuals
Ph.D.	640
M.S.	350
B.S.	500
Total	1,490

Occupation	Number
Engineers	525
Computer Scientists/ Mathematicians	115
Life Scientists (includes 50 ecologists)	325
Physical Scientists	525
Technicians	598
Other	1,849
Total	3,937

In addition, the 800-member design and general engineering staff for the three AEC plants at Oak Ridge is centrally managed and available to the separate plants as needed.

Current Activities and Mission

Applied programs in the field of reactor and engineering science include strong programs in reactor engineering, instrumentation, chemistry, chemical technology, and materials. Nuclear energy development programs include liquid metal fast breeder (LMFBR) and gas-cooled reactors, controlled thermonuclear reactors, reactor safety, isotopic heat sources, structural design methods for steel and prestressed concrete useful for reactor



The animal experimentation facilities at the Oak Ridge National Laboratory are used to study the genetic and somatic effects of ionizing radiation as well as the effects of environmental pollutants from fossil-fuel plants and internal combustion engines. The Laboratory includes germ-free environments, animal care areas for life-span studies, and the capacity to test large numbers of animals.

vessels, remote handling operations, preparation of design and safety standards, radioactive and chemical waste disposal systems, development of containers for the transport of hazardous materials, and studies of the environmental impact of power plants.

Other energy-related work includes investigations of energy conservation technology, energy use in transportation, waste management, desalting, power-plant effluents in the environment, topping cycles for increasing efficiency, superconducting electric transmission, and integrated urban energy systems. Present and future technical, environmental and economic aspects of nuclear and fossil-fueled power plants are being evaluated, as well as alternative energy sources and conversion devices. Systems analysis models are being developed for application to operation and expansion planning in electric power generation systems.

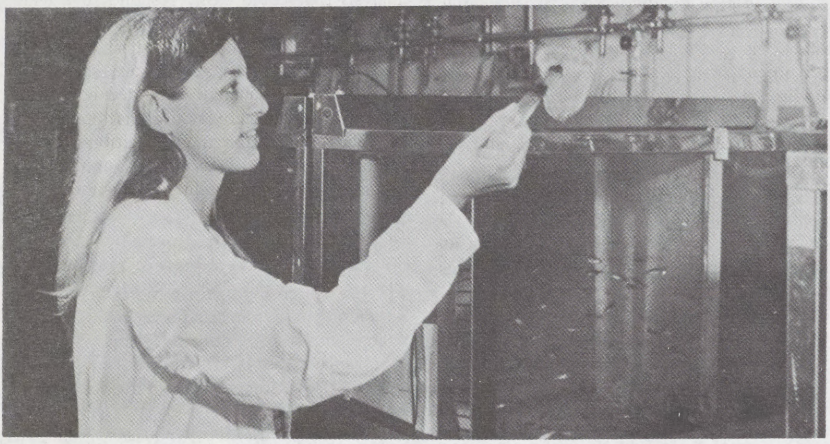
Evaluation programs include coal liquefaction and gasification, electricity generation from solar energy, low-temperature power cycles applicable to geothermal and solar energy, microbiological production of hydrogen and methane, and production and use of hydrogen and other synthetic fuels from non fossil sources.

A 25-year program in biology on the genetic effects of radiation on mice has provided information of major significance in the setting of radiation safety standards. ORNL biologists are also conducting research on the genetic and somatic effects of drugs, gasoline smog, and other toxic materials in the environment. Research in health physics and ecology has led to advanced techniques and instruments for environmental monitoring of aquatic, terrestrial, and atmospheric radioactive releases. Many ORNL dispersion models and sampling and measurement methods are being directly applied to broader non-nuclear environmental energy pollutants such as arsenic, cadmium, mercury, and heavy elements. The AEC was provided with major assistance in preparing environmental impact reports to meet National Environmental Policy Act obligations.

ORNL has many years of experience and a high level of capability in carrying on basic research in the physical sciences. It performs research at the frontiers of nuclear science and in solid state and plasma physics, in chemistry, and in mathematics.

Significant Accomplishments

1. Extensive contributions to the development of nuclear power plants, including those now operating and the more advanced plants of the future.
2. Development of graphite for resisting heat and radiation.
3. Preparation of industrial standards for the design and construction of nuclear reactor components and systems.
4. Production of radioisotopes and development of techniques for their use that have wide application in industry, medicine, and agriculture.
5. Development of solvent extraction processes for the recovery and purification of uranium and plutonium, which are used worldwide for recovering uranium from raw ore and plutonium and uranium from spent fuels.
6. Development of ultra-centrifuge techniques for producing pure vaccines and performing rapid medical diagnoses that are now used commercially.
7. Demonstration of techniques for preserving embryos for long periods that are now being investigated by commercial interests as a technique for improving meat production and quality.
8. Development of INOR-8, a nickel-based alloy that is now an industrially used commercial material.
9. Development of methods for separating zirconium and hafnium, and thus making these two important commercial materials available.



An undergraduate student participates in a research program at the Oak Ridge National Laboratory. The young fish in the tank are exposed to a thermal shock. The student then studies their vulnerability to largemouth bass, their natural predators. These projects introduce students to research and allow them to make significant contributions to current environmental problems.

10. Development of isotope heat sources for use in space, remote meteorological stations, underseas transmitters, etc.

11. Development of the neutron activation analysis method that permits precise analyses not possible by other techniques.

12. Development of a phase-sensitive eddy-current technique that is in wide use industrially for nondestructive testing.

13. Operation of ORMAK, the Oak Ridge tokamak that represents a significant advance toward fusion reactor power plants.

Adaptability to New Programs and Problems

ORNL's experience in the development of chemical processes through the demonstration plant stage can be of value in the development of techniques for coal gasification, liquefaction, and sulfur removal. Coal processing technology and catalysts are currently being evaluated.

Successful development of virtually every energy technology—MHD, coal processing, power transmission, geothermal energy, and solar energy—will rest on the availability of specialized materials. An important asset could be ORNL's capabilities and facilities for characterizing and developing metal alloys and ceramics. Staff expertise in molten-salt technology may be pertinent to the fields of coal processing and solid waste reprocessing.

In future environmental research, techniques for identifying carcinogenic materials will find new applications. The Laboratory staff and the small-animal experimental facility would be an important resource for applying these techniques for environmental studies.

The current research program on dielectric properties of liquid helium and improvement of conductor materials for cryogenic temperatures is basic to successful development of superconducting power transmission.

Capabilities in preparing environmental statements for nuclear power stations could also be used for fossil-fuel power stations, coal processing plants, and oil shale extraction and processing facilities.

ORNL's adaptability is also enhanced by a general capability in analytical chemistry, instrument development, health physics, information handling and computerized system analysis that could easily respond to a wide spectrum of energy, environment, safety, and other scientific and technological problems.

Genetic and other biological studies of radiation effects can be extended readily to include effects of toxic substances produced by energy generation and utilization and will provide essential information needed for setting standards for pollutant emissions.

CURRENT ACTIVITIES AND MISSION OF ORNL

Reactor and Engineering Science
- Reactor engineering
- Instrumentation
- Chemistry
- Chemical technology
- Materials

Reactor Development
- Liquid-metal, fast-breeder reactor
- Gas cooled reactor
- Controlled thermonuclear reactor
- Reactor safety
- Preparation of design and safety standards
- Structural design for reactor vessel materials
- Environmental impact

Nuclear Development
- Remote handling operations
- Waste disposal systems
- Isotopic heat source
- Containers for transporting waste

Energy-Related Studies
- Conservation technology
- Transportation requirements
- Waste management requirements
- Desalting
- Efficiency technology
- Superconducting electrical transmission
- Integrated urban energy systems

Energy Evaluation Programs
- Coal liquefaction and gasification
- Solar-electric power
- Geothermal-electric power
- Microbiological production of hydrogen and methane
- Production and use of hydrogen and other synthetic fuels

Biological and Medical Research
- Genetic effects of radiation
- Genetic effects of drugs, smog and other toxins
- Health physics
- Ecological monitoring and modeling

Physical Research
- Solid state physics
- Plasma physics
- Chemistry
- Mathematics
- Nuclear physics
- Materials science

Lawrence Livermore Laboratory (LLL)

Livermore, California

The main site of the E. O. Lawrence Livermore Laboratory (LLL), operated by the University of California, is on 640 acres about three miles east of Livermore (population 37,703) and about 40 miles from San Francisco. A 7,000-acre test site is 15 miles east of Livermore. Since LLL's establishment in 1952, its primary program has been the design of nuclear weapons. Additionally, from its beginnings, LLL has maintained programs in peaceful technology development.

Program Funding

In FY 1973, LLL had an operating budget of approximately $135.9 million; 92 percent of the funds came from the AEC and 8 percent, or about $12 million, came from other Federal agencies, primarily the Department of Defense. Total full-time employment has averaged 5,400. In FY 1973 the major operating programs were as follows:

AEC	FY 1973 Operating Funds (In Millions)
Nuclear Materials	$ 0.3
Weapons (Laser Fusion 13.5)	107.4
Controlled Thermonuclear Research	7.8
Biomedical and Environmental Research	3.3
Isotopes Development	0.1
Civilian Application of Nuclear Explosives	5.2
Regulation	0.6
Total	$124.7

Other Federal Agencies	
Advanced Research Projects Agency	$ 4.4
Defense Nuclear Agency	1.9
Department of Defense	0.9
Department of Transportation	0.5
National Aeronautics and Space Administration	0.1
Environmental Protection Agency	0.1
National Science Foundation	0.1
Health, Education, and Welfare	0.1
Other	2.8
Total	$10.9

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Facilities

The authorized investment in plant and equipment in FY 1973 was $278 million. Significant facilities include:

1. Several accelerators, including a 100-MeV electron-positron accelerator and a cyclograaff.
2. A 3-MW pool-type reactor.
3. Controlled thermonuclear research machines.
4. One of the largest computer facilities in the world containing four CDC 7600s, two CDC 6600s, one SDS Sigma-7/Sigma-3, and a partially completed CDC prototype STAR.
5. Extensive engineering and machine-shop facilities for designing, testing, fabricating, and assembling virtually any electronic or mechanical device.
6. Extensive facilities for research in rock mechanics, chemistry, chemical engineering, and metallurgy.
7. A 7,000-acre chemical explosives test site for formulating, fabricating, and firing explosives, equipped with sophisticated diagnostic equipment, including X-ray and neutron radiography and high-speed photography for hydrodynamic research.
8. Laser fusion research resources, including a 200-joule glass disk laser, a 100-joule carbon dioxide laser, and an intermediate laser facility for developing a 1,000-joule glass disk laser.
9. A marine facility for studies of accumulation and metabolism of radioactivity in oysters and other shell fish.
10. Modern facilities for small and large animals.
11. Sophisticated instrumentation for the detection of low levels of radioactivity and for analysis of biological materials.

Personnel Information

LLL personnel include the following:

Highest Degree Attained	No. of Individuals
Ph.D.	560
M.S.	512
B.S.	934
Total	2,006

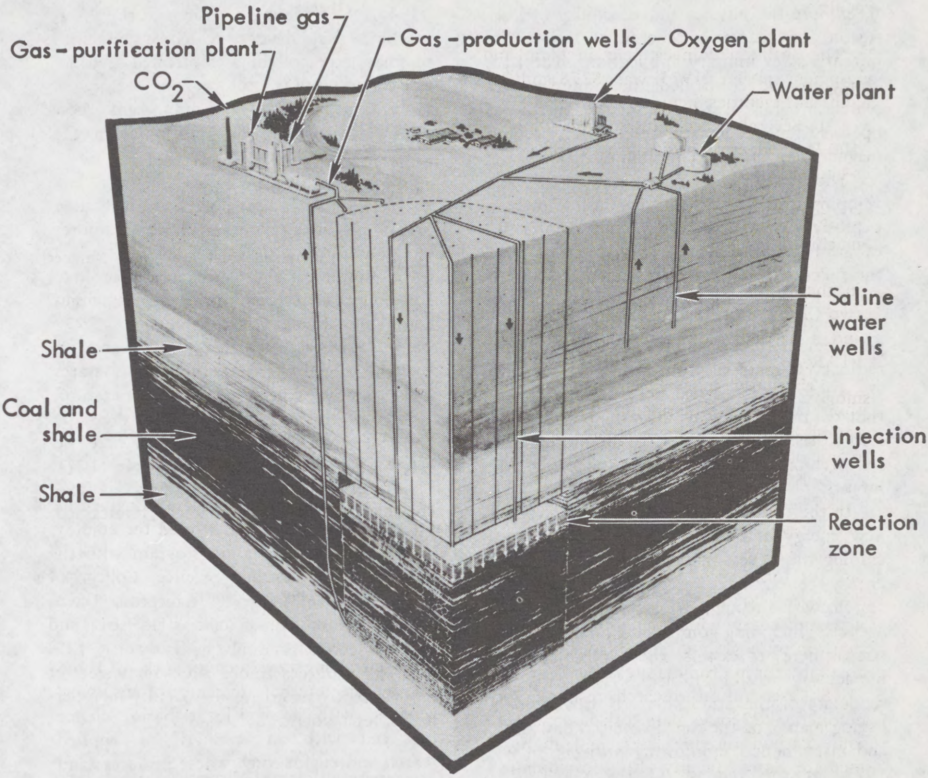
Occupation	Number
Physicists	540
Chemists	236
Life Scientists	54
Metallurgists	27
Mathematicians	23
Mathematical Programmers	172
Engineers	719
Total	1,771

The M.S. and Ph.D. degrees in Engineering and Applied Science are offered for employees and others in a joint program with the Department of Applied Science, College of Engineering, University of California, Davis. There are classroom facilities at LLL, and thesis research is done with diverse LLL research resources under the supervision of senior scientists who are also faculty members of the Department.

Current Activities and Mission

Nuclear explosives research and development continues to be the largest program at LLL. The main goals are to help keep the U. S. defense abreast of new potentials of evolving nuclear explosives and other technology and to design military weapons upon request by government agencies.

In the laser fusion program, funded as part of the weapons program, a 1,000-joule neodymium glass disk laser prototype is being developed. Plans call for designing 12 of these to form a High Energy Laser Fusion Facility



The ready transferability of large-scale underground nuclear energy technology developed in the Plowshare Program to nonnuclear energy processes is illustrated in this Lawrence Livermore Laboratory concept of in-situ coal gasification. In this kind of experiment chemical explosives would be used to crack a zone of coal 600 to 3,000 feet below the surface. This zone, being under high pressure and high temperature, would constitute a natural retort in which chemical reactions would take place between coal and an oxygen-steam mixture, yielding methane. Many of the skills and technologies developed at Livermore for underground nuclear testing and Plowshare's gas stimulation program are immediately transferable to such an experiment; for example, rock mechanics, geophysics, geology, hydrology, remote monitoring, and sampling, etc. The studies indicate that the method might produce enough gas to supply the U. S. for 100 years, at an economic cost and without strip mining or surface waste.

to explore the physics and feasibility of laser fusion for generating energy as well as its potentials for military applications. The LLL effort in the controlled thermonuclear research program is to explore the mirror, or open, system for generating electricity by the magnetic confinement method of fusion.

The Plowshare program is presently developing the technology for using nuclear explosives to release large quantities of natural gas from deep, tight rock formations; e.g., the recent Rio Blanco experiment in western Colorado. Focus in the biomedical and environmental program is mainly on the environmental relationships in the transport of radioactive material from source to man and the study of biological control mechanisms that control cell behavior, with special attention to the vulnerability of these mechanisms to carcinogens and radiation and other pollutants.

In the last two years LLL has undertaken new energy and environmental projects, including the development of new concepts in energy generation; active environmental research, with financing from other government agencies, including computer modeling of the stratosphere to assess the global climatic impact of possible future SST flights and modeling of the atmosphere to provide local "smog maps" of the San Francisco Bay Area; and instrumental monitoring projects. In FY 1973, at the request of the AEC, LLL assigned a group of 20 employees to work with the AEC Regulatory Division in Washington, D. C., to provide needed expertise.

Significant Accomplishments

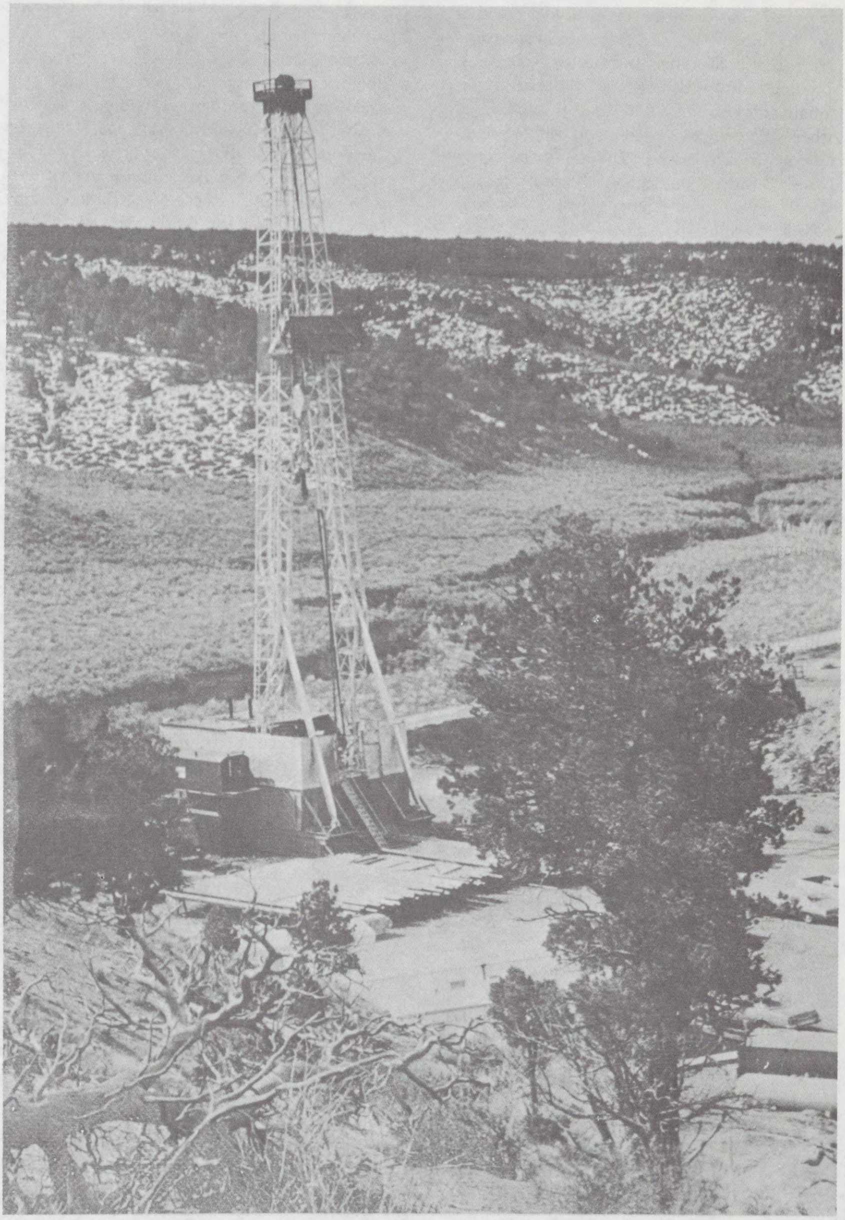
1. Development of strategic warheads small enough to fit into missiles.
2. Development of the Spartan warhead, tested at Amchitka, and of the warheads for the Polaris, Poseidon, and Minuteman missiles.
3. Extensive contributions to an understanding of controlled thermonuclear reactions.
4. Achievement of plasmas in the 2X II machine that have provided insight into plasmas expected in a controlled thermonuclear research reactor.
5. Contributions of important new knowledge in hydrodynamics and in the properties of materials.
6. Innovations in new computer languages, software concepts, and detailed programs for integrating varied computer equipment into a total system.
7. Unique applications to meteorology and geophysics of combined hydrodynamics and numerical methods.
8. Extensive new information and refinements relating to nuclear energy states and processes relevant to energy generation.
9. The theory which provides the basis for the hope that laser fusion may be achieved at practical laser energy levels.
10. Entirely new techniques in machining, especially to previously unattained tolerances and accuracies.

Adaptability to New Programs and Problems

In generating new technologies, LLL has built up an unusual diversity of technical resources, with a significant basic science effort but with an emphasis on applied research and engineering. These resources and the Laboratory's successes in goal-oriented technology have increasingly involved LLL in problem-solving in the energy and environmental fields and in other fields of national concern.

1. LLL operational philosophy calls for a minimum of formal organizational structure and a maximum of flexibility in chang-

The site of Project Rio Blanco, a peaceful underground nuclear explosives test for gas stimulation, for which the Lawrence Livermore Laboratory designed three nuclear charges. The emplacement rig was used to lower three 30-kiloton nuclear explosives down a well bore more than a mile deep.



ing directions to meet new problems. Today the Laboratory can quickly mobilize special interdisciplinary task forces of scientists, engineers, and technicians to concentrate on a new technical mission.

2. To meet high-priority national-defense challenges, LLL has built strong bases of human and material resources in a wide spectrum of science, engineering, and technical support. These resources are equally fundamental to the solution of other diverse technical problems of contemporary social significance.

3. In accomplishing national defense and other programs, LLL has carried out operations ranging from basic research to applied science to engineering, design, and testing of new hardware; design and supervision of large-scale field operations; extraction of data with remote techniques under extreme conditions (underground testing); collation of these data; and the fabrication of prototypes, supervision of production, deployment in the field, and long-term surveillance of product viability under field conditions. This experience has application to present socio-technical problems.

4. The ready transfer of LLL scientific and engineering techniques to contemporary social problems is illustrated by LLL's stratospheric and atmospheric modeling to determine the effects on global climate of possible SST fleets and regional atmospheric pollution for the San Francisco Bay Area. Other possibilities include atmospheric modeling combined with LLL's skills in detection and analysis of trace elements to facilitate the use of catalytic converters in automobiles, and modeling to approach the problems of energy conversion, electrical power grid systems, national transportation systems, and metropolitan traffic movement. Sophisticated electronic instrumentation has already been adapted to radioactive and nonradioactive pollution monitoring and can be greatly expanded. Rock mechanics, geophysics, hydrology, etc. have been adapted to scoping and initial investigations of large-scale energy development concepts, such as in-situ coal gasification and geothermal energy and the in-situ processing of oil shale. LLL's highly developed seismology program can be adapted to earthquake engineering studies to minimize the effects of earthquakes on, for example, underground utility pipes. The Laboratory's experience in materials development, hazards control, and precision machining and engineering can offer techniques to help upgrade current technology.

5. The biomedical and environment programs at LLL can easily be adapted to the study of the chemistry, photochemistry, transport, and effects, both biological and environmental, of pollutants from fossil-fuel power plants. The unique ability to use automated and semi-automated techniques to measure biological effects is an outstanding asset of this laboratory.

CURRENT ACTIVITIES AND MISSION OF LLL

Energy Development	Weapons research and development Civilian application of nuclear explosives Lasers Controlled thermonuclear research
Biomedical and Environmental	Transport of radioactive materials through the environment Air quality research Cellular biology

Lawrence Berkeley Laboratory (LBL)

Berkeley, California

Lawrence Berkeley Laboratory (LBL), operated by the University of California, is on the campus of the university at Berkeley. LBL is a major training facility for graduate students; more nuclear scientists have earned their Ph. D. degrees at LBL than at any institution in the world.

The major effort at LBL is in nuclear and high-energy particle research.

Program Funding

In FY 1973, LBL's operating budget was about $36 million, of which almost 90 percent was for AEC work and the remainder was primarily for other Federal agencies. Total employment in June 1973 was 2,135, down 25 percent from FY 1969. Major operating programs at LBL in FY 1973 included:

AEC	FY 1973 Operating Funds (In Millions)
Physical Research	$29.0
Biomedical and Environmental Research	4.1
Total	$33.1

Other Federal Agencies	
National Institutes of Health	0.3
National Science Foundation	0.6
National Aeronautics and Space Administration	0.6
Department of Transportation	0.2
Department of Labor	0.4
Navy	0.3
Total	$2.4

The NIH funding was from the National Cancer Institute; NSF funding was primarily for environmental instrumentation and atmospheric studies. Half the NASA funding was for biomedical studies, and the other half was for computer use. Department of Transportation funding was for the study of stratospheric ozone; and Department of Labor funding was for computation and programming of census data. Navy funding was primarily from the Office of Naval Research.

Facilities

Total authorized investment in plant and equipment through FY 1973 was $156 million. Significant and specialized facilities include:

1. Automatic data-processing equipment; e.g., a CDC 7600, a 6200, and a 6600 computer system.
2. A Bevatron, a proton accelerator in the 2- to 6-BeV range.
3. An 88-inch variable-energy cyclotron.
4. A heavy-ion linear accelerator capable of accelerating heavy ions from any element.
5. A wide variety of sophisticated energy and environmental instrumentation.

Under cooperative programs with the Berkeley campus, special university facilities are often used; for example, such a cooperative program is now under way using a unique earthquake simulator for seismic studies.

Personnel Information

The LBL staff in June 1973 included:

Highest Degree Attained	Number of Individuals
Ph.D.	319
M.S.	152
B.S.	409
Total	880

Occupation	Number
Engineers	153
Computer Scientists/ Mathematicians	92
Life Scientists	52
Physical Scientists	348
Technicians	693
Other	797
Total	2,135

Seven LBL employees have won Nobel prizes; 12 have been elected to the National Academy of Sciences, and 3 have been elected to the National Academy of Engineering. Fifteen LBL employees won prestigious awards during the 1971 to 1973 period.

Current Activities and Mission

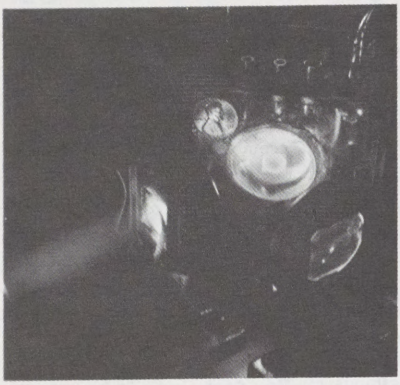
LBL is the prototype of the multidisciplinary national laboratory, with major research focuses in physics, chemistry, biology, medicine, and materials science. Energy and environment studies draw on the diverse human and material resources of the Berkeley campus.

Over half the LBL effort is directed toward nuclear and high-energy particle research with four major operating particle accelerators—the high-energy Bevatron, the medium-energy 184-inch cyclotron, the low-energy 88-inch cyclotron, and the SuperHILAC. Improvements in radiation detection, in electronics and computer interfacing, and in large-magnet technology are among the practical benefits of the LBL nuclear research program as are applications to energy and environmental problems; e.g., new pollution-monitoring instrumentation and the use of accelerators for tunnel boring.

The unique SuperHILAC bombards various targets with nuclei as heavy as uranium. It will be used to explore nuclear reactions, the behavior of unstable heavy nuclei, and the synthesis and identification of new chemical elements.

LBL is creating a versatile and unique facility by linking the SuperHILAC and the Bevatron to form the BEVALAC. When finished, the BEVALAC will accelerate a wide range of heavy particles to high energy; it will be used in space biology, tumor therapy, nuclear chemistry, physics, and cosmology.

LBL has developed a number of significant biomedical techniques, such as the scintillation camera and other specialized devices for nuclear imaging. Biomedical effort is



One of the steps in photosynthesis, nature's primary method of capturing the sun's energy, is being applied in experiments at the Lawrence Berkeley Laboratory to explore new concepts in solar energy conversion. Using a newly developed chlorophyll solar cell, scientists have demonstrated that they can get a continuous flow of electricity by shining light on chlorophyll spread on a zinc oxide crystal. (Penny in picture shows size of device.)

currently being applied to a number of environmental problems; e.g., a study of potential tritium levels and effects, and a study of cadmium in the biosphere and its turnover in man.

A tissue-culture facility is used for the study of the processes responsible for malignant transformation in mammalian cells and methods for interfering with those processes. Other biodynamics efforts include studies on a molecular level of intelligence, learning, and memory.

Interdisciplinary materials research at LBL has created the capacity for tailoring alloys from basic scientific considerations. TRIP steels, having both high strength and ductility, were an earlier result of such work; more sophisticated materials and materials treatment processes have followed: Steels that are both strong and ductile at cryogenic temperatures, techniques for greatly increasing the resistance of an alloy to fracture, and superconductors with new properties.

Significant Accomplishments

1. Extensive contributions in development and use of particle accelerators.
2. Development of the BEVALAC, a heavy-particle accelerator.
3. Application of nuclear energy to medicine.
4. Development of the scintillation camera and other imaging devices.
5. Extensive contributions to materials research and applications.
6. Development of techniques for the analysis of ultra-trace elements.
7. Discovery or codiscovery for each of the transuranium elements (for which discovery has been confirmed).

Adaptability to New Programs and Problems

Under the guidance of the Energy and Environment Program, new energy-related projects have focused upon solar, geothermal, and synthetic fuel synthesis. LBL is also investigating the generation of hydrogen (the ideal pollution-free fuel) from water. Solar energy research covers a wide spectrum of solar energy utilization. The photochemical effort is based upon use of the photosynthetic mechanism in living plants; photovoltaic research takes advantage of an on-going basic research program on the properties of surfaces. Geothermal research investigates hot brines, believing this to be the resource with the greatest potential in the near future. The LBL project is aimed at laboratory, field, and engineering research to demonstrate the economic feasibility of natural hot-brine energy. An unusual element of the energy program deals with the reconversion of cellulose wastes into useful fuels.

Environmental projects include an epidemiological study of the relationship of urban air pollutants to diseases such as cancer; a study of the chemistry and dynamics of atmospheric particulate solutions, particularly the sulfates; a study of the effects of trace-metal contamination at the cellular level; and an investigation of the effects of pollutants upon marine ecosystems. The potential effect of a fleet of SST aircraft on the ozone layer of the stratosphere is also being investigated. A major accomplishment in the environmental area has been the development of several techniques for the analysis of ultra-trace substances.

CURRENT ACTIVITIES AND MISSION OF LBL

Energy and Environment	Solar Geothermal Synthetic fuels Hydrogen generation Air pollution Marine ecology pollution
Biomedical Research	Nuclear medicine instrumentation Chemical biodynamics Molecular and cellular radiobiology Heavy particle radiobiology
Physical Research	Nuclear and high-energy particle research Synthesis of new elements Materials development

Brookhaven National Laboratory (BNL)

Upton, New York

Brookhaven National Laboratory (BNL), operated by Associated Universities, Inc., is close to the geographic center of Long Island and about 75 miles east of New York City. It is approximately equidistant (10 to 12 miles) from three of the principal population centers of central Suffolk County—Patchogue (population 11,582), Port Jefferson (population 5,515), and Riverhead (population 7,585). BNL's research program explores the basic structure of fundamental particles and nuclei; studies the physical, chemical, and biological effects of radiation, including beneficial effects in the treatment of diseases and in improving manufacturing processes; provides underlying chemical and metallurgical research data of potential benefit to applied development programs; and develops special research tools, equipment, and methods for general application.

Program Funding

The total AEC operating cost for FY 1973 was about $50 million. This is a 6.5 percent increase over FY 1972, but only a 1.8 percent increase over FY 1970. The authorized investment in plant and equipment through 1973 was $329 million.

The principal AEC-administered programs in FY 1973 and their operating costs were:

Physical Research	$37,939,000
Biomedical and Environmental Research	$ 8,321,000
Total	$46,260,000

The estimated cost of work for other Federal agencies in FY 1973 was $2,913,000. The agencies and the major projects they support are:

National Science Foundation. Superconducting electrical power transmission line study, development of crystallographic computing network with 3-D display capability, future energy options for New York City, and carbon content of the Flax Pond Estuary.

National Science Foundation and National Institutes of Health. Electron microscope facility.

Department of the Interior. Concrete polymers, mine safety.

Department of Transportation. Road applications of concrete polymers.

In addition, $765,000 in grants was funded directly by Associated Universities, Inc., in FY 1973. These grant funds were received primarily from the National Institutes of Health.

Facilities

The major facilities are the Alternating Gradient Synchrotron (AGS), the High Flux Beam Reactor (HFBR), and the Double Tandem Van de Graaff accelerator. All of these are used for research concerning the basic structure of matter.

Complementing these facilities are several smaller accelerators, mass spectrometers, electron microscopes, a large central computing facility (two CDC 6600's) and many smaller special purpose computers, a research hospital, an irradiated forest, towers for micrometeorology studies of dispersal of pollutants, facilities for handling large quantities of radioactive materials, and many other specialized facilities for research and development.

Personnel Information

Highest Degree Attained	No. of Individuals
Ph.D./ M.D.	362
M.S.	119
B.S.	269
Total	750

Occupation	Number
Engineers	229
Mathematicians	47
Physical Scientists	343
Life Scientists	131
Technicians	466
Others	1,221
Total	2,437

Three Brookhaven National Laboratory research biologists examine the first mature hybrid tobacco plant grown from the fused somatic cells of two different species. This new method, called parasexual hybridization, bypasses natural barriers.

Current Activities and Mission

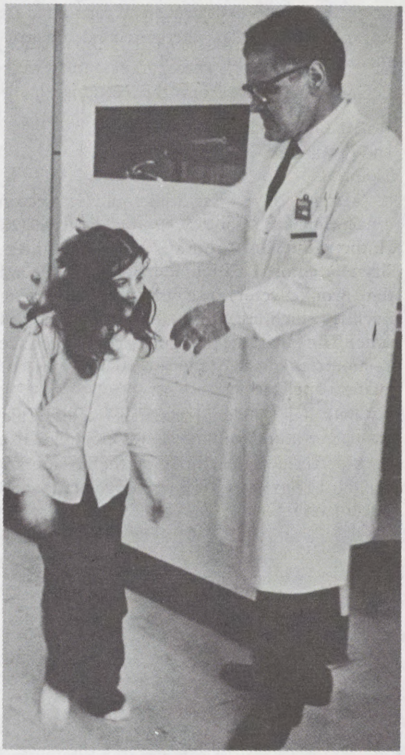
BNL's major programs are in physical science research, particularly high-energy and nuclear physics, solid-state physics, and chemistry. In high-energy physics the program is mainly concerned with experiments on "particles" or "resonances" which advance the knowledge of the structure of matter at the deepest levels as well as leading to understanding of the forces that hold nuclei together.

In the life sciences, emphasis has been on the genetic and somatic effects of radiation on animals and plants, molecular biology, and use of isotopes and activation analysis to study metabolism of trace elements. The latter work led to the development of L-Dopa as an effective treatment for Parkinson's disease. Multidisciplinary work in molecular biology has led to better understanding of enzymes, viruses, and proteins, including their synthesis in some cases.

Recently BNL has made advances related to energy problems in the fields of superconducting transmission, hydrogen storage systems, and controlled thermonuclear fusion.

An AC superconducting transmission line is under development; this line could move large blocks of electrical power over long distances. Conceptual design studies are being made of energy storage systems based on hydrogen for both mobile and stationary applications. The fusion technology program has focused on the analysis and design of magnets for large devices, and on the properties of materials for their construction.

Energy systems analysis work at BNL involves the assessment of new energy technologies and policies by considering economic, environmental, and resource implications. Structural models of the energy systems have been developed that include all resources and both electrical and nonelectrical energy forms, which have been used in energy technology assessments by the Office of Science and Technology.



At Brookhaven National Laboratory Dr. George Cotzias discovered that large daily doses of L-Dopa medication provided relief to patients with Parkinson's Disease. Above, Dr. Cotzias evaluates the improvement caused by L-Dopa in a patient suffering from a form of shaking palsy that affects children.

Significant Accomplishments

Among the significant accomplishments at BNL is the application of the strong focusing principle in accelerators that increased the energy range available to high-energy physicists. Numerous fundamental particles were discovered at BNL, and experiments with the AGS revealed that the important principle known as conservation of parity is violated in some types of interactions.

In studies of the behavior of water under irradiation (of importance both in radiation biology and water-moderated reactors), BNL scientists revealed the importance of the long unrecognized hydrated electron. The use of labelled compounds such as tritiated thymidine has shed light on many biological and physiological problems.

In solid-state research many important points relating to the production of defects by irradiation have been clarified; and much has been learned about how such defects change the properties of materials.

On the applied side, there have been significant accomplishments in many areas, among them improved instrumentation for radiation measurements, "generators" for iodine-132 and technetium-99m for medical use, and development of concrete polymer materials.

BNL has performed extensive and significant past work on sulfur dioxide atmospheric diagnostics. This experience and capability are quite important in energy-related environmental analysis and control.

Adaptability to New Programs and Problems

Many of BNL's facilities could be used on a part-time basis for new work. The Research Hospital, the Hot Laboratory, the High Intensity Radiation Development Laboratory, and the Brookhaven Linac Isotope Production Facility which are, for example, not used full time. The latter, in particular, could produce commercial quantities of some isotopes for medical applications.

BNL has wide experience in studies of air- and water-borne pollutants. Research has also been performed in ecology on the production of mutations for crop improvements and insect sterility.

A large central computer facility with an appropriate staff of mathematicians, programmers, and technicians is at hand for use in connection with modeling studies or processing of experimental data.

Pilot plants have been built for such processes as incorporating high-level radioactive waste in ceramics, production of concrete polymer and glass polymer materials for a variety of purposes, and high-level irradiation of foods.

BNL has an extensive program in nonnuclear technology. For example, significant research is being performed on superconductors to improve underground power transmission cables and systems.

From time to time BNL has undertaken special studies for the AEC or others on such work as safeguards for fissionable material and the radiation hazards that might be encountered in supersonic flight at high altitudes.

CURRENT ACTIVITIES AND MISSION OF BNL

Physical Sciences
- High energy and nuclear physics
- Solid state physics
- Chemistry

Life Sciences
- Genetic effects of radiation
- Somatic effects of radiation
- Molecular biology
- Metabolic processes

Energy Development
- Superconducting transmission
- Hydrogen storage
- Fusion reactor components
- Evaluation of alternative systems and technologies

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Pacific Northwest Laboratory (PNL)

Richland, Washington

Pacific Northwest Laboratory (PNL), operated by Battelle Memorial Institute, is near the city of Richland (population 26,290) in south-central Washington. Its main research facilities are within or adjacent to the 570-square-mile Hanford Project area.

The Laboratory, which performs research for the AEC, other government agencies, and private industry, has been operated by Battelle Memorial Institute since 1965. Its main effort is in biomedical and environmental research.

Program Funding

In FY 1973 PNL's operating costs totaled $37,627,000 of which $21,600,000 (or 65 percent) was for AEC. The remaining $16,000,000 was for research under separate contracts with industry and other government agencies. Major FY 1973 programs included:

	FY 1973 Operating Funds (In Millions)
PNL-managed AEC programs	
Biomedical and Environmental	$6.3
Regulatory	2.6
Physical Research	2.2
Waste Management	1.6
Weapons	1.5
Reactor development, isotope development, etc.	1.4
Support for other contractors	
Primarily production and reactor development	5.0
Support for other AEC sites	
Primarily Livermore (weapons) and Union Carbide (production)	0.3
Other Federal agencies	
Through AEC contract (primarily DOD and HEW)	2.8
Battelle contracts (primarily government agencies other than AEC)	5.3
Total	**$29.0**

Facilities

The authorized investment in plant and equipment through FY 1973 was $58 million. In addition, Battelle itself has invested $13.5 million in developing and equipping an integrated research and development complex at Richland and a new Marine Research Laboratory on the Pacific Coast at Sequim, Washington. Major facilities include the AEC Life Sciences Laboratory, the AEC Atmospheric Sciences facilities, the AEC Metallurgical Development Laboratory, and a major addition to Battelle's Life Sciences Laboratory II. Some specialized facilities include:

1. An extensive meteorological-tower grid system that is used in conjunction with aircraft-mounted equipment for trace-element release studies and atmospheric sampling.
2. Aquatic systems for controlled marine and freshwater studies.
3. High-level radiochemistry laboratories.
4. A critical-mass laboratory.
5. Plutonium-handling facilities and laboratories.
6. Ultra-sensitive radiation-counting facilities.
7. High-rate sputtering equipment.
8. A large outdoor water basin for oil-spill-recovery studies.
9. A pyrolysis-gasification pilot plant.
10. Aircraft-mounted equipment for remote sensing of thermal distributions.

Personnel Information

As of March 8, 1973, the PNL staff included:

Highest Degree Attained	No. of Individuals
Ph.D.	179
M.S.	169
B.S.	232
Total	580

Occupation	Number
Engineers	180
Mathematicians	20
Life scientists	82
Physical scientists	234
Technicians	288
Other	663
Total	1,467

Current Activities and Mission

PNL activities span the entire nuclear power cycle from the safety analysis of commercial fuel designs to the ultimate disposal of long-lived radioactive wastes. Specifically, PNL is evaluating nuclear-fuel densification; studying nuclear-fuel failure (energy) thresholds; conducting an experimental program in plenum filling as an aspect of emergency core-cooling systems; providing the safety performance review and analysis of liquid metal fast breeder reactor (LMFBR) materials and fuels; assisting the Power Burst Facility test-development and evaluation program; managing the AEC study of long-range nuclear-waste-disposal concepts; forecasting nuclear-fuel reprocessing, plutonium recycle, and energy resources; and conducting programs in environmental radiation monitoring, health physics, and personnel safety practices.

In the fossil-fuel area, PNL is exploring methods for removing sulfur compounds from hot fuel gases and for cleaning flue gas. Looking to new energy sources, PNL is investigating a major geothermal field for the National Science Foundation and has been funded for work in the controlled thermonuclear research program.

In the life sciences, PNL has for 25 years been engaged in radionuclide-inhalation studies, some of which cover successive generations of laboratory animals. The PNL study of the combined somatic effects of inhaled air pollutants includes one long-term animal research program involving atmospheres simulating those encountered by uranium miners. The long-term biological effects of plutonium, the transplutonium elements, and noble gases are also being investigated. Cancer studies include basic research in the life processes at

Atmospheric sampling equipment is used for meteorological studies.

An area of 120 square miles, undisturbed by man for 30 years, has been reserved by PNL for Project ALE (Arid Lands Ecology). Plant and animal life systems are studied in this outdoor laboratory.

the cellular and molecular level and biomedical applications of radioisotopes. In bioengineering, PNL is investigating the effects of implanted isotopic heat sources and is developing new materials for prosthetic applications.

A special microwave laboratory is used in the study of mutagenic, physiological, and central nervous system effects of high-flux microwave fields. Work is also being done on soil retention and uptake by plants of heavy metals and heavy-metal complexes, uptake and concentration of radionuclides by aquatic organisms, and the movement of radionuclides through the food chain to humans. Project ALE (Arid Lands Ecology), a 110-square-mile reserve, is the site for basic study of the functional roles of plants and animals in the shrub-steppe ecosystem.

Significant Accomplishments

1. The Plutonium Utilization Program, which provided the basis for commercial use of plutonium fuels.
2. Extensive contributions from uranium-fuels research to the current technology in commerical power reactors.
3. Contributions to safety research, including the AEC Containment Systems Experiment.
4. Development of methods for predicting steady-state and transient light-water reactor fuel performance.
5. Contributions in shielding, reactor kinetics, transient thermal hydraulics, and plant operational control and systems reliability.

Adaptability to New Programs and Problems

PNL's diverse research program and diverse funding sources (approximately one-third of current research support comes from industry and government agencies other than AEC) illustrate the laboratory's flexibility in response to new problems.

In addition to extending its research activities into geothermal and controlled thermonuclear reaction areas, PNL is becoming involved in solar-energy and energy-conservation studies. Also, the Laboratory has proposed that presently idle Hanford equipment—generators and switching and transmission hardware associated with decommissioned reactors—be used for an electrical testing laboratory. With these facilities electrical systems can be isolated to permit evaluation of system-fault and load-shedding conditions.

Biomedical research is under way at PNL to determine the effects of environmental energy effluents on living systems. This work benefits from prior PNL experience in the toxicology of radionuclides.

CURRENT ACTIVITIES AND MISSION OF PNL

Nuclear Fuel Cycle Studies	Fuel design safety Evaluation of reactor fuel performance and problems Radioactive waste disposal Commercial uses of plutonium Uranium fuels research
Fossil and other Energy Development	Sulfur removal Flue gas cleanup Geothermal field investigations
Biomedical and Ecological Research	Effects of inhaling radionuclides Cancer studies Applications of radioisotopes Prosthetic applications of nuclear energy Industrial pollutant toxicity Environmental transport of radioactive elements Arid Lands Ecology Program Modeling of pollution in large ecosystems

Los Alamos Scientific Laboratory (LASL)

Los Alamos, New Mexico

The Los Alamos Scientific Laboratory (LASL), operated by the University of California, is in Los Alamos (population 16,000) in north central New Mexico about 35 miles from Santa Fe (population 41,167) and 100 miles from Albuquerque (population 350,000). Regular air service (six flights each way per day) is provided to Albuquerque to connect with other airlines, the Sandia Laboratory, the Albuquerque Operations Office of the AEC, and the University of California.

Program Funding

In FY 1973, the total operating budget funded by the AEC was approximately $108 million; an additional $12 million was spent on work done for other Federal agencies. The total full-time employees numbered 4,500. The major programs in FY 1973 were:

AEC	FY 1973 Operating Funds (In Millions)
Weapons	$77.4
Physical Research—Medium Energy Physics	9.4
Reactor Development	9.3
Controlled Thermonuclear Research	5.6
Biomedical and Environmental Research	2.8
Total	$104.5

Other Sources	
National Aeronautics & Space Administration (terminated as of 6/30/73)	3.1
Defense Nuclear Agency	2.9
National Institutes of Health	1.6
Advanced Research Projects Agency	1.3
Total	$8.9

Facilities

The authorized investment in plant and equipment through FY 1973 was $491 million, including $62 million in general maintenance facilities operated for LASL by a separate corporation (The Zia Company). Some of these facilities are (1) the Clinton P. Anderson Meson Physics Facility, costing $56 million; (2) the pulsed high-intensity X-ray machine called PHERMEX, costing $11 million; (3) the Scyllac controlled thermonuclear research experiment, costing $8.5 million; and (4) the plutonium fabrication, reprocessing, and recovery plant, costing about $16 million when constructed over 20 years ago. This facility will probably be replaced by a new plant costing $55 million and designed according to modern standards and using LASL's experience combined with the latest knowledge of seismic, tornado, and other hazards.

Other special facilities include a fast critical assembly laboratory and numerous particle accelerators, large and well-equipped Biomedical and Occupational Health Research Laboratories, and extensive animal holding facilities. The Nevada Test Site (NTS) and the Nuclear Rocket Development Station (NRDS) are used for field tests and for weapons-related or hazardous experimentation. High-explosive fabrication and experimentation can also be performed at LASL.

In addition to these facilities, LASL has a large machine shop employing 300 professional machinists; centralized electronics services; analytical, standards, and monitoring laboratories; and a high-speed computing capability, including two CDC 7600's, three CDC 6600's, and ancillary facilities.

Personnel Information

The current staff includes:

Highest Degree Attained	No. of Individuals
Ph.D.	886
M.S.	582
B.S.	861
Total	2,329

Occupation	Number
Engineers	588
Computer Scientists/ Mathematicians	150
Life Scientists	69
Physical Scientists	911
Technicians	1,308
Other	1,453
Total	4,479

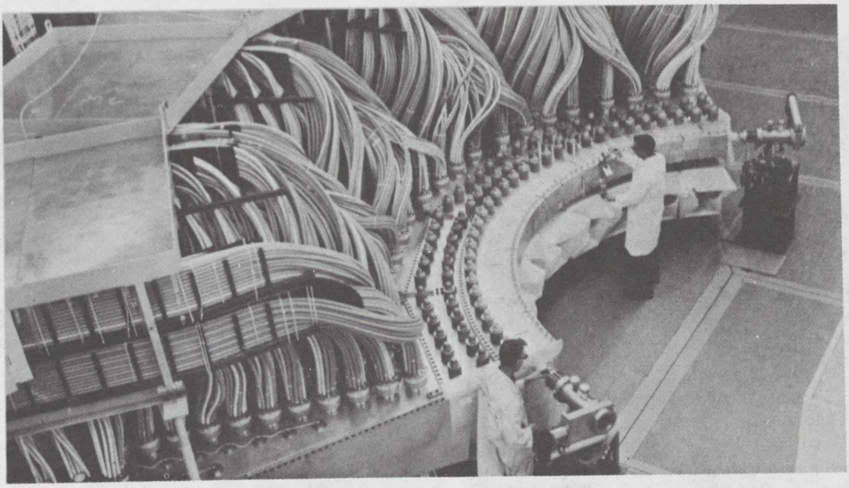
Current Activities and Mission

The major mission of LASL is the nuclear weapons program. Also funded within this program is the laser fusion effort that has potential applications both in weapons and civilian power. This effort is being strengthened through the construction of a specialized research and development laboratory.

The meson facility, the theta-pinch device called Scyllac, and radioactive waste management and biological research programs are expanding rapidly.

Special activities carried out within the framework of the Laboratory range from underground nuclear tests to satellites that can monitor clandestine nuclear explosions in space and perform atmospheric physics studies. The Laboratory maintains a laboratory in a plane that collects airborne radioactivity and other materials for environmental monitoring, and unique analytical methods have been developed for measurements of such materials.

Research in many areas ranging from nuclear physics to the properties of materials at high temperatures and pressures are a large part of the Laboratory's program. Recent new energy projects include the hot rock dry geothermal energy concept, the subterrene (a rock-melting drill), and high-temperature reactor systems. Similarly, direct current superconducting electrical power transmission and storage are now being pursued to help alleviate the energy problem and in support of



An arc of the Scyllac controlled thermonuclear device at the Los Alamos Scientific Laboratory.

specialized, efficient, pulsed-energy storage for the LASL controlled thermonuclear research program.

The Biomedical and Occupational Health programs at LASL are broad in scope, ranging from basic studies on molecular and cellular phenomena to applied efforts in industrial toxicology and inhalation technology. These programs are currently dealing with biomedical consequences of nuclear energy production and are capable of expansion to match program needs in these aspects of nonnuclear energy production.

Significant Accomplishments

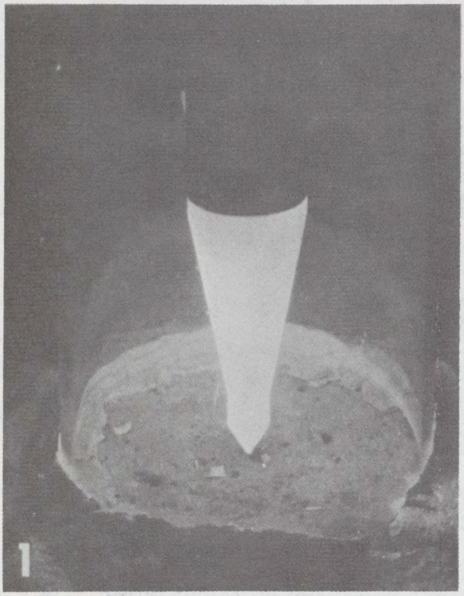
In addition to developing the original fission nuclear weapons and thermonuclear weapons, LASL has made other notable contributions such as:

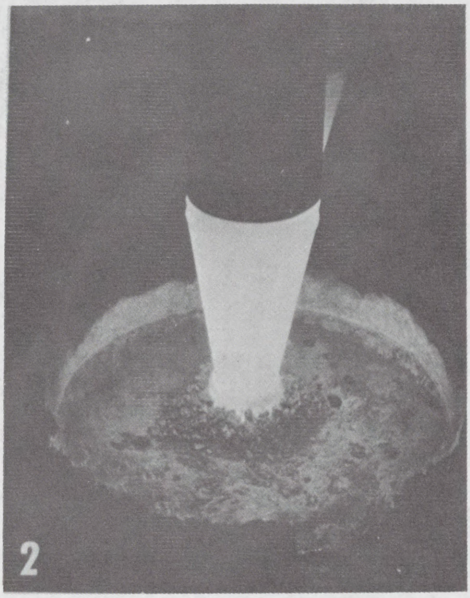
1. The development of nuclear rocket propulsion engines.
2. The first laboratory demonstration of a controlled thermonuclear reaction.
3. The first homogeneous reactor and the first all-metal fast reactor.
4. Development of the first large-scale liquid-hydrogen-handling facilities.

Accomplishments of the Biomedical Program include:

1. Discoveries leading to liquid scintillation counting.
2. Design and fabrication of the multiparameter fast-flow analyzer and cell separator for use in biological research and clinical screening.
3. Establishment of engineering and occupational standards for the use of hydrogen fuels.
4. Establishment of environmental and occupational standards for particle inhalation and inhalation protective devices.
5. Basic discoveries relating DNA content, chromosome number, and malignancy in cancer cells.

Out of the nuclear weapons program has come the ability to design, build, and test nuclear rocket engines. From the rocket





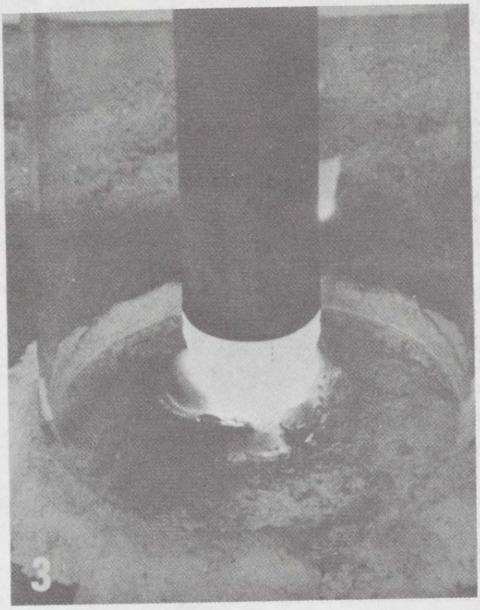
The Subterrene rock-melting bit, operating at a temperature of about 1800°F, bores a hole through a prepared rock specimen during a demonstration test and leaves a smooth glass lining. The Subterrene holds promise as a

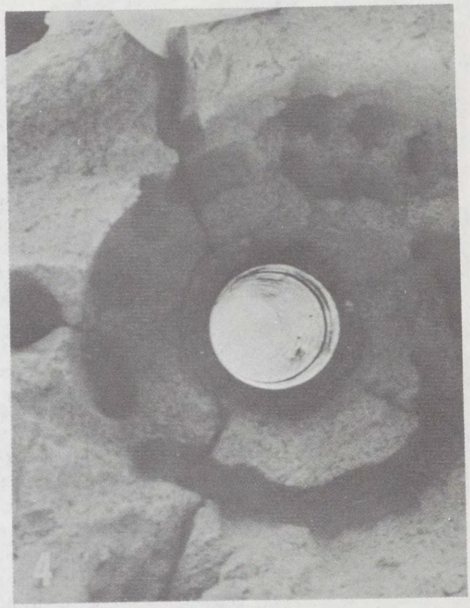
engine programs have come the possibilities of devising very-high-temperature reactors for special purposes, such as coal gasification, hydrogen manufacture from water, and power production. LASL's theta-pinch reactor concept, the Scyllac, appears to have an excellent chance of becoming one of the major contenders for solving the controlled thermonuclear energy production problem.

The techniques for producing and handling large quantities of liquid hydrogen are likely to be of immediate help to the present liquid and gaseous fuels problem as well as being a possible coolant for superconducting electric power transmission lines and storage devices.

The safeguards program for nuclear material control at LASL provides basic science and technology in this field for the United States. Cheap stable isotopes of carbon, nitrogen, and oxygen produced in this Laboratory are likely to improve environmental and ecological monitoring without the associated hazards of using radioactive tracers.

LASL has acquired many completely unique capabilities and one-of-a-kind facilities. For example, it can handle aspects of plutonium technology from basic research to fabrication and biological hazards. Another capability exists in the Laboratory's high explosives expertise and facilities, which range from the machining of special explosive shapes to the use of explosives in shock wave physics and equation-of-state studies. A pulsed X-ray machine of high intensity allows flash X-ray pictures of rapid dynamic changes in heavy metals. The Meson Physics Facility is the only accelerator of its kind and intensity in the world. In addition to its use in basic research, it provides strong proton and neutron beams of immediate application to radiation damage and biomedical problems. LASL is a lead laboratory in studies on waste management of alpha radioactive materials and will build the first complete facility solely devoted to this problem.





method of excavating tunnels and boring deep holes faster and more economically than other methods. It is being developed by the Los Alamos Scientific Laboratory.

Adaptability to New Programs and Problems

In energy and energy-related fields, LASL is working on:

1. Dry geothermal energy development.
2. Excavation technology by rock melting that will be applicable to deep drilling, water and power tunnel boring, and drilling into hot rock for geothermal sources.
3. Low-temperature engineering experience to test a model of a high-power superconducting electrical transmission line.
4. Special high-temperature fuels for high-temperature, gas-cooled reactor systems based on its unique knowledge of nuclear propulsion reactors.
5. Long-lived and inexpensive heat pipes for efficient high-temperature heat transfer.
6. Simulation of all aspects of fluid dynamics important to ecology, wind and water hazards, heat flow, and tornado dynamics.

The Laboratory is fully experienced in the areas of explosion containment, both for physical containment of debris and shock and for containment against radioactive leakage with all the necessary seismic, explosive, and related capability required.

In biomedical and environmental areas LASL has developed expertise in many areas related to the biological and environmental effects of energy production. Genetic and cellular studies can provide screening systems for testing the mutagenicity and carcinogenicity of energy effluents, while animal programs allow the extrapolation of screened effluents to whole animals and provide additional information on their uptake and metabolism. Basic studies on the mechanisms of damage of environmental pollutants have been coupled with fast-flow cell analysis devices to provide early diagnosis of pollutant effects. Stable isotopes of carbon, oxygen, nitrogen, and sulfur may be used as non-hazardous tracers to follow a variety of pollutants through natural ecosystems.

CURRENT ACTIVITIES AND MISSION OF LASL

Energy Development	Weapons research and development Civilian applications of nuclear explosives Laser beams technology Controlled thermonuclear research Nuclear rocket propulsion engines Very-high temperature nuclear reactors for special purposes Superconducting electric power transmission Dry geothermal heat source development Excavation technology by rock melting Heat transfer mechanics Hydrogen fuels handling and use Nuclear material safeguarding
Biomedical and Environmental	Liquid scintillation counting techniques Cellular separation and fast-flow analyzing Genetic and cellular screening Cancer research and therapy development Environmental sampling and pollutant tracing Basic mechanisms of damage from environmental pollutants Waste management of radioactive materials, especially alpha-emitters Plutonium toxicity and biological hazards Industrial toxicology and inhalation technology Cheap, stable isotope production
Physical Research	Meson physics research Particle-beam damage to materials Nuclear fissioning Basic plutonium research Shock-wave physics Equation-of-state studies Pulsed X-ray use to study metallurgical changes Plasma and solid-state physics

Dr. RAY. As I mentioned earlier, over the years personnel at the AEC laboratories have conducted much basic research that is applicable to solar research and development. As part of the accelerated national solar program, the AEC spent $600,000 on solar energy research in fiscal year 1974 and will spend $1.2 million in fiscal year 1975. While this is a relatively small amount when compared to NSF's $13.2 million in fiscal year 1974 and $50 million in fiscal year 1975, the AEC projects are significant.

Let me describe our fiscal year 1974 program briefly.

At Sandia Laboratory, $400,000 was used to establish a pilot project to test a new solar community concept. The pilot project is designed to provide electricity, space heating, air-conditioning, and hot water for a 12,000-square-foot building at Sandia Laboratory by June 1975. The basic equipment will include solar heat collectors, insulated storage tanks, a turbogenerator and an absorption air-conditioner. This research work also is expected to give scientists and engineers good data on the strengths and weaknesses of the system and to permit testing of components and subsystems developed by solar energy researchers outside Sandia Laboratory. The larger solar community concept to follow would involve the central collection and storage of solar energy and its distribution to individual homes and businesses.

The Argonne National Laboratory project, with funding of $140,000, is developing a device which holds promise as an extremely efficient concentrator of the sun's rays. This trough-shaped device has the potential for gathering the sun's rays to provide electricity from a central steam power station or through the photovoltaic process, which converts the sunlight directly to electricity, and for providing energy for heating and cooling of all sizes of buildings, including homes.

At Los Alamos Scientific Laboratory, scientists began working with a funding of $60,000 to perfect an advanced flatplate solar collector that eventually can be built as part of the roof structure of homes and buildings. An industrial partner will be selected soon to provide high volume manufacturing experience necessary for the successful transfer of this technology to the private sector. The collector-roof structure will be designed so it can be built on an assembly-line basis as a unit suitable for site installation on a wide variety of residential and commercial structures. It would be an insulated, weather-tight barrier against the elements and a compatible architectural feature of the building.

As you mentioned a few moments ago, there have been allegations that the AEC has kept information from being available to the public in the solar energy area. I would like briefly to comment upon that.

These allegations arose in connection with the report known as "The Nation's Energy Future" which I was asked to provide for the President. It was submitted the 1st of December of last year. Let me take a moment to point out that that project was initiated with certain constraining features and those constraints were that the recommendations should cover research and development projects to be recommended within the framework of a 5-year and $10 billion project total.

The report was based on several major and somewhat independent efforts. The preliminary reports prepared by the groups involved have been available for public inspection in the AEC's public document room since early January. One of these was a group of energy workshops organized by Cornell University to consider the major directions of a national program. A second effort was that of the 16 technical review panels that were established to review the 1,100 research and development proposals that were received. These panels, one of which was Solar Energy Panel IX, chaired by Alfred J. Eggers, Jr., of NSF, were made up of 121 Federal employees from over 30 departments and agencies assisted by 282 consultants. Finally, an Overview Panel was established to review the results of the workshops and panels and present specific recommendations to me on the composition of the 5-year $10 billion program. The members of the Overview Panel were:

Mr. Stephen A. Wakefield, Assistant Secretary for Energy and Minerals, Department of the Interior.

Mr. William E. Simon, now Secretary of the Treasury.

Dr. Beatrice E. Willard, member, Council of Environmental Quality.

Dr. Betsy Ancker-Johnson, Assistant Secretary for Science and Technology, Department of Commerce.

Dr. Stanley M. Greenfield, then Assistant Administrator for Research and Development, Environmental Protection Agency.

Mr. William A. Anders, Commissioner, Atomic Energy Commission.

Mr. Bruce T. Lundin, Director, Lewis Research Center, National Aeronautics and Space Administration.

Mr. John P. Abbadessa, Controller, Atomic Energy Commission.

The recommendations which went into the final report were those which were reached by consensus of the overview panel members whose names I just read. Each one of the 16 subpanels referred to the overview group their priority recommendations. The sum total of all of these exceeded $20 billion, if all had been accepted as referred by the subpanels. All had to be cut back, and in reviewing the recommendations from subpanel IX, the individual members of the overview panel differed significantly in their individual recommendations. For the 5-year program four of them recommended that the amount to be allocated for solar research should be at a level of $150 million. The other four made recommendations of $240, $300, $350, and $500 million. After discussion and after thorough review of the panel recommendations, a consensus was reached by the overview panel. Given the state of technology and the total budget constraints, the consensus recommendation was $200 million.

In that I concurred. We were very pleased when the fiscal 1975 budget actually included an increased recommendation over and above that.

Mr. Chairman, the total report from subpanel IX, which has been the subject of some discussion, is right here. This is the same report that is in the Public Document Room. None of the subpanel reports were published. All are available, and has been available since the report was presented, in the Public Document Room at 1717 H Street.

The United States can ill afford to leave untapped any potential energy resource. Solar energy is especially attractive, because of its probable limited effects on the environment, because it is adaptable for use in small packages independent of centrally located generating stations, and because the resource exists and the technology base to put it to us can be developed. With research and development effort on the part of the Federal Government and industry, solar energy systems should become commercially competitive and contribute to our national energy base.

Thank you very much.

Mr. McCormack. Thank you very much, Commissioner Ray, for that statement.

I want to say for anyone who hears my voice, I don't think any responsible person ever believed for a single second that anybody in the AEC or anybody else suppressed for a single moment any scientific information, or anything else, with respect to solar energy R. & D. We are sure all responsible people knew the truth.

Dr. Ray. Thank you.

Mr. McCormack. I want you to know that I spoke out on that the next day, as a matter of fact. I think it is regrettable there are those in our society who are so obsessed with this sort of fanaticism that we don't seek the truth and choose instead to see what is sensational.

I congratulate you and all the panel who worked on the subject.

Dr. Ray. Thank you.

[Subpanel IX report follows:]

SUBPANEL IX

SOLAR AND OTHER ENERGY SOURCES

Alfred J. Eggers, Jr., Subpanel Chairman

National Science Foundation

October 27, 1973

Prepared for the Chairman U. S. Atomic Energy Commission in support of her development of a comprehensive Federal energy research and development program to be recommended to the President on December 1, 1973.

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SECTION 1 - OVERVIEW

1. Program Goal:

To develop, at the earliest feasible time, those applications of solar energy that can be made economically competitive and environmentally acceptable as alternative energy sources.

2. Background and Approach:

The sun is an inexhaustible source of an enormous amount of clean energy available nearly everywhere in the world. The technical feasibility of using solar energy for terrestrial applications is well established. On the other hand, solar energy is diffuse (17 watts/ft^2, twenty-four hour average in the U.S.) and variable (from zero to a maximum and back to zero each twenty-four hours). These two factors of low energy density and variability, combined with the ready availability of inexpensive fossil fuels, have until now, discouraged the development of systems suitable for widespread use. However, a recent study conducted by leading university, industry and government experts[1] concluded that a substantial development program could achieve the technical and economic objectives necessary for practical systems. In certain areas, practical systems are already in operation, e.g., domestic hot water heaters, remotely located buoy power systems, house heating systems, and waste conversion plants.

1. Solar Energy as a National Resource, NSF/NASA Solar Energy Panel, December 1972.

Solar energy can be used to generate electric power, to heat and cool buildings and to produce renewable supplies of clean hydrocarbon fuels. It is proposed to conduct six, phased subprograms covering the three areas. The six subprograms are:

1. Heating, and Cooling of Buildings (HCB)
2. Solar Thermal Conversion Systems (STC)
3. Wind Electric Power Systems (WEP)
4. Bioconversion to Fuels (BCF)
5. Ocean Thermal Electric Power Systems (OTEP)
6. Photovoltaic Electric Power Systems (PEP)

It is important to recognize that each of the above subprograms can make a substantial contribution without which the full potential of solar energy will not be realized.

Three of the four electric power generation system concepts, STC, WEP, and PEP, may require some form of energy storage for most effective central power station applications in order to compensate for the variable solar insolation. This energy storage requirement can be met by a variety of systems, e.g., pumped hydroelectric concepts, advanced pneumatic and electro-chemical systems or alleviated by utility grid operating procedures. The fourth system concept, OTEP, is unique in that it does not require energy storage or collectors since the ocean provides these functions.

While as many concepts and approaches as appear useful will be investigated in the early research and technology phases of each sup-program, only the most promising will be pursued to the point of demonstration. Special attention will be devoted to assuring that refinement and/or the development of advanced systems will be conducted and funded by industry at a later date. Concurrently with the technology development, an incentive research and development program would be carried out. This program would provide an evaluation of the policy alternatives concerning legal, regulatory, and institutional barriers and issues, and evaluate incentives additional to those intrinsic to the technological program elements. Incentives to be considered and evaluated in this program to overcome any initially unattractive features or startup costs of large scale development include; 1) subsidies on capital investment, 2) subsidies on initial operating costs, 3) guaranteed or low interest rate loans and 4) guaranteed minimum sales on equipment development. A significant portion of the overall program is designed to provide incentives to motivate industry to develop solar energy systems.

Figure 1 lists the resources required for the period FY 75 - FY 79 for two program levels; the minimum viable (~$400 million), and an accelerated, orderly program (~$1 billion) having a high probability of early success.

3. Significance and Benefits:

At an average energy conversion efficiency of 5%, less than 4% of the U.S. continental land mass could supply 100% of the Nation's

FIGURE 1 - SOLAR ENERGY PROGRAM RESOURCES

(Millions of $)

PROGRAM	1975	1976	1977	1978	1979	Totals
HEATING AND COOLING						
a. Accelerated	17.8	35.7	50.7	57.5	42.6	204.3
b. Minimum	8.1	20.0	22.0	19.0	17.8	86.9
SOLAR THERMAL						
a. Accelerated	31.1	51.1	59.0	60.0	74.0	275.2
b. Minimum	15.8	16.8	31.5	43.0	38.0	145.1
WIND ENERGY						
a. Accelerated	8.5	17.3	23.5	33.9	23.0	106.2
b. Minimum	3.8	5.4	7.1	6.9	3.7	26.9
BIOCONVERSION						
a. Accelerated	12.1	17.3	23.7	30.1	40.6	123.8
b. Minimum	8.5	10.5	10.5	10.5	12.5	52.5
OCEAN-THERMAL						
a. Accelerated	8.6	19.2	16.4	28.8	26.5	99.5
b. Minimum	4.0	4.5	7.6	12.2	13.0	41.3
PHOTOVOLTAIC						
a. Accelerated	28.3	48.3	63.9	54.1	53.1	247.7
b. Minimum	10.3	10.3	11.0	13.2	12.4	57.2
TOTALS						
a. Accelerated	106.4	188.9	237.2	264.4	259.8	1056.7
b. Minimum	50.5	67.5	89.7	104.8	97.4	409.9

current energy needs. Thus, solar energy could contribute significantly to the national goal of permanent energy self-sufficiency while minimizing environmental degradation. In addition, this technology will be an exportable item for use by other energy deficient areas of the world. Although the full impact of solar energy probably won't occur until the turn of the century, the economic viability of several of the applications, e.g., heating and cooling of buildings (HCB), wind electric power (WEP) and bioconversion to fuels (BCF) could be developed and demonstrated in the next five years. Ultimately, practical solar energy systems could easily contribute 15-30% of the Nation's energy requirements.[1]

In most cases, photovoltaics being the primary exception, the development of practical systems will not require high technology. Thus, the research and development costs for solar energy should be very small in relation to the value of the energy saved. Current estimates indicate that the value of the fossil fuel to be saved in one sub-program area alone, i.e., HCB, would equal the cost of the entire accelerated ($1 billion) R&D program seven years after practical systems become commercially available.

Since solar energy systems are capital intensive and practical systems have not yet been developed, federal involvement in the development program is warranted.

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1. Ibid. p. 10

4. Program Plan Summary:

A. Heating and Cooling of Buildings (HCB)

Approximately 25% of the Nation's current energy consumption is used for HCB purposes. For maximum utilization, solar HCB systems including domestic hot water systems suitable for both new construction and existing buildings must be investigated. Ultimately, 30-50% of the national heating and cooling energy requirement could be furnished by solar energy with the accompanying benefits of fuel savings, reduced pollution, and independence from complex energy transmission and distribution systems.

No major technical barriers exist to prevent the development of practical systems. Most of the technical problems to be solved involve the development of low-cost per unit of energy components. Specifically, the collectors and cooling systems require the most improvement, but appear amenable to a determined development program.

There are major uncertainties with regard to public acceptance, legal rights to unshaded sun, the establishment of a supporting industry, and methods of marketing and financing high, first cost solar HCB systems. However, it seems probable that with the development of economically competitive systems, the benefits associated with solar HCB systems will provide major incentives for solving or accommodating these problems.

Two program levels are projected, (see Figure 1). The accelerated program is aimed at achieving commercial availability by 1979 and requires a budget of $204 million through FY 1979. The minimum viable program, $87M through FY 79 eliminates three out of five demonstration programs, reduces the number of pilot plant experiments from fifteen to ten, reduces component research and technology efforts from $114M to $5M, and for the most part eliminates parallel efforts. The end result is a relatively high risk program with an undesirable lower probability of success.

B. Solar Thermal Conversion Systems (STC)

Approximately 20% of the U.S. current energy consumption is used to generate electric power. Ultimately STC systems could provide 10-20% of the electric power requirement. In addition, the STC solar collection subsystem developed for electric power generation could provide thermal energy for process heat for decentralized (local) and/or centralized applications.

There appear to be no major fundamental barriers requiring basic research. On the other hand, material and equipment development is required to obtain competitive performance and economics. The key technology areas include low cost, high temperature (focusing and tracking) collectors, thermal energy storage and distribution and alternate system concept trade-offs. In addition, there are problems to be defined and resolved arising from the large areas of land required, (10-20 square miles per 1000 Mwe).

The two program levels, with the accelerated program at approximately $275M and the minimum viable at approximately $145M, are shown in Figure 1. The accelerated program includes four different power plant pilot and demonstration projects and a research and technology program aimed at proving technical and economic feasibility by 1985. The minimum viable program eliminates one power plant project, and reduces the research and technology program from $64M to $32M. This program requires 1-2 years longer and lowers the probability of success.

C. Wind Electric Power (WEP)

The maximum electric energy that can be practically extracted from the winds available to the U.S. has not been determined. However, areas of the continental U.S., the Aleutian arc and off the eastern seaboard have been identified for which it is estimated that $1\text{-}2 \times 10^{12}$ kilowatt-hours per year could be generated by wind systems by the year 2000[1]. The total U.S. production was 1.6×10^{12} KW-hrs in 1969 and is projected to grow to 8×10^{12} KW-hrs by 2000. Thus, significant amounts of electric energy are potentially available from the wind.

Based on world wide experience to date, no major technical barriers to the development of practical systems are foreseen. The specific

1. Ibid. Table 24. p. 69.

goal of the accelerated program ($106 million) is to have cost effective, 10 Mwe systems in operation by 1979, leading to the demonstration of 100 Mwe systems by 1981. The program includes a subsystem and component cost reduction program, research on and the collection of wind characteristics, user requirements, legal, environmental, institutional and aesthetic issues, optimization of design concepts, and the testing of single and multi-rotor systems of increasing size and performance, culminating in 10 and 100 Mwe projects. The minimum viable program ($27 million) maintains the same subelement structure but reduces the research and technology program form $20 million to $5.0 million, reduces the number of and delays the 10 Mwe system projects by one year, and delays the 100 Mwe project by four years.

The WEP program will yield definitive test data by 1976-77 as to whether practical systems can be developed. Should the early data be favorable, then a crash program may well be in order to significantly advance the rate and level of impact on the national energy problem.

D. Bioconversion to Fuels (BCF)

BCF systems offer the potential of furnishing replenishable supplies of clean hydrocarbon fuels. Estimates of the potential production capability range as high as 50% of the current gas or oil requirements. However, the extent to which these projections can be fulfilled will depend basically upon the amount of land available and the efficiency and economy of biomass production from that land.

The major problems to be solved involve increasing the energy yield of the production process and trying to accelerate and reduce the costs of the various conversion processes. The accelerated program ($124 million) is aimed at demonstrations of conversion plants of up to 100 tons/day capacity as well as developing high yield energy crops by 1980. In addition, a goal has been established for the practical production of hydrogen by photosynethetic and biochemical methods in the same time period.

The minimum viable program ($53 million) stretches out the program 3-5 years and reduces the number of demonstration plants from eight to four.

As in the case of the wind system program, the bioconversion program will yield early definitive test data as to whether practical systems can be developed. Thus, a crash program may well be in order at a later date.

E. Ocean Thermal Electric Power (OTEP)

In 1929, Claude demonstrated using a 22 Kw unit that the thermal difference between the surface and deep ocean waters can be used to generate electric power. Although the feasibility of the concept was established, the project did not result in a practical system. Modern technology together with the nearly unlimited availability of ocean thermal energy makes this concept of interest. The accelerated program ($100 million) is intended to demonstrate the practical feasibility of converting ocean thermal energy into electricity by 1985. Both near-shore and ocean pilot plant and demonstration projects will be conducted at 10 Mwe and 100 Mwe respectively. System reliability and economic viability will be determined, along with an associated assessment of the technology and environmental impacts. The potential for production of protein and fresh water as valuable by-products will be investigated. Engineering problems to be solved include the development of deep-water pipes of large e.g., 50 foot diameter, along with methods for their deployment and the design of appropriate heat exchangers and pumping systems. A selection must be made between an open or a closed thermodynamic cycle and as to the means for transmitting energy from ocean locations to land. In addition, legal questions associated with operations in international waters must be examined.

The minimum viable program ($41M) would confine the demonstration program to only one near-shore pilot plant/test facility. Consequently, the feasibility determination and ultimate commercial implementation of ocean plants would be delayed.

F. Photovoltaic Electric Power (PEP)

As noted previously, some 20% of the current U.S. energy consumption is used to generate electric power by a total installed capacity near 400,000 megawatts. This level is projected to double over the next decade and become a larger portion of the U.S. energy consumption. Terrestrial photovoltaic systems could provide 10-20% of the electric power requirement. These systems may be employed for central station power systems and as local systems, for example, on rooftops to provide for heating and cooling of buildings. In addition there is the longer range potential of space systems (synchronous satellites) providing as much as power as desired.

The major obstacle to be overcome is the development of the technology and processes which will permit the production of very large quantities of photovoltaic arrays at low costs, e.g., at $0.10-0.30 per ft^2. The accelerated program focuses on the exploration and exploitation of selected single crystal, thin film, and new concept approaches which are intended to establish a high degree of confidence in successfully accomplishing the low cost objective. The minimum viable program would force a substantial and very premature reduction in the number of options to be investigated and would stretch out the program from 3 to 8 years.

Section 2. HEATING AND COOLING OF BUILDINGS

I. SUBPROGRAM SUMMARY

A. Introduction

Heating, cooling, and domestic hot water needs of institutional, industrial, and residential buildings can be met by using solar energy with existing technology. Achieving commercial availability for such systems by 1979, coupled with user acceptance, for large parts of the United States requires a development effort and demonstration of system performance. Proof of concept experiments will demonstrate systems performance and acceptability in various geographic locations. Several types of heating and cooling systems are envisioned.

The objective of the heating and cooling of buildings program is the achievement of commercial availability and widespread use of solar energy systems. Problems which must be addressed are developmental, economic, and societal. Development of components (energy collectors, refrigeration subsystems, storage subsystems, and conversion machinery) will result in lower costs, improved performance, and increased societal and commercial acceptability. Proof of concept experiments using Government and privately-owned residential structures will result in demonstrations of improved economics and will serve as open laboratories to persuade industry and the public of the profitability and utility of solar energy systems. These experiments will be carefully designed to provide the data required by architects, system and component manufacturers, financers, builders, owners, and operators.

The sub-program is structured to provide: (1) component research to increase the number of solar system combinations which will permit the greatest potential for meeting the varied requirements of building types in differing climatic regions of the United States; (2) point demonstrations of custom built systems for design, construction and operational experience and performance data; (3) proof of concept experiments (pilot plants) on a selected set of building type/system type/region combinations throughout the United States to establish the viable range of systems applications and compile performance and life cycle cost data; and (4) small solar communities, perhaps initially on Federal installations, to demonstrate the potential economics of scale and increase operational experience. Demonstration in privately developed small communities would then be undertaken with appropriate underwriting of solar equipment incremental costs.

B. R&D Programs

1. Description of the Accelerated/Orderly Program and Minimum Viable Program.

The Accelerated Orderly Program recognizes that there are a wide variety of climates and system requirements which can only be met with a wide variety of subsystem options to be utilized in systems in a modular or building block fashion. Such an approach will result in a capability of meeting many systems requirements in most of climatological areas of the United States.

The Minimum Viable program will be executed by selecting a few applications where the risks in achieving performance goals are minimal. It would then be expected that the limited demonstrations will be impressive enough to get industry to develop on its own, the subsystems which will increase the number of viable options.

Both programs reach the Proof of Concept Experiment stage at the same time. However, the minimum program would take a great deal longer to generate the variety of systems needed by different building types.

The uncertainty of the program is the rate at which there will be general public acceptance and demand for solar energy systems. The fewer the demonstrated applications, the longer the time to reach a self-sustaining industry.

C. Implementation

1. Projected size of the applications - Current useage of energy for heating and cooling of buildings is estimated to be 15×10^{15} BTU/Yr., this requirement is projected to be 30×10^{15} by the year 2020. A realistic goal would be to supply approximately 30% of the required BTU's by the year 2000 and 50% by 2020.

2. Time schedule - Proof of concept experiments completed by 1979 with commercial products beginning to be available in the marketplace.

3. Possible barriers to implementation are:

   a. Acquisition costs exceed required "pay back" thru reduced fuel usage. Note that the current rate of fuel price increases assures eventual economic success of solar systems.

   b. Resistance to change by manufacturers, architects, builders, financiers, and the public will affect the rate at which the useage increases. The POCE's will be designed to anticipate and answer as many as possible of the concerns of the above groups.

c. Since the "resource" is the sun, it may be considered inexhaustible.

II. STATUS OF TECHNOLOGY

A. Present Status

Domestic Water Heating - The technology of solar domestic water heaters is well developed. Units are commercially manufactured and used in Australia, Israel, Japan, USSR, and on a small scale in the U.S. Increasing fuel costs, product improvement, and large scale production will make solar units competitive.

Space Heating - About 20 experimental solar heated structures have been built and operated. Some were laboratory models and others were residences. Economic studies show that in a wide variety of U.S. climates, solar heating could now be competitive with electric heating. Architects are becoming interested in commercial construction of solar heated homes and commercial buildings. However, subsystems, and building solar systems integration data required by architects and HVAC designers are not available. Each building is a development project. Also, there is not sufficient component and building solar systems design, integration, and operational experience to convince the building industry and the public that solar heating is economic and reliable. The lack of a demonstrated solar cooling system also hinders implementation of solar heating because many potential users would like a heating system to which a cooling system can be readily added.

Space Cooling and Humidity Control - Solar cooling and humidity control is in the early development stage. Development of solar cooling and humidity control systems, particularly for hot humid areas, will be more expensive than the development of solar heating systems. The air conditioning equipment companies are reluctant to make the required investment before a market is assured and government funding is required. There are two classes of cooling and humidity control problems; one pertains to hot dry climates and the other to hot humid climates. Systems for hot dry climates are easier to develop and earlier implementation is possible. Combined solar heating and cooling systems for hot dry areas look economically promising now but component and system development and demonstration data are not sufficient to permit use by the building industry and the public. Climate data showing where such systems are feasible are also not available or not compiled in a useful way. The adaptation of air conditioning systems (e.g., evaporative, dessicant, night radiation, absorption, compressor, and heat pumps) to solar energy use is technically feasible but with more effort required for the systems for hot humid areas.

B. Barriers to Implementation

No research barriers are delaying the implementation of solar heating and cooling of buildings. Rather, development is required to make systems economically attractive. Systems studies, using widely different climatic conditions and building requirements will specify the range of performance needed from the various components. An array of designs, making most efficient use of collected energy, will be developed for the various applications. Thus, component parts development, namely collectors, energy storage and refrigeration systems using low grade thermal energy, and heat exchangers suitable for solar application will remove the barriers to applications. Problems of obtaining widespread acceptance are complex. The high first cost of solar equipment is incompatible with current marketing practices which emphasize low acquisition cost. Demonstration projects, with fully reported details are required to prove system economies, aesthetics, performance and reliability.

Rights to sun angles must be guaranteed by legislation or an investor cannot risk the possibility of construction adjacent to his building site obstructing the sun. Detailed design sutdies must be made to prove that new solar systems designs meet safety and health requirements. Planning commissions, coding authorities, and local trade unions must be convinced and modify appropriate regulations and practices which may interfere with solar powered building construction.

C. Ongoing R&D Efforts to Overcome Barriers

The national solar heating and cooling program is being coordinated by the NSF. Several other government agencies are working on various parts of the program. The objective is the widespread utilization and availability of solar energy systems for all building types and geographic regions in the United States. Proof of concept experiments, initiated in FY 1974 will be carried into subsequent phases of the effort with emphasis on system definition and critical subsystems research. The efforts are described below by agency, total FY 74 funding, total FY 74 Federal manpower, and list main components of the effort.

NSF FY 74 - $5600K - 100 manyears

* Development of solar collectors, solar powered refrigeration subsystems, and storage subsystems.
* Computer modeling and simulation of heating and cooling systems.
* Studies of alternative solar systems that do not require collectors.
* Studies of solar powered air conditioning systems.
* Evaluation studies of completed buildings with solar systems.
* ASHRAE guide preparations.
* Consumer use studies based on the existing solar water heating industry.
* Design, construct, and operate a solar system for a laboratory for system testing and advanced components evaluation.
* Economic studies of effects of scale of utilization.

* Systems analysis to identify most promising system applications and locations; outline development and implementation programs, and estimate benefits.

AEC FY 74-$600K - 10 MY

* Solar total energy community program.

  Systems analysis collector, turbogenerator, absorption air conditioner, and energy storage technology.

* Solar heating and cooling of mobile modular homes systems analysis, collector technology

GSA FY 74 - $100 - 1 MY

* Design, construct, and operate a federal building in Saginaw, Michigan, as an Environmental Demonstration Project including the use of an 8,000 ft^2 solar collector as a heat source for domestic hot water and for a heat pump heating and cooling system with provisions for solar cooling at a later date. Solar system cost estimate $562K (FY 75).

* Design, construct and operate a federal building in Manchester, N.H. as an Energy Conservation Demonstration Project including the use of a 15,000 ft^2 collector to provide water heating and a substantial part of the space heating, cooling, and humidity control. Solar system cost estimate is $530K (FY 75).

NASA FY 74 - $550K - 25 MY

* Systems analysis of building and heating, ventilating and air conditioning type and location.
* Development of collector, air conditioner, and solar heat engine technology.
* Solar HVAC model system test.
* Office building test bed for component and system test.

HUD FY 74 - $40K - 1 MY

* Evaluation of a solar heating and cooling system in a single family house constructed by Sky Therm Corp. The solar heating and cooling system is applicable to hot dry areas.

NBS FY 74 - $1K - 2MY

* Write solar system component testing and evaluation procedures.
* Compile weather data applicable to the design of solar HVAC systems.
* Development of a computer program to determine the hourly building heating and cooling loads.

DOD FY 74 $350K - 2MY

The feasibility of utilizing solar energy on DOD facilities is being investigated. The initial investigations are to develop design concepts for solar energy systems for heating and air conditioning of buildings typical of those found on military bases. Product of this effort will be the performance parameters, concept designs and cost analysis. Recommendations will be developed relating to promising component development for improved performance and/or cost effectiveness and to construct actual demonstration systems for augmenting current thermal systems.

Private Projects FY 74

Various universities, companies, and individuals are conducting studies in all phases of the solar energy for heating and cooling buildings. Initial analysis and small scale facilities and tests are being funded privately but the groups are requesting funds from NSF to support their larger projects. As a consequence much of the effort being expended privately will become a part of the Federal program to the extent that they can be integrated into the overall solar program without significant duplication. Larger organizations, e.g., Electric Power Research Institute, and Institute of Gas Technology, are studying ways in which they can participate in the national solar energy program and this could result in significant private funding.

III. RATIONALE FOR FEDERAL INVOLVEMENT AND INSTITUTIONAL ARRANGEMENTS FOR IMPLEMENTATION.

A. Federal involvement is warranted in the development of equipment for solar heating and cooling of buildings. Private industry is unwilling to invest in the development at the necessary rate because such equipment cannot yet be marketed profitably. The price and availablity of alternate energy sources is expected to rise in the next few years. In order to achieve energy self-sufficiency by 1980 the government needs to invest now in the development of solar energy utilization systems.

B. A number of government actions, other than direct support, would be appropriate and effective in the stimulation of private investment in the development of systems for the solar heating and cooling of buildings. Examples are: a) of purchase of systems for incorporation in government buildings; b) tax or loan incentives for the use and manufacture of solar systems.

C. The construction industry is very sensitive to basic design and construction changes in a short period of time. Building purchasers are reluctant to incorporate experimental or untried systems in new construction and hold the architect and builder responsible for performance, dependability and safety of the building. The government may want to offset these risks.

D. Other government actions which would support the R&D program include: model zoning and development regulations favoring solar energy systems; modification of utility rate structures; and tax incentives which promote manufacture and incorporation of solar heating and cooling systems in buildings.

IV. CRITERIA AND PRIORITIES

A. Criteria

The following criteria have been used in establishing priorities:

a) ability to demonstrate substantial reduction of fuel consumption.

b) Probability of obtaining substantial cost reduction.

c) Impact on industrial and user acceptance.

d) Ability to demonstrate proof of concept early.

e) Opening of new options.

B. Application of Criteria

The proposed effort is comprised of proof of concept experiments and demonstration plants in parallel with advanced developmental efforts for subsystems. The above criteria were applied to each of these categories as follows: Emphasis was placed on (a) and (d) above for whole system and demonstration plant programs, while subsystem developmental programs were judged principally by (b), (c), and (e). The following table illustrates, for several proposed program elements, how criteria could be applied to the establishment of priorities.

Figure 2

PROGRAM	Early POCE Demonstation	System Cost Effectiveness	Industry & User Acceptance	Substantial Regional Impact	New Options	Total Points
Collector development	1	4	3	1	2	11
Concentrator development	1	1	1	1	3	7
Storage System development	2	3	3	5	4	17
Solar heating & cooling of mobile homes	4	3	3	4	1	15
Demonstration plant small communities H & CS	2	1	3	2	1	9
Single family residence pilot plant	5	1	4	4	1	15

RATINGS: 1 - low to 5 - high

V. ALTERNATIVE R&D PROGRAMS

A. In projecting the needs for the heating and cooling of buildings program, a target of obtaining commercial systems for an array of applications by 1979 was established. NSF, NASA, HUD, Department of Agriculture, Department of Defense, and AEC projects were included. This represents an accelerated program with a projected budget of $204 million through FY 1979.

B. The minimum viable development program has a lower probability of obtaining commercial acceptability of more than one system by 1979. Only one large scale demonstration is included in this plan and proof of concept experiments are limited to ten in number. The reduced funding level for subsystem development will result in fewer systems design options for systems variability to meet regional and building type needs.

1 through 7 applies to both A&B above.

1. The milestones given reflect decision points where results warrant continuation of the effort, or where completion of a task permits imitation of a POCE. These milestones reflect measureable achievement points in the programs, both in terms of technology and expenditure of funds. Paralled efforts are to be carried out in supporting technology development areas. Solar energy collector development is one of these areas where the objective is to obtain near optimum collecor designs

on region/cost basis. POCE and demonstration plants in various regions of the country will also be run in parallel. Success in obtaining a commercially acceptable system in some parts of the country are high. However, overall success will require that industry participate in manufacturing systems for sale by 1979. The level of confidence in achieving each of the stated milestones is high because the existing technology will initially be used. Milestones and workflow are shown on Fig 3 and 4.

2. Two budget projections for the five year program are given (Fig 5 and 6). The first of these, in the amount of $204 million is for the accelerated program having the highest probability of success. The tables show expenditures in correlation with milestones. The minimum program in the amount of $87 million reflects a greatly reduced effort, eliminating three demonstration programs, reducing POCE's to ten from 15, reducing supporting technology development efforts, and for the most part eliminating parallel efforts. At this time some private funds are envisaged from industry to evaluate the commercial viability of producing lines of equipment. Substantial private investment, in time for establishing system production facilities, is expected in the 1978-1979 time frame. It is expected that cost sharing in terms of using Federal, State, municipal, or private foundation buildings as demonstration sites will occur.

Figure 3

PROGRAM FLOW CHART

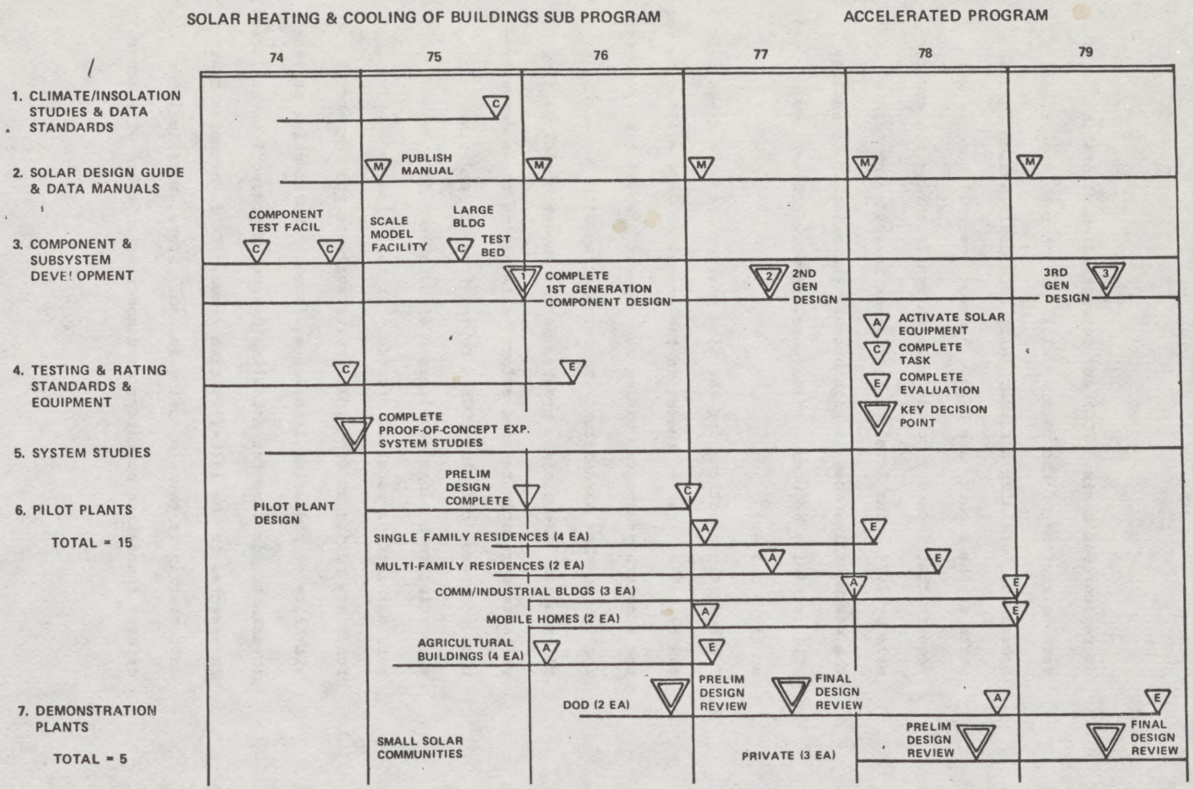

Figure 4
PROGRAM FLOW CHART

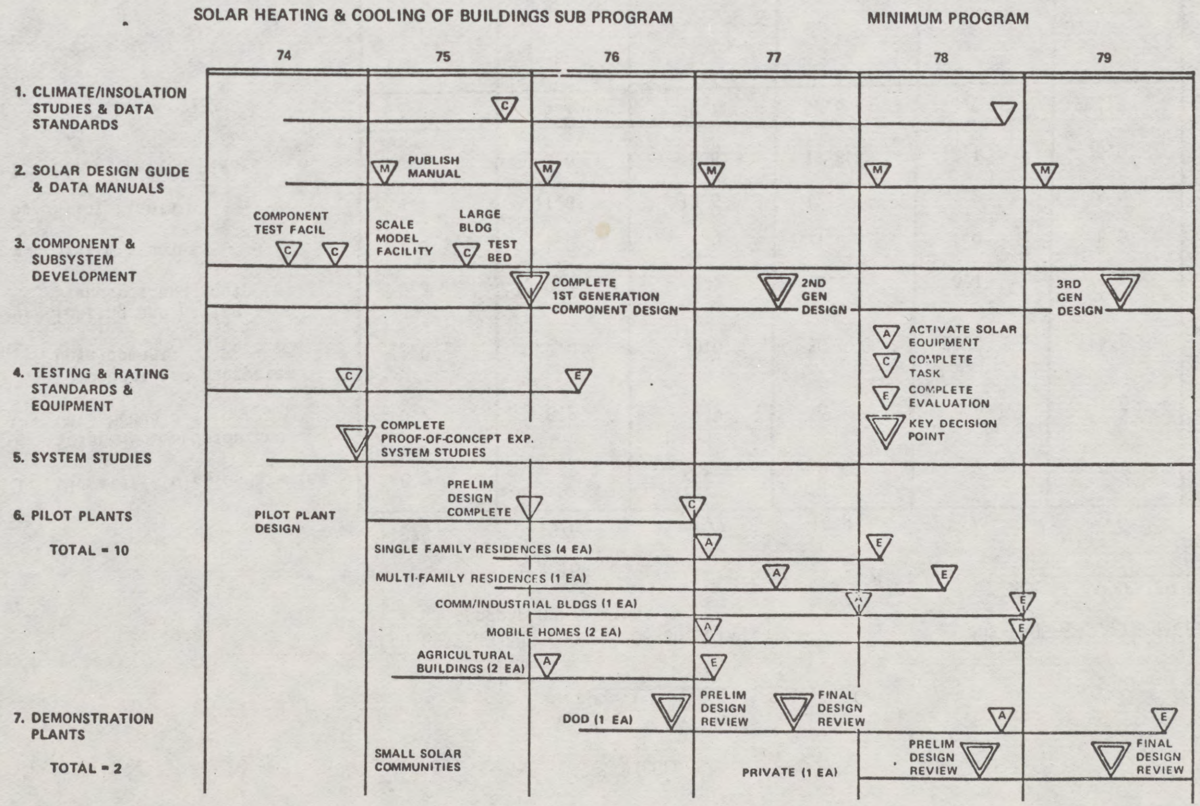

FIGURE 5

ENERGY R&D PROGRAM
BUDGET SUMMARY

SOLAR HEATING AND COOLING OF BUILDINGS
FEDERAL OBLIGATIONS

SUB-PROGRAM ALTERNATIVE

A. ACCELERATED

$\$ \times 10^6$

	1975	1976	1977	1978	1979	TOTAL
1. Climate/Insolation Studies	0.2	-	-	0.2	-	0.4
2. Solar Design Guide and Data Manuals	0.2	0.2	0.2	0.2	0.2	1.0
3. Component and Subsystem Development	12.0	22.0	30.0	30.0	20.0	114.0
4. Testing and Rating Standards and Equipment	0.3	0.3	0.3	0.1	0.1	1.1
5. System Studies	1.0	1.0	1.0	1.0	1.0	5.0
6. Pilot Plants	4.1	11.6	13.6	12.4	4.2	45.9
7. Demonstration Plants	-	0.6	5.6	13.6	17.1	36.9
	17.8	35.7	50.7	57.5	42.6	204.3

FIGURE 6

BUDGET SUMMARY

SOLAR HEATING AND COOLING OF BUILDINGS SUBPROGRAM

MINIMUM VIABLE ALTERNATIVE

(Millions of $)

	FY 75	FY 76	FY 77	FY 78	FY 79	TOTAL FY 75 - FY 79
1. Climate/Insolation Study and Standardization of Data	0.2			0.2		0.4
2. Solar Design Guide & Data Manuals	0.2	0.2	0.2	0.2	0.2	1.0
3. Component & Sub-System Developments	5.0	15.0	15.0	10.0	5.0	50.0
4. Testing & Rating Standards and Equipment	.2	.3	.3	.1	.1	1.0
5. Systems Studies	.5	.5	.5	.5	.5	2.5
6. Pilot Plants	2.0	2.0	4.0	4.0	4.0	16.0
7. Demonstration Plants		2.0	2.0	4.0	8.0	16.0
TOTAL	8.1	20.0	22.0	19.0	17.8	86.9

The Federal outlays are given for both the accelerated and the minimal program. The funding uncertainties relate to the scale of the demonstration plants resulting from the particular Federal or State buildings selected and from the subsystem development programs undertaken to reduce manufacturing costs.

3. It is anticipated that the programs can be completed within the manpower limitations of the various Federal agencies and the staff capabilities of subcontractor firms. No special facility needs are anticipated. During FY 74, an estimated 120 contractor man years and 50 Federal Government man years will be required. Over the FY 75-79 period and estimated 4000 man years of effort will be expended.

4. The management plan will coordinate federal government, private industry and academic research efforts with the intent of handing-off to industry full development of the heating and cooling of buildings by 1979. National laboratories will be utilized, where possible, in the first phases to manage, at a Field Center Level, the individual elements of the sub-program. These laboratories will conduct portions of the research in-house, contracting wherever advantageous for subprograms based on detailed program development plans. Industrial involvement will be used to stimulate early commercialization. In addition, system application to Government buildings will be

stressed as an incentive to industry to establish commercial lines of heating and cooling equipment.

5. The criteria for the establishment of program priorities has already been given. These can be summmarized by stating that all program elements should contribute to the early commerciali- zational of solar heating and cooling systems. The following program areas as examples were not included for this reason.
   a. Focusing collectors - high temperature not needed and high costs.
   b. Combined Photovoltaic/Heat collector - Too expensive now and requires basis long term research.
6. Existing technology is sufficient to demonstrate a successful system for some geographical areas. Success in subsystem development will enhance the commercial value of these systems and improve the impact on the energy economy. This program is not dependent upon other solar energy research programs.
7. There is no potential impact from the solar energy heating and cooling system on the environment or safety. There are problems associated with public and institutional acceptability, e.g., system lifetime and operating costs vs. initial capital cost, building codes, financing regulations, labor practices, urban sun rights or three dimensional zoning.

VI. IMPLEMENTATION

A. Benefits of Implementation

The benefits of implementing a program to develop solar heating and cooling systems are many and include reduction of conventional energy consumption with attendant reduction of environmental pollution, decreased dependence on foreign fuel sources and a potential export market. The supply, maketing, and consumer sectors involved with solar heating and cooling are the same as those sectors concerned with conventional space heating and cooling and hot water functions. The estimated energy used for these functions in 1985 is projected to be 17 x 10^{15} BTU/year. This represents a limit to the energy that can be replaced by the application of solar energy to completely satisfy these functions. Forecasting an ultimate goal of 50% saving of fuels and electricity used through economically feasible applications of solar energy to space heating and cooling of buildings and hot water service, then the equivalent of 8.5 x 10^{15} BTU/year can be saved. The application of solar energy to these functions is not a simple substitution of one fuel for another or for electricity, but requires important changes in construction technology and institutional concepts.

Certainly the implementation of this program will, in the long term, result in a reduction of fuel imports from abroad. With 25% of total national energy consumed now going into heating and cooling of buildings, achieving a 10% application of this technology would result in a 2.5% reduction in fuel comsumption. In particular, however, it could have its greatest impact in high fuel cost regions.

Reliability of solar energy utilization systems should be high in the sense that the supply of energy cannot be limited by political or economic processes, either local or foreign. Lack of sunlight for periods of time can be mitigated through the use of storage systems.

From an environmental standpoint, solar energy for heating and cooling adds no pollutants or thermal emissions. Solar energy does not disturb the balance of energy on earth and is environmentally non-degrading.

In summary, the benefits of implementing solar energy utilization for heating and cooling of buildings include increased efficiency of energy utilization and increased independence from fossil fuel sources.

B. Economics of Implementation

The estimated price of delivered solar energy for space heating and cooling and water heating depends on its location. At a collector cost of $4.00/sq. ft., an interest rate of 8%, a useful life of 20 years, a cost per MBTU of $1.60 in Santa Maria to $4.60 in Miami has been estimated for space and water heating. If the cost of collectors, is $10/sq. ft; the cost per MBTU of energy will increase to $3.10 in Santa Maria and $6.78 in Miami. Ultimately, viable solar systems will offset their purchase price by fuel savings in a reasonable time period.

Optimal systems will provide between 40-60% of the heating and cooling requirement for those homes (and buildings) installing the systems. The remaining requirements will be satisfied by conventional energy sources.

Implementation of the system will have a favorable effect on the labor market. The technology and production knowledge exist for all components of the system. Collector technology will permit use of mass production techniques. Installation of systems will not require special skills. Some minimal amount of training will be required.

The energy crisis is worldwide; therefore, development of an economically viable system will result in potential markets for the export of technology or capital goods to other countries after a U.S. market is developed.

If, as an estimate, one assumes that by the year 2000, solar space and water heating can be suppling 8.5×10^{15} BTU's/yr. This represents a savings of $8.5 Billion/yr. at a rate of $1/MBTU.

Although economic viability is the objective of the R&D program, there are several other incentives which the Federal government might institute to stimulate the production and implementation of the system:

1. require solar systems in all government sponsored building construction, as applicable,
2. provide low interest loans for solar systems,
3. permit home owners to depreciate solar systems for income tax purposes, and
4. provide federally backed low interest loans for homes having solar systems.

C. Impacts of Implementation

There are specific payoffs which result from the application of solar energy to heating and cooling. Existing basic technology is used with minimal impact on existing installed systems, permitting both new installation and retrofit. Next, there is a decrease in pollution which results from the installation of these systems although there is an increase in net useful work. Finally, the use of solar energy offers independence for at least some of man's needs from depletable energy sources. Although these goals can be realized although to only a small extent by 1980, the nucleus of the business will be established (many years ahead of the expected time required for the normal market development).

There do not appear to be any substantial negative impacts resulting from the utilization of solar energy. The materials of construction exist and are commonly used by the industry at present. These include glass, thermal insulating materials, plumbing materials, working fluids, and thermostatic control systems. Application of these materials to solar energy utilization will not compete with other uses since this will supplement existing heating systems. Legal or Regulatory restrictions do not appear to exist.

Work proposed under this subprogram should have a slight but favorable effect on employment. However, if solar heating and cooling of buildings were to achieve wide-scale acceptance and application, substantial changes in the equipment and building industries might occur. Equipment sales of $4.5 billion are projected as possible by the year 2000. An export market may also develop although it can be expected to lag behind the domestic market.

The costs of the first solar heating and cooling systems will be greater than conventional systems but more development and the large scale production will reduce the costs.

The major capital investments necessary for implement of this R&D program are for solar collectors, energy storage, and associated pumping and control equipment. These are above the cost of conventional HVAC systems. This project will involve buildings already in existence or planned for rehabilitation or which are planned to be built as part of Federal and private construction programs. This subprogram will be carried out on Government property when applicable or on privately owned property with federal funding of the incremental cost of the solar equipment only. No land acquisition is required. Utilization of solar energy for heating and cooling is fully compatible with some existing systems, thus, in many regions of the country hybrid systems, employing supplementary energy sources, may be used.

With regard to the impact of these systems on the environment, the systems which we envision today cause neither atmospheric nor net thermal pollution. Moreover, no operational or health hazards are foreseen. Early units, not economically or commercially competitive, have been installed by individuals in residential communities and all regulatory requirements have been met. In the long term, the benefits to society are that it will make man almost independent of fossil fuels, thus conserving a vital resource.

SECTION 3 - SOLAR THERMAL CONVERSION

I. SUBPROGRAM SUMMARY

A. Introduction

1. Solar Thermal Conversion (STC) systems collect solar radiation and convert it to thermal energy and electric power. The heat is transferred to a working fluid for use in a solar thermal electric conversion system or, in a solar total energy system, for delivering both electrical and thermal energy.

2. The objective of the Solar Thermal Sub-Program is to provide the full system capability for the widespread production of supplementary electric energy in the late 1980's and with the potential for meeting baseload electric energy requirements for electric utilities, and providing total energy systems for military and other installations. In order to meet the baseload power plant and total energy system requirements, storage technology must be developed. There are no fundamental technical limitations that would prevent substantial application of solar thermal conversion systems. The primary questions concerning application have stemmed from energy costs as compared to those for conventional fossil fuel or nuclear sources. Cost estimates to date for solar thermal systems have been very preliminary and have generally estimated the costs of solar thermal systems for baseload application (including energy storage). Recent cost estimates for STC systems for plants operating in a load following mode (intermediate and peaking power) indicate that

energy costs in the 1980 time period will be competitive with fossil fuel sources particularly in the southwestern U. S. In addition, cost projections for solar total energy systems operating in the 1980s also appear to be competitive with conventional energy sources.

B. R&D Programs

1a. Accelerated/Orderly Program. The 5 year scope of the proposed Accelerated/Orderly program in solar thermal conversion includes:

i. A Central Receiver, Load Following Power Plant Project including design, fabrication and testing of a 10 Mwe pilot plant, and design, fabrication and assembly of equipment for a 100 Mwe demonstration plant.

ii. A Solar Total Energy System for Community or Military Base Applications including design, fabrication and testing of 200 Kwe, 2 Mwth (delivered) pilot plant and design fabrication and assembly of equipment for a 10 Mwe, 200 Mwth (delivered) demonstration plant.

iii. A Distributed Collector, Load Following Power Plant Project including design, fabrication, and testing of a 10 Mwe pilot plant.

iv. A Solar Total Energy System for an Industrial Load Center including design, fabrication, and testing of a 200 Kwe, 2 Mwth (delivered) pilot plant and design, fabrication, and assembly of equipment for a 5 Mwe, 50 Mwth (delivered) demonstration plant.

v. An Advanced Research and Technology sub-program element which will address: a) critical technology problems stemming from each project, b) environmental and technology assessment issues, c) solar insolation measurement requirements and development of new instrumentation and d) advanced energy storage subsystem research and development problems.

1b. Minimum Viable Program. The 5 year scope of the Minimum Viable Program on Solar Thermal Conversion includes:

i. A Central Receiver, Load Following Power Plant Project as proposed in the Accelerated program but pilot and demonstration plant schedules delayed 1 year.

ii. A Solar Total Energy System for Community or Military Base Application as proposed in the Accelerated program but pilot and demonstration plant schedules delayed six months.

iii. A Distributed Collector Research and Development effort through bench model testing as proposed only.

iv. This option completely eliminated.

v. An Advanced Research and Technology (ART) sub-program element which will address the same issues as proposed in the Accelerated program; however, funding for the ART is lower by approximately a factor of two.

2. The Mimimum Viable Program stretches the scheduled operation of the pilot and demonstration plants for each system by 6 months to a year, eliminates one of the electrical load following pilot

plants, and eliminates a potentially important solar total energy option. In addition, greater risks must be accepted during the R&D program due to the reduction of the ART program by a factor of 2. The summary budget comparison of the two options is:

	Fiscal Year (Millions of $)							
	75	76	77	78	79	Total 75-79	Runout to Completion	Total
Program Alternative								
Accelerated Orderly	33.1	51.1	57.0	60.0	74.0	275.2	84.0	359.2
Minimum Viable	15.8	16.8	31.5	43.0	38.0	145.1	113.0	239.1

C. Implementation

1. It is projected that solar thermal electric conversion and solar total energy systems could deliver 40,000 Mwe and 8,000 Mwth by the year 2000. Ultimately solar thermal conversion systems could be expected to supply 30% of the Nation's electrical energy, and 50% of the Nation's energy for residential, commercial, and industrial needs.

2. Earliest commercial application of solar thermal conversion systems is expected to be in the 1983-1988 time frame. Growth of the application is projected to be 40,000 Mwe by the year 2000 and 8,000 Mwth annually for the succeeding 25 years.

3. The major barrier to implementation is expected to be the high capital investment presently projected for solar thermal conversion systems.

II. STATUS OF THE TECHNOLOGY

A. Present Status

The utilization of solar energy for electrical power production by thermal conversion processes is essentially nonexistent. Solar furnaces and other collector configurations built in this country and abroad, have achieved temperatures necessary for power generation; however, these programs have been limited to power production in the Kwe range. The thermal conversion technology is generally consistent with present power plant operating regimes. Total energy concepts using fossil fuels have been demonstrated in over 500 installations. The use of solar energy as the energy source necessitates a re-examination of each subsystem and component to maximize thermal energy efficiency.

B. Barriers to Implementation

There are no fundamental technical barriers requiring basic research. A multiplicity of system concepts must be studied and several systems must be tested to verify overall performance and economics. A major factor limiting performance is the low power plant capacity factor attendant with utilization unless thermal storage is provided.

C. Ongoing R&D Efforts to Overcome Barriers

1. The present R&D efforts on solar thermal electric power plants are being conducted at three levels. The major mission level effort is to define the function and scale of solar thermal power plants. System level efforts include technical and economic parametric studies of a variety of solar thermal conversion concepts, and system point-designs involving parabolic trough collection and central receivers. Subsystem and component R&D activities include development of scale model collectors and high efficiency solar absorption coatings. NSF funding for FY 1973 was \$1.4M and \$2.5M is projected for FY 1974. NASA funding for 1973-74 is \$.2M.

   The solar total energy concept is being examined in house at AEC and DOD laboratories and under DOD contracts.

2. Some of the foreign efforts directly applicable to solar thermal conversion include:

   USSR - analysis, design and testing of central receiver systems and components.

   France - a one Mwth solar furnace is in operation, with elements common with the central receiver solar thermal system.

   Israel - specialized solar thermal power system operating in the Kwe range have been built and operated.

Italy - a solar thermal central receiver/boiler in the 100 Kwth range has been built and operated.

III. RATIONALE FOR FEDERAL INVOLVEMENT

A. Federal involvement is necessary in order to stimulate research and development of solar thermal systems on a timely basis. History has shown that complex systems involving many disciplines require federal sponsorship of R&D until the economics are proven. The federal government, through tax structure, regulation, and a variety of incentives and disincentives is already involved in all other means for electric power generation. There is a rapidly expanding market for electric power and total energy systems. Federal action can help determine the mix of electric power generation and total energy methods which will be utilized to meet future energy needs.

B. Government actions such as enforcement of EPA standards, elimination of depletion allowance on fossil fuels, and decreasing subsidies for nuclear energy could be as effective in stimulating R&D on solar thermal conversion systems in the private sector as direct subsidy.

C. The industry has tended to respond to fuel price changes over the long term. Thus, natural gas and fuel oils have displaced coal. The scarcity of gas and petroleum suggests coal will make a comeback in central power plant and industrial applications. Present projections indicate that fossil fuel costs may double within the next ten years. Doubling the price of fuel increases production costs by up to 33% and the cost to the consumer by approximately 10%.

Solar thermal systems must have projected costs competitive with these production costs to attract industry. In the residential sector, price increases in these fuels are reflected more directly to the consumer. Total solar energy systems will have a more favorable economic position.

D. It is not yet clear what additional government actions are required to support the R&D program. The Federal Power Commission should issue recommended accounting standards and review their regulatory requirements for the utility industry. The Environmental Protection Agency should perform land-use tradeoffs including assessment of the environmental impact of solar energy utilization.

IV. CRITERIA AND PRIORITIES

A. <u>The Major Criteria for Setting Project Priorities Are:</u>

1. Projects which are expected to result in cost competitive solar thermal systems in the mid 1980's with projected production costs of 25-45 mils/Kwhr for electrical systems and delivered costs of $2-3 per million BTU for total energy systems.

2. Projects which can provide the basis for systems which in wide scale utilization could provide up to 30% of the total electrical energy requirements and 50% of the thermal energy requirements of the Nation.

3. Projects which are oriented toward reducing fossil fuel (natural gas and fuel oil) consumption; specifically intermediate and peaking electrical power plants and systems which can provide both electrical and thermal energy.

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4. Projects which cover a broad range of collection/conversion approaches (with collector temperatures from 400° to 1000°F).

B. General Strategic Considerations

1a. Timing:

The accelerated program is believed to be extremely urgent and an aggressive program has been laid out to demonstrate competititve solar thermal conversion systems by 1985. Since no fundamental technical limitations exist for solar thermal systems, it is necessary that demonstration plants be constructed within the next 5-7 years in order to assess the economics of these plants.

1b. The rationale for the accelerated program is:

i. Two Solar Thermal Conversion options should be carried at least through pilot plant operation for the electrical power plant applications, one based on optical transmission/central receiver (expected temperature 1000°F), and the second based on distributed collection/thermal transmission (expected temperature 600°F).

Although either or both of these options may prove to be economically competitive in electrical load following applications, only a single 100 Mwe demonstration plant is proposed within this program.

ii. Two solar total energy options should be carried through demonstration plants, the first oriented toward a military base or community total energy requirement, the second toward an industrial application requiring process heat and relatively low electrical energy requirements.

iii. An advanced Research and Technology program is necessary to address technical problems which develop during the project efforts and begin research and development of second generation subsystems particularly energy storage.

1c. The rationale for the minimum viable program:

The minimum viable program includes the same projects as the accelerated program with the exception of the total energy system for the industrial user. In addition, the projects are stretched out and both the Distributed Collection and the Advanced Research and Technology subprograms are reduced in scope and funding. The industrial total energy system was eliminated to reduce cost. If viability is demonstrated for solar energy utilization, the private sector is likely to support this concept.

2. Application of Criteria

Priority listing of program elements are as follows:

a. Central Receiver Load Following Power Plant Project

b. Solar Total Energy System for Community or Military Base Application

c. Distributed Collector Load Following Power Plant Project

d. Advanced Research and Technology Subprogram

e. Solar Total Energy System for an Industrial Load Center

V. ALTERNATIVE R&D PROGRAMS

Both the accelerated and a minimum viable program are presented and discussed below:

A. Schedules and Milestones

1. Milestones:

Milestones and power levels of pilot plants and demonstration plants are presented Fig. 8, 10 for the two program alternatives. Bench model and pilot plant decisions will be made primarily by government agencies. However, it is anticipated that private industry, particularly the utilities, will participate in the decision to proceed with the Demonstration Plant. Some joint Government/private sector funding is anticipated for Demonstration Plant development.

2. Parallel Programs:

The Accelerated program has two electrical generation system and two total energy system options conducted in parallel. The electrical systems differ in collection temperature and consequently in system hardware requirements. The total energy concepts differ in the ratio of electric to thermal load requirements and also in application targets. Consequently, they also have different system hardware requirements. These options will all be carried through the pilot plant stage in order to compare their relative economic potentials. In the Minimum Viable Program the two electric power plant options have been maintained but only a single pilot and demonstration plant will be developed within the

FIGURE 7

PROGRAM BUDGET SUMMARY

Solar Thermal Conversion Subprogram

ACCELERATED ALTERNATIVE

FEDERAL OBLIGATIONS
(Millions of $)

PROGRAM ELEMENT	1975	1976	1977	1978	1979	1980-1989	1990-1
1. Central Receiver Powerplant Project							
Component Testing	2.7	1.7	2.0	2.0	2.0	4.0 thru 1981	
Bench Model (300 KWe)	2.5	3.5					
Pilot Plant (10 MWe)	2.0	7.0	4.0	1.0			
Demonstration Plant (100 MWe)			8.0	9.0	18.0	26.0 thru 1983	
2. Solar Total Energy (Community/Military)							
Component Testing	3.7	2.3	2.0	2.0	2.0	4.0 thru 1981	
Bench Model	1.0	1.3					
Pilot Plant (200 KWe), 2 Mwth)		1.0	2.0	1.0			
Demonstration Plant (10 MWe, 200 Mwth)			8.0	13.0	28.0	22.0 thru 1983	
3. Distributed Collector Powerplant Project							
Component Testing	4.5	2.7					
Bench Model (400 KWe)	1.0	4.0					
Pilot Plant (10 MWe)		13.0	15.0	7.0			
4. Solar Total Energy (Industrial)							
Component Testing	3.7	2.3	2.0	2.0	2.0	2.0 thru 1981	
Bench Model	1.0	1.3					
Pilot Plant (200 KWe, 2 Mwth)		1.0	2.0	1.0			
Demonstration Plant (5 MWe, 50 Mwth)			5.0	13.0	13.0	8.0 thru 1982	
5. Advanced Research and Technology	9.0	10.0	9.0	9.0	9.0	18.0 thru 1981	
TOTALS	31.1	51.1	59.0	60.0	74.0	84.0	

Figure 8

PROGRAM FLOW CHART

SOLAR THERMAL CONVERSION SUBPROGRAM

ACCELERATED/ORDERLY

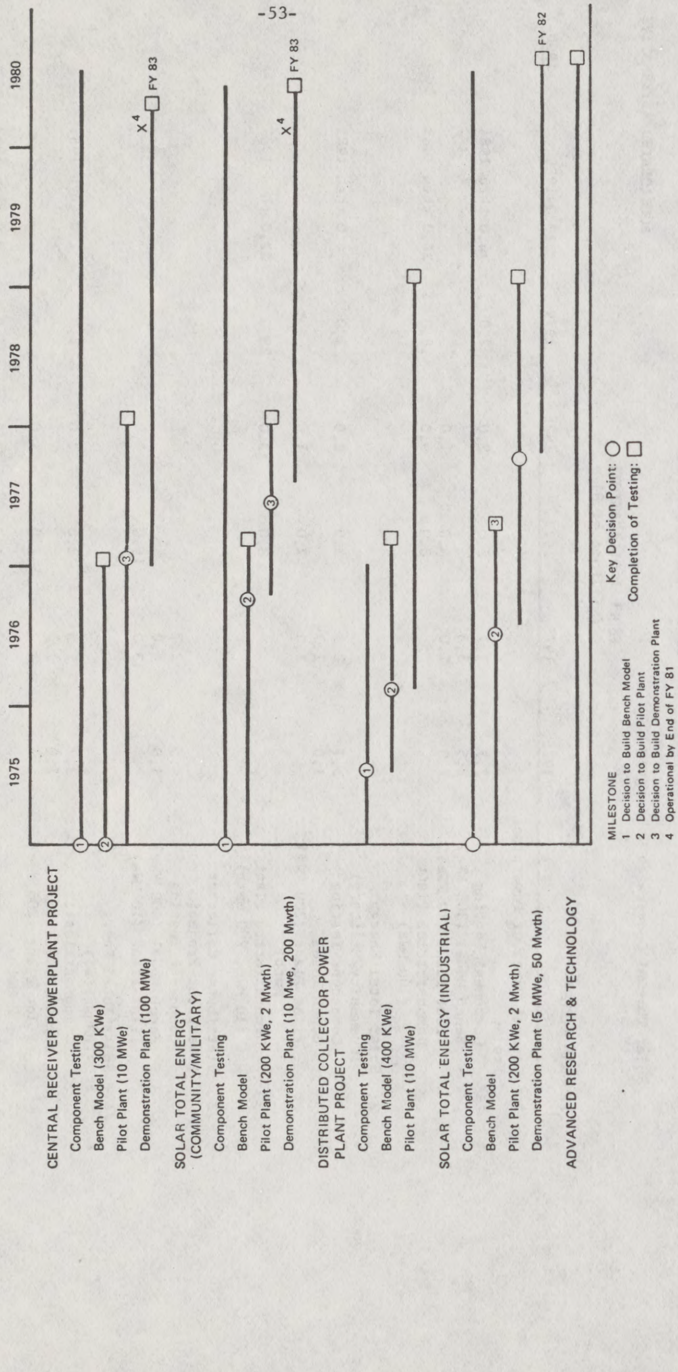


FIGURE 9

PROGRAM BUDGET SUMMARY

Solar Thermal Conversion Subprogram — Minimum Viable Alternative

FEDERAL OBLIGATIONS
(Millions of $)

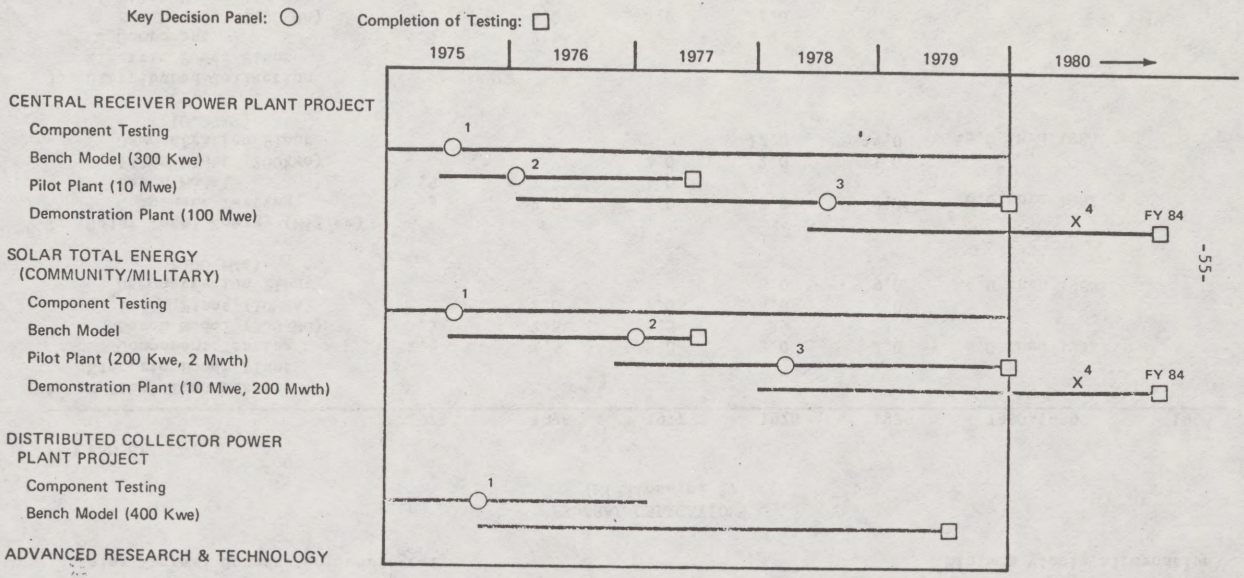
PROGRAM ELEMENT	1975	1976	1977	1978	1979	1980-1989	1990-1
1. Optical Transmission Electric Power Plant							
Component Testing	2.5	1.5	2.0	2.0	2.0	6.0 thru 1982	
Bench Model (300KWe)	.5	2.5	3.5				
Pilot Plant (10MWe)		2.0	7.0	4.0	1.0		
*Demonstration Plant (100 MWe)				8.0	9.0	44.0 thru 1984	
2. Solar Total Energy (Mil/cm)							
Component Testing	3.5	2.0	2.0	2.0	2.0	6.0 thru 1982	
Bench Model	.5	1.3	1.0				
Pilot Plant (200KWe)			2.0	2.0	1.0		
Demonstration Plant (10-20MW)				12.0	14.0	45.0 thru 1984	
3. Distributed Collection Electric Power Plant							
Component	4.3	2.5					
Bench Model (400KWe)	.5	1.0	4.0	1.0			
Pilot Plant (5Mwe)			6.0	8.0	5.0		
4. A.R.T.	4.0	4.0	4.0	4.0	4.0	12.0 thru 1982	
TOTALS	15.8	16.8	31.5	43.0	38.0	113.0	

*One demonstration plant is planned for either option 1 or option 3.

Figure 10

PROGRAM FLOW CHART

SOLAR THERMAL CONVERSION SUBPROGRAM
MINIMUM VIABLE OPTION



MILESTONE
1 Decision to Build Bench Model
2 Decision to Build Pilot Plant
3 Decision to Build Demonstration Plant
4 Operational by End of FY 82

scope of this program. One of the total energy options, i.e., the industrial load center application has been deleted.

2. Likelihood of Success:

It is anticipated that all milestones will be reached successfully. The consequence of failure is the loss of money spent to that milestone in the project.

B. Cost and Budget Projectsions

1. Projected Total Cost:

Costs to meet each milestone starting from FY 75 are summarized below:

Cumulative Cost to Decision Point (Millions of $)

Program Element	Bench Model		Pilot Plant		Demonstration Plant	
	Accelerated	Min.	Accelerated	Min.	Accelerated	Min.
Central Receiver	10.4	12.5	28.4	30.5	95.4	97.5
Solar Total Energy (C/M)	8.3	10.3	16.3	19.3	93.3	96.3
Distributed Collector	12.2	13.3	47.2	32.3	00.0	00.0
Solar Total Energy (IND)	8.3	00.0	16.3	00.0	61.3	00.0

2. The budget presented herein assumes that the federal government will finance the entire program as proposed. However, private sector financial participation in the Demonstration Plant development is likely; possible up to 25% to 50% of the costs. There is the potential of the Electric Power Research Institute sharing in the Demonstration Power Plant sponsorship and an

interest has already been expressed by an electric utility to participate in the total energy demonstration plants.

Private industry will be involved in the development of system components and Demonstration Plant efforts will be predominantly contracted to industry.

3. Federal outlays required in FY 75 through FY 79 for both the Accelerated and Minimum Viable Programs are presented in Figs. 7 and 9.

4. The major uncertainty in funding levels are associated with the power level and cost of the pilot and demonstration plants. If it is determined that smaller plants would provide meaningful technical and economic data these costs could be substantially reduced.

C. Other Requirements

1. Manpower Needs:

It is estimated that the total manpower needs of the Accelerated program in the years FY 75-79 are 7000 manyears. The manpower needs for the Minimum Viable Program effort for the years FY 75-79 are 3400 manyears.

2. Facilities:

No new facilities are required for either the Accelerated or Minimum Viable Programs assuming the work will be conducted at existing government facilities.

D. Management Plan

The management plan will coordinate federal government, private industry, and academic research efforts with the intent of transferring the design and development effort to industry at the earliest possible time. National laboratories will be utilized to manage, at a Field Center Level, the individual elements of the subprogram. These laboratories will conduct research and manage specific projects based on detailed Program Development Plans. Coordination and involvement of the three major research groups mentioned above is already underway. It is planned that, as demonstration and development projects mature, private and public utilities will assume an increasing share of the fiscal and management responsibilities.

E. Alternatives and Criteria

1a. The major alternative system which has been considered, but not proposed, is the utilization of solar thermal conversion systems for base electrical power. This application is not projected to be cost competitive with other base plant sources in the 1980s. Some other alternative projects will be assessed within the Advanced Research and Technology subprogram including a) Solar Augmentation for Geothermal Power Plants, b) an integrated solar energy system utilizing integral photovoltaic converters for electric energy and thermal collection for space conditioning, c) utilization of solar thermal energy in a solar chemical reactor, and d) projected high temperature uses of the optical transmission/central collector concept including production of synthetic fuels from coal. These projects will include analysis and limited laboratory experimentation only during the period of FY 1975 through 1979.

2a. Criteria

The major criteria which have been employed in defining the accelerated program are:

i. Develop solar thermal conversion electrical generation systems for load following (intermediate and peaking power) applications with system projected generation costs of 25-45 mils/kwhr in the mid 1980's.

ii. Develop total solar energy systems for community, military base or industrial applications with system projected energy costs of $2-3 per million BTU in the mid 1980's.

iii. Develop systems which, in widespread application, could provide up to 30% of the total electrical energy requirements and 50% of the thermal energy requirements of the Nation.

iv. Develop systems which are oriented toward reducing fossil fuel (natural gas and fuel oil) consumption.

v. Propose a set of options which cover a broad range of collection/conversion approaches with collector temperatures from 400°F to 1000°F.

3. Dependence of Other R&D to Progress in This Technology

The successful implementation of the solar thermal conversion technology is not dependent on any research or development effort not included with the development program. However, the work underway in solar heating and cooling of buildings is applicable to the solar total energy concepts.

No other R&D efforts depend on the success of this R&D program.

4. Acceptability of R&D Program

The only known environmental problem associated with the program is the waste heat disposal problem common to all thermal power plants.

Public acceptance is anticipated for all four concepts. Each of the concepts lends itself to operation as a utility thereby shifting the higher initial cost from the consumer. Environmental impact statements will be required prior to construction of Pilot and Demonstration Plants for each of the program elements.

VI. IMPLEMENTATION OF PLAN

A. Direct Benefits of Implementation

1. Implementation will stimulate several industries. Among these are:

a. glass or plastic sheets (for reflectors)

b. aluminum and silver coating (for reflectors)

c. heat pipes (potentially for heat transmission)

2. Solar Thermal Conversion has the potential for capturing up to 30% of the electrical capacity and up to 50% of the residential/commercial space conditioning market.

3. As solar thermal succeeds in penetrating the energy market, the dependence on foreign energy resources--oil and gas--is reduced. These resources now become available to satisfy transportation and petrochemical requirements.

4. Reliability and security of a solar thermal system is comparable to that of fossil fuel and nuclear plants.

5. Solar thermal conversion to electricity decreases the dependence of the national energy system on fossil and nuclear fuels. This dependence is further decreased by solar thermal total energy systems which would provide space conditioning of residential and commercial buildings.

B. <u>Economics of Implementation</u>

1. It is projected that Solar Thermal Conversion systems will produce electricity in the southwestern United States for 25-45 mils/Kwhr. Slightly higher costs will be expected in the southeastern United States.

2. Costs:

a. The cost estimate presented above is based on the following capital cost estimates for solar thermal conversion system.

Collector & Receiver	\$250 - 350/Kwe
Boiler-Turbine-Generator	\$100 - 150/Kwe
High Temperature Storage (3 hour capacity)	\$100 - 300/Kwe
Total Capital Cost	\$450 - 800/Kwe[1]

Although operating and maintenance (O&M) cost estimates are not available, it appears realistic that O&M cost of 2 to 3 mills/Kwh can be achieved.[2] The projected useful life of the system is 25 years and a cost of capital equal to 15 percent was used to obtain energy cost estimates. There are no significant energy (fuel) inputs required to operate the system. As such, it will compete against alternative means of generating peak and intermediate electric power, e.g., gas turbines, diesel, or fuel oil plants. The cost of generating conventional peak power is estimated to be 25 mills/Kwh for 1975 and 30 mills/Kwh by 1985.[3]

b. The total solar energy system is used to provide industry, electricity, heating, cooling, and domestic hot water.

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1 These estimates do not include R&D costs.
2 This cost is approximately twice that required for conventional systems.
3. Based upon estimate of 40 percent increase in 1970 oil prices and a 100 percent increase by 1985.

As a result, it is difficult to calculate a single cost for energy delivered by the system. The equivalent delivered energy cost is estimated to be $2 to 3/M BTU. Specific analyses have indicated that systems designed for 20 - 2000 housing unit subdivisions can be competitive with conventional energy systems by the late 1980s, assuming collector costs of $4/sq. ft. and a capitalization rate of 8%. Economic viability at higher capitalization rates is feasible if collector costs can be reduced. The system evaluated provided 67% of the communities energy demand for a capital cost of $65,000 for 20 houses or an additional cost of $1000 to $1500 per residence over conventional systems. Operating costs of .5 mils/Kwh were assumed.

Similar analyses conducted for military installations indicate even better relative economics. One study indicates that collector costs of $6 - 8/sq. ft. are acceptable for military installations assuming a 6-1/2% capitalization factor. These systems are also expected to provide approximately 60% of the total energy needs of these installations.

c. There appear to be no significant labor problems. Construction of the system is well within the capabilities of the construction industry and all system components except for collectors, have been built. Labor requirements for operating the system will be similar to that of existing power plants. Some training will be required, but no serious problems are anticipated.

4. It is impossible to estimate the impact which the export of solar-thermal technology and capital goods will have on the balance of payments. Several European countries, Russia, France, and Italy are interested in solar-thermal systems and have initiated R&D efforts. The impact on the balance of payments of a successful R&D program in the United States will, of course, depend upon the success of R&D efforts conducted in other countries. In light of their expressed interest, a potential market does exist in Europe. In terms of imports, the system has the potential of reducing oil imports by 431 thousand barrels/day or $944 million/year in 2000 if the price of imported oil is $6 per barrel, commercial operation begins in 1988[4] and industry's production capability grows at a rate of 20 percent per year.[5]

5. It was assumed that:

   a. Necessary labor and natural resources (e.g., land, glass, silver, or aluminum) would be available, and

4. Commercial operation begins in 1988 if the minimum plan is funded. The accelerated plan will result in commercial operation by 1983.
5. First year production capacity is two 500 Mwe plants.

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b. The real price of these commodities would not change significantly from today's prices.

6. Incentive:

Although economic viability is the objective of the R&D program, there are several incentives which the federal government might institute to stimulate the use of the system:

a. Permit the use of federal lands for power plant siting for the solar system.

b. Permit faster depreciation, or special tax credits.

c. Alter taxation or allowances on other fuel sources which will allow a free market price on these sources.

C. Impacts of Implementation

1a. Natural resources required:

Resources required for solar thermal conversion plants are approximately equivalent to a conventional fossil fuel plant with the exception of the solar collection subsystem. Specific resources required for solar collection are estimated as follows:

a. Approximately six months output of one float-glass line per 100 Mwe capacity.

b. Approximately .5-1 million cubic yards of concrete per 100 Mwe capacity.

c. Approximately 50 tons of aluminum per 100 Mwe capacity.

d. Approximately 20,000 tons of re-enforcement bars (steel) per 100 Mwe capacity.

1b. These materilas are not considered to be in short supply.

1c. Float glass is the modern approach to the manufacture of flat glass inexpensively. Currently, this method of manufacture is spreading because of its favorable economics. It is doubtful if a solar system would find serious competition for the output of this industrial process.

The other materials requirements are sufficiently modest as not to constitute serious competition for resources.

1d. Not considered to be applicable.

2. Energy inputs required:

a. Capital equipment costs have been estimated to be from \$450 - 800/Kwe of installed capacity for a load following electrical system and capital and operating costs with equivalent fuel costs of \$2-3/M BTU for total energy system.

b. Operation will not require outside energy sources except possibly for startup and shutdown and to accommodate thermal transients. This energy is expected to be minimal and will be drawn from the system into which the solar plant is integrated. For total energy systems, a fossil fuel backup system will be required and it will require 30 - 40% of the fuel required for a nonsolar augmented total energy system.

3. It appears that solar thermal conversion power plants will be compatible with an existing national energy system. The solar energy system should be capable of supplying electricity to the national energy system and will be designed to be capable of sustaining transients in its proposed mode for load following.

4. It is anticipated that an environmental impacts statement will be filed. Solar thermal conversion concepts require a substantial amount of earth moving for construction, and when built, shadow a substantial fraction of the land. Moreover, like any other power station, waste heat must be rejected.

5. Occupational Health and Safety - no major problem anticipated.

6. Other Factors:

    a. Unlike nuclear of fossil fueled electric power generation stations, there appears to be little or no economic advantage of large scale for solar thermal conversion systems. Thus, the potential for neighborhood solar electric or total energy stations is large. The proximity to be the neighborhood user may be significant since the cost of transmission of energy is minimized. Overall utility land use planning and neighborhood planning should be integrated.

b. The use of solar energy reduces overall pollution problems but may introduce other problems by proximity to the user. Solar-electric systems will require waste heat disposal to air or water. The appearance of the equipment, the water spray, in the event of a cooling tower, or the heated air man not be entirely acceptable. Central stations avoid or localize these potential problems. A total energy system would normally consume more of the energy and not necessitate large waste heat rejection.

c. Long term impact of solar thermal electric or total energy systems will require a reivew of land use practices to utilize small neighborhood units more effectively.

d. In central station application, solar thermal systems may necessitate greater margin requirements than conventional systems due to statistical variations of solar energy.

SECTION 4 - WIND ENERGY CONVERSION

I. SUBPROGRAM SUMMARY

A. Introduction

1. The research area is concerned with practical extraction of energy from the wind, primarily directed toward the generation of electricity on a large scale. The research area includes efforts on cost reduction of subsystems and components, research and data collection on wind characteristics, user requirements, legal, environmental, institutional and aesthetic issues, optimization of design concepts, and the testing of a series of systems of increasing size and performance.

2. The objective of the Wind Energy Conversion Program is to develop reliable and cost competitive wind energy conversion systems capable of rapid commercial expansion for appropriate regions to produce significant quantities of supplemental electrical power by the early 1980's with the potential for meeting base load electrical power requirements.

A characteristic of Wind Systems is that the cost of the energy produced is a function of site wind characteristics as well as the technological capability. Thus, a characteristic of the program is that there is no question of success versus failure per se, but rather an increasing competitiveness over wider regions as system performance is increased. Therefore, the basic problem being addressed is to reduce the cost of wind energy systems and to verify and demonstrate that reduction.

B. R&D Programs

1. Description:

a. The specific goal of the Accelerated/Orderly Program is, by 1979, to have in operation cost effective systems in the 10 MWe range, along with completed preliminary design and component development to allow the operation of 100 MWe or larger systems by 1981. The program contains four program elements: 1) the Program Development and Technology element includes system and user requirement studies, supporting and advanced research and development on components and sub-systems, micro and macro scale wind and site characterization and research on legal, environmental, aesthetic and applications issues; 2) the Small Scale Systems Element will develop and test a 100 KWe wind-generator in FY 75 to provide the initial experimental cost and performance information, to be followed by similar sized units for diverse site conditions and special applications; 3) the MWe Scale Systems Element will develop and test larger wind-generators (1 to 2 MWe size) to provide cost and performance information at a scale appropriate for eventual commercial use to be followed by operation of similar sized units for diverse site conditions, higher performance and special applications; and 4) the Large

Multi-unit Scale Element will develop and demonstrate two economically viable 10 MWe systems of large wind-generators and complete the preliminary design of a 100 MWe system of large wind-generators.

b. The minimum Viable Program maintains the same sub-element structure, with a stretched schedule, a smaller supporting research element examining fewer component and subsystem alternatives and fewer test units. The specific goal for FY 79 is to have in test one 5-10 MWe multi-unit test system.

c. A crash program has been considered but at the present time, insufficient recent experimental data and analyses exist to allow speed up to the accelerated program in FY 75-77. Upon completion of the initial tests of the first MWe scale unit and based upon its performance, a considerable speed-up could be obtained at an expenditure of additional funds. At some risk, the 100 MW scale demonstrations could be moved up from FY 81 to FY 79; the merits of this option can be examined in FY 77.

2. Schedule and Budget:

	Accelerated	Minimum Viable
1) First 100 KWe Test	FY 75	FY 75
2) First MWe Scale Test	FY 76	FY 77
3) First Multi-unit Test	FY 78	FY 79
4) 2-10 MWe Wind-Generator systems	FY 79	FY 81
5) 100 Mw Viable	FY 81	FY 85-86
6) FY 75 Funding	$8.5M	$3.8M
7) FY 76-79 Funding	$97.7M	$23.1M
8) Runout to Demonstration	$150M	$150M

Cost uncertainty rests on lack of system level experience to determine both configuration dependent initial costs and life-time operating costs and because of presently inadequate wind data and prediction methodology. Additional uncertainty exists in the requirements for storage as a function of application.

C. Implementation

1. The maximum possible energy that can be practically extracted from the wind in the U.S. has not been determined. However, the NSF/NASA Solar Energy Panel has identified areas of the U.S. which could be used to generate 1.5×10^{12} KW-HR/yr or nearly all the electric power presently generated in the U.S. If all these areas were utilized, approximately 18 percent of our estimated power generation of 8×10^{12} KW-HR/yr for the year 2000 could be supplied by wind energy systems. The actual implementation could be considerable larger or smaller than these estimates based on the results of actual performance achieved and detailed wind surveys.

2. Implementation of additional wind-energy systems after successful demonstrations should be relatively straightforward. Rapid expansion following the 1981-82 period can be expected from the accelerated program. The minimum-viable program will result in a slower implementation due to the larger time required to reach demonstration systems.

3. Possible barriers to implementation include:

   a. unknown reaction of utility community due to unusual characteristics of wind-energy systems and limited lifetime proof from early test units

b. unknown public reaction to aesthetics

c. possible "wind rights" legal questions

d. effects on micro and macro climate are expected to be negligible, but the degree of proof required is unknown at this time.

II. STATUS OF THE TECHNOLOGY

A. Present Status

1. In 1910, Denmark was generating 5×10^5 MWe-HR/year from wind systems with a total installed capacity of 200 MWe. From 1930 to 1960, considerable interest existed in Europe (and in the United States in the 1940's) in developing large, more modern, wind-driven, generating systems as a source of electrical power. These systems typically included a multi-bladed wind-turbine, an electrical generator and a control system, mounted on a tower. An energy storage system, usually pumped water or batteries, was sometimes included in the system. The test systems were rated from 100 Kw to 1250 Kw and provided power to both individual users as well as to existing power networks. However, interest in these test systems declined because they were not cost-competitive with fossil fuel plants of that era. These efforts were generally individually entrepreneured and suffered from the lack of a sustained R&D effort. Wind-generator technology has thus been arrested since the mid-1950's, and

little of the technological development of the past two decades has been applied to wind-generator systems.

B. Barriers to Implementation

1. Research Barriers:

There are no barriers to implementation which require basic scientific research.

2. Development Barriers:

a. System configurations must be examined in order to identify those cost sensitive systems which can provide the most cost reduction through R&D and which can provide satisfactory power for existing electric systems.

b. Data must be acquired, and a methodology developed to adequately characterize the wind as an energy source. Temporal, geographic, and altitude related variation of wind velocity and direction are part of the needed characterization.

c. Although the effects of the large scale use of wind systems on micro-climate and on local ecology are expected to be negligible, studies are required to provide adequate assurance that the present expectations are valid.

d. The possible requirements and relative advantages for storage systems for enhancing the value of power produced by wind systems needs to be identified. It is not known if statistically reliable power from multiple generators can minimize storage requirements.

3. Implementation Barriers:

   a. Acceptance by the utility industry will have to be nurtured. The unorthodox nature and unfamiliar aspects of the large scale use of wind systems may result in a hesitant acceptance even if cost effectiveness is demonstrated.

   b. Acceptance by the public is unknown. The aesthetic impact of the large scale use of wind systems is highly subjective and will be influenced by many factors, inlcuding energy supply.

   c. Areas able to accommodate a large number of wind generators and having wind characteristics adequate for the economic production of power must be identified, and the ability to predetermine adequately site wind characteristics must be proven to the satisfaction of the user.

   d. Legal questions associated with wind rights and land use require early identification and assessment.

C. <u>Ongoing R&D Efforts to Overcome Barriers</u>

1. Little effort, private or federal, has been performed in recent years. In FY 73, the NSF funded $200K for two initial supporting research activities. In FY 74, with a level of $1.2 million, NSF commenced the studies and research to support this program. The initial 100 KWe experimental unit is under preliminary design, to be constructed and tested in FY 75 at the NASA/Lewis Research Center. Studies to determine system and user requirements, meterological studies, parametric design analyses and initial research on nontechnical issues are also planned for FY 74.

In foreign countries, development and manufacture of small 1-10 Kw units continue on a modest scale. In the USSR, however, a group of over 100 professionals are working on the development of wind power. Present priority is on 10 Kw remote use applications, but a 400 Kw multi-unit system is in operation and interst in increasing.

2. Through the March '73 US/USSR cooperative agreement, an information exchange on these efforts is expected to be maintained.

III. RATIONALE FOR FEDERAL INVOLVEMENT AND INSTITUTIONAL ARRANGEMENTS FOR IMPLEMENTATION

A. Rationale for Federal Government

Present uncertainties in the ultimate cost effectiveness of large scale systems, coupled with their unusual nature requires federal involvement in the initial R&D program.

Technology and environmental assessments and the identification of viable means of assuring early commercialization requires federal involvement to bring together the various groups required to address these issues.

B. Government Actions Other Than Direct Support

Government purchase of early systems for use at Federal installations, remote sites in national recreation areas as well as the establishment of a federal "loan guarantee or fund" to support initial capital acquisition (to be repaid from operational savings) for selected community or agricultural joint land usage systems would be effective in the early implementation stages.

C. <u>Sensitivity of Industry Attitude</u>

Industy attitude toward wind systems is likely to be insensitive under changing conditions until a demonstrated, cost-effective technological base is demonstrated because of the untraditional nature of these systems. This attitude may change if fuel supply problems become more aggravated and/or pollution or safety related construction delays for conventional power generation systems increase.

D. <u>Other Government Actions Required to Support the R&D Program</u>

Clarification of the "wind rights" issues is needed. No other actions are presently identified.

IV. CRITERIA AND PRIORITIES

A. The criteria used for setting priorities among the wind energy projects are:

1. Structure projects schedules so that significant milestones occur prior to major funding commitment points.
2. Timely identification/elimination of barriers to implementation.
3. Reduce cost uncertainty of program and systems.
4. Maximize probability of obtaining cost goals.

B. Strategy and Application of Criteria

1. General Strategic Considerations:

a. Timing

The schedule of the accelerated program is based on meeting the program objectives. It provides for a significant demonstration so that commercial decisions for implementation can be made in time to contribute to national energy production in the 1980's. A key attribute of wind systems is the exprected short implementation time provided the cost goals are achieved. The minimum viable program accepts a delay of 3-5 years in this implementation.

b. Rationale

The general program rationale is based on the fact that wind energy systems have been proven to be technically feasible, and cost effective in special situations, based on technology which is fifteen to twenty years old. When the techncial advances in solid state electronic devices, control systems, structural dynamics, aerodynamics, materials technology, meteorology, instrumentation, and mathematical systems modeling of the past twenty years are applied to wind energy systems, they should become cost effective in a much broader spectrum of applications. Further advances in the relevant basic technologies mentioned above are not expected to make further dramatic improvements in the potential for wind energy systems. The proposed program will permit a definitive conclusion to be made about the applicability of these systems in a timely manner.

2. Application of Criteria:

Applying the criteria and rationale described above leads to the following priority for the elements of the subprogram.

a. Develop capital, maintenance and operating cost data using present state-of-the art technology by means of early experimental 100 KWe wind-energy systems.

b. Develop the data base and methodology required to characterize the wind as an energy source and to expedite effective site selection.

c. Define system requirements for, and interface problems associated with, wind energy systems.

d. Identify legal, environmental and social issues affecting commercial implementation.

e. Define and verify system characteristics at the single megawatt scale.

f. Define the requirements for and verify the capabilities of multi-wind-generator systems.

V. ALTERNATIVE R&D PROGRAMS

A. Accelerated Program

1. Schedule and Milestones:

a. Milestones

Figure 11 presents the significant milestones, principally the successful operation of systems of increasing size and performance, and includes a significant supporting research element to develop alternate and advanced components to successfully achieve system cost goals. During this five-year program, the public sector will determine continuation of the large scale systems at each major milestone. The private sector will determine commercialization of the small scale systems for special applications. The construction of the 100 MWe demonstration scale system, under possible joint funding, will be in part determined by the private sector. Implementation of additional commercial systems would be expected to be predominantly private sector decisions.

b. Parallel Programs:

The program is primarily a partially overlapping sequential development effort as indicated by Figure 11. Significant parallel efforts are included in component research and conceptual and design study activity.

c. Likelihood of Success:

It is highly likely that all significant milestones will be met, any delays most likely being caused by relatively minor engineering problems. If performance and economic goals are not achieved, the system would still be expected to be viable at favorable remote sites with sufficient winds; complete failure is not considered likely.

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2. Cost and Budget Projections

a. The cost to meet each program element is shown in figure 12 for each year FY '74 through FY '79. The program is estimated to be totally federally funded with a projected cost for FY '75-79 of $\$106 \times 10^6$.

b. Evolution of Public and Private Sector Roles

Federal/private sector cost sharing arrangements will be negotiated during the program in anticipation of the follow-on 100 MW demonstration construction to begin in FY '80.

c. See Fig. 12.

d. Funding level uncertainties are associated with lack of initial experimental results and specific program detail at this time. Funding is based on estimated manpower requirements, estimates of development costs of similar type hardware, and extrapolation from earlier systems. Note that significant milestones leading to a major reduction in funding uncertainty occur before the 10% and 30% points of the planned program obligation curve.

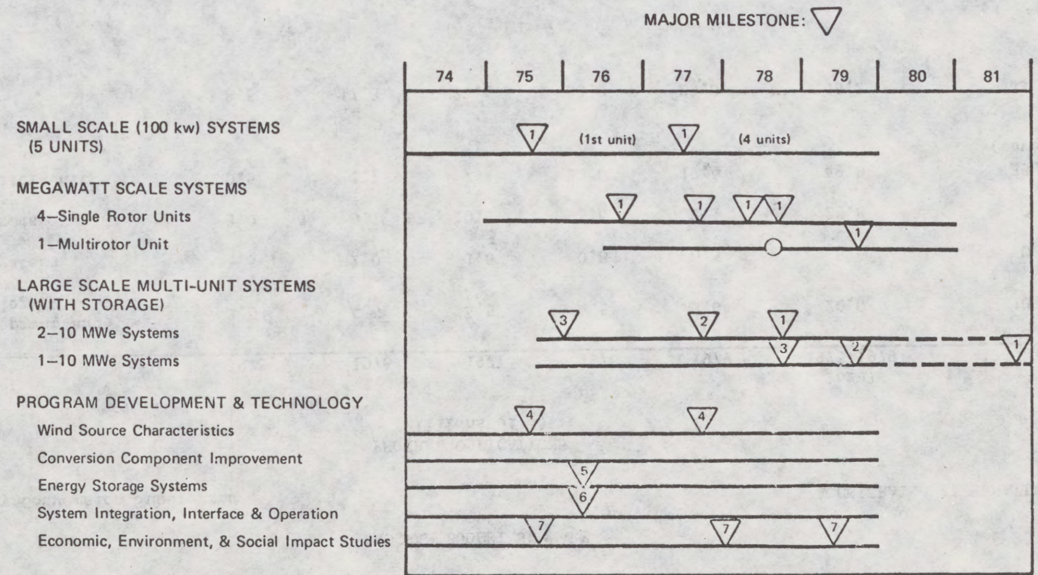
B. <u>Minimum Viable Program</u>

1. Schedule and Milestones:

a. Milestones

Figure 13 presents milestones and estimated size of each of the significant developments. This program alternative slips testing of larger scale units into the 1980's and

Figure 11
PROGRAM FLOW CHART
WIND ENERGY CONVERSION SUBPROGRAM
ACCELERATED ALTERNATIVE



1 Fabrication Completed, Testing Started
2 Detail Desing Complete, Fabrication Started
3 Conceptual Design Complete, Detail Design Started
4 Sites Selected for Megawatt and Large Scale Systems
5 Storage Systems Selected for Large Scale Systems
6 Model of Utility System plus Wind Power Plant System Complete
7 Environmental Impact Statements for Megawatt and Large Scale Systems Complete

FIGURE 12

PROGRAM BUDGET SUMMARY

Wind Energy Conversion Subprogram

ACCELERATED ALTERNATIVE

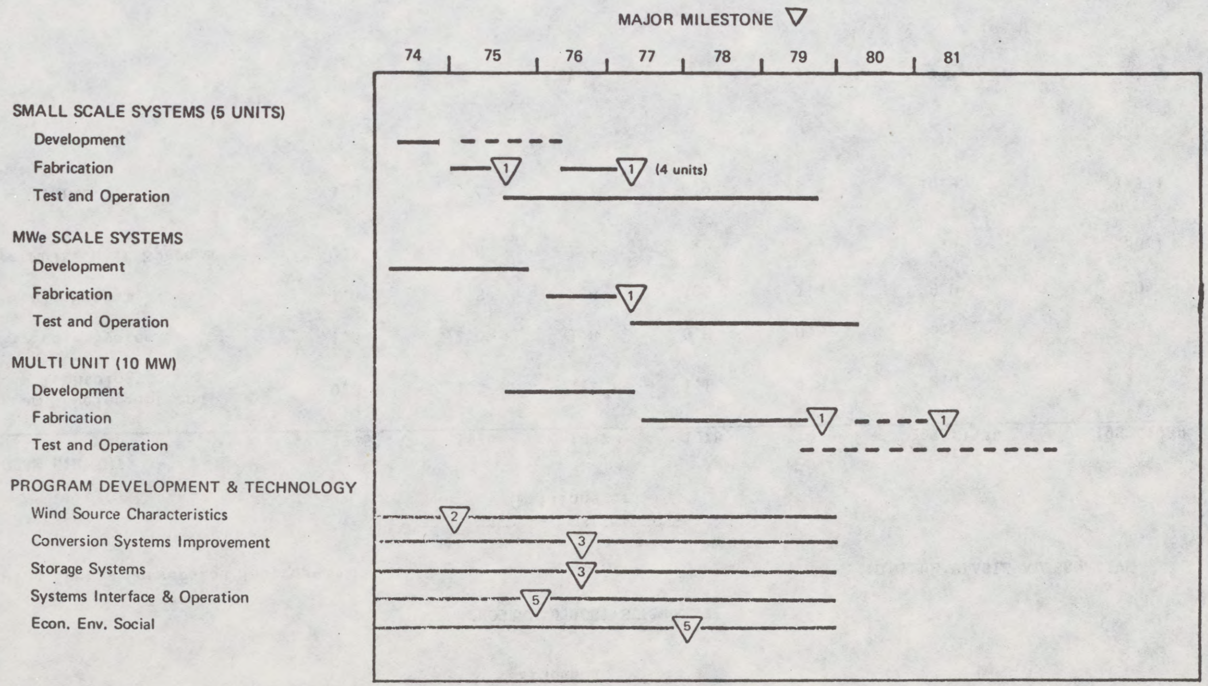
FEDERAL OBLIGATIONS
(Millions of $)

PROGRAM ELEMENT	1975	1976	1977	1978	1979	Total 1975-1979	1980-1989
Program Development and Technology	3.5	4.5	4.5	4.5	3.0	20.0	10
Small Scale Systems	1.5	2.0	1.8	0.8	0.5	6.6	0
MWe Scale Systems	3.0	9.1	10.0	5.6	2.1	29.8	0
Large Scale Multi-Unit	0.5	1.7	7.2	23.0	17.4	49.8	33.8 (thru 1982)
TOTAL	8.5	17.3	23.5	33.9	23.0	106.2	43.8

Figure 13

PROGRAM FLOW CHART

WIND ENERGY CONVERSION SUBPROGRAM
MINIMUM VIABLE OPTION



1 Fab Complete, Testing Start
2 Site Selections and Initial Wind Characterizations
3 Storage System Selection for Multi-Unit System
4 Model of Utiiity Plus Wind Power Systems Complete
5 Environmental Impact Statement for MWe Scale Units and Multi-Unit System

FIGURE 14

PROGRAM BUDGET SUMMARY

Wind Energy Conversion Subprogram

MINIMUM VIABLE ALTERNATIVE

FEDERAL OBLIGATIONS
(Millions of $)

PROGRAM ELEMENT	1975	1976	1977	1978	1979	Total 1975-1979	1980-1989
Program Development and Technology	0.8	1.1	1.2	1.1	0.8	5.0	15
Small Scale System	1.5	2.0	1.8	0.8	0.5	6.6	
MWe Scale System	1.0	1.5	2.6	1.5	1.4	8.0	20
Large Multi-Unit Systems*	0.5	0.8	1.5	3.5	1.0	7.3	88.1
TOTAL	3.8	5.4	7.1	6.9	3.7	26.9	123.1

*10MWe system by 1981 and
100 MWe system by 1986

provides for fewer component and configuration alternatives. Follow-on efforts at the 10 MW and 100 MW scales in 1980-85 would still be required before implementation by industry could be expected. Initial economic performance in FY '79 would be expected to be somewhat lower than the accelerated program due to the smaller SR&T element.

b. Parallel Programs

The program is primarily a sequential development effort. A more limited number of early conceptual study activities and component research is included.

c. Likelihood of Success

It is highly likely that all significant milestones would be met.

2. Cost and Budget Projections:

a. Projected total cost for FY 75-79 is $\$26.9 \times 10^6$, all in federal funds. Total funding including that required in 1980-85 would be expected to equal that of the accelerated program, federal funds being merely deferred to a later date. See Fig. 14.

b. Evolution of Public and Private Sector

A phasing similar to the accelerated program is expected. Significant private sector funding cannot be expected until similar milestones are achieved, here deferred into the follow-on program.

c. See Figure 14.

d. Funding level uncertainties are the same as for the accelerated program, clarification occurring at the same percentage expenditure but later in time.

3. Other Requirements (Both Programs):

a. No unusual manpower needs are anticipated.

b. Currently existing facilities required include wind tunnels for testing models of the wind conversion systems, studies of the interaction between the wind and topographic conditions, as well as laboratory facilities for testing rotors and the drive trains and electrical subsystems.

Minor new facilities will be required for on-site field testing of the various experimental units.

4. Management Plan (Both Programs):

The management plan will coordinate federal government, private industry and academic research efforts with the intent of handing off to industy full development of the subprogram at the earliest possible time. Federal laboratories will be utilized in the first phases to manage, at a Field Center Level, the individual elements of the subprogram. These laboratories will conduct the research, both in-house and out-of-house, and manage projects within the sub-program based on detailed Program Development Plans. Coordination and involvement of the three major research groups mentioned above is already underway. The involvement will be broadened to include representative groups in industry or professional associations as well as the potential user community.

5. Criteria Employed by the Subpanel in Construction of Proposed R&D Program (Both Programs):

Proposals were submitted to this sub-program area from the NSF, EPA, NASA (Lewis), BuMines, and AEC (LLL); in all cases these reflected an equivalent approach to or a subset of the base September '73 plan. Thus, this plan reflects the similar thinking of all interested agencies and represents a systematic development of the resource.

The criteria used in developing the plan, therefore, consisted of:

a. Developing empirical cost, maintenance, and problem identification information early and commensurate with phased program expenditures,
b. Developing systems of increasing technical and economic performance, the interim systems capable of commercial use in special applications, and
c. Developing a program capable of producing a useful system without dependence on offshore installations, advanced storage techniques, or hydrogen production.

While studies and limited subsystems work are included for these latter areas under the SR&T sub-element, major R&D expenditures for these areas in this subprogram were bypassed. This reflects considerations regarding schedule, expected performance and developments on these subjects expected from other programs which could be included as post-program growth capability in the 1980's

6. Dependence of other R&D to Progress in Wind Technology:

   a. Dependency on results of other efforts

      The results of this R&D effort are not dependent on the results of other efforts in the energy R&D program. However, development of practical energy storage systems would make wind energy systems available for additional applications.

   b. Dependency of other R&D on Results of the Program

      No other R&D efforts are known to depend directly on wind power R&D. However, some spinoff results are to be expected such as in predicting the effects of wind on various structures. In addition, other research such as agriculture use of remote areas might be stimulated as a result of this program.

7. Potential Problems of Environment, Safety, or Public Acceptability:

   Potential environmental effects such as meteorological modifications and consequent effects on miniclimate and ecology are expected to be insignificant; however, early research is required and included to verify this. This effort will develop the information and methodology required to write environmental impact statements for the R&D program experiments as well as for operational use.

All presently identified safety issues are amenable to normal engineering treatment and should not lead to problems in the R&D and operational programs. Aesthetic acceptability by the public is a potential problem not amenable to simple treatment. Consequently, public surveys and human factor design considerations are included in the SR&T program element.

VI. IMPLEMENTATION

A. Direct Benefits

1. Identification of sectors involved:

Commercial equipment suppliers and construction contractors would be the producers of the systems for operation by public utilities and in special cases by private industries or individual areas of government; the electircal energy then being distributed through existing networks to the individual consumer in a standard manner.

2. Ultimate market:

The energy available practically from the wind in the appropriate regions of the U.S. was estimated by the NSF/NASA Solar Energy Panel to be 1.5×10^{12} kwhr/yr. It is estimated that the growth of wind energy usage could be made to grow from 3×10^{8} kwhr/yr from a single 100 MWe plant in 1981 to 10^{9} kwhr/yr in 1985, 10^{10} kwhr/yr in 1990 to the above estimate by the turn of the century. However, the actual growth will be determined by several factors; the system costs achieved by this program as compared to the costs of fossil and nuclear fuels and plants and other advanced alternative energy sources, and the social pressures for a cleaner environment and more energy.

3. Foreign dependence:

The technical capability and essentially all materials required for construction are available domestically and in quantities which would not impose significant demand. No fuels are required and thus the system removes that portion of the energy demand provided from foreign dependence.

4. Reliability and Security:

Wind conversion systems will consist of geographically widely distributed multi-unit systems. As such it would be difficult to cripple large segments of the system by sabotage or unusual atmospheric or geological phenomena. The systems are relatively simple rotating machinery and have shown to be reliable devices when designed for the weather conditions to which they will be exposed. Sabotage of individual, relatively unattended units is possible, but of little effect outside of the fractional system loss involved.

5. Efficiency:

The wind conversion systems operate fuel free and thus efficiency per se is not applicable except as affecting costs described below.

B. Economics of Implementation

1. The price of electrical energy from wind conversion systems is dependent on the achieved operating costs, the amortized capital investment, and most importantly, the wind characteristics of the region and specific site. Detailed analyses made in the 1940's from the Smith-Putnam system in Vermont estimated 5-7 mils/kwhr at the site. As discussed under 3 below the technological advances of the past 25 years plus the proposed R&D program are expected to counterbalance inflation and achieve the same order price by 1980. The program milestones, particularly the early experimental units are designed to determine cost information prior to major R&D expenditures.

2. Not applicable.

3. Capital costs for the 1.25 MWe U.S. system of the 1940's approximated $200/KW installed capacity as compared to about $125/KW for hydro or fossil plants of that era. Studies have scaled these data for replication at today's prices to $600 - $800/KWe. Because the wind does not blow continuously, wind-energy systems require higher installed capacity than other plants to generate the equivalent amount of average power per year. It has been calculated that 1940 type wind-generators on reasonable sites would cost $1,200 - 1,800/KW today to produce the same average power as that produced from conventional plants. However, preliminary assessment concludes that the technological developments from 1940 to the present plus this R&D program could lead to costs approximating $300 - $500 per avg. KWe with best performance at the more favorable wind sites.

Operating and maintenance costs, estimated from Smith-Putnam data should approximate 3%-5% per year of the capital costs and decrease with increasing size. Thus, the primary annual costs are the costs of capital.

4. Projected Impact on Labor Market:

   Because the components of wind power systems and the skills needed to fabricate, erect, and maintain them are not much different than those that exist in other commercial fields, serious dislocations in the labor market are not expected.

5. Projected Impacts on International Markets and on Balance of Payments:

   The U.S. balance-of-payment situation would be improved by the decrease in the need to import fuel for power plants. In addition, wind power systems can be export items, particularly to under-developed nations in view of the modest skills necessary for maintenance and operation.

6. Assumptions Underlying the Above Projections:

   a. Since no fuel is required, the only natural resources needed will be those for the equipment such as steel, concrete, fiber glass, copper (as well as the required land), and that the quantities required would not deflect the market price from standard inflation estimates.

   b. It is postulated that the price of electrical energy from other sources will increase modestly.

   c. The amortization of R&D is not added to price. It should be noted that all experimental systems except the first 100 KWe unit will continue in operation producing useable electric power. This return has not been included.

d. The labor costs are assumed to be approximately the same as presently available since no unusual skills will be needed to fabricate, operate, and maintain wind plants. Skills from the aerospace technology and industry will be directly applicable to the development of the resource.

e. Costs of capital will be about the same as present.

f. Date of commercial availability: 1981 (100 MWe system scale).

g. Useful lifetime: 20 years

Maintenance: The wind-generators are to be designed for unattended operation and only minimal maintenance is expected.

h. The output of wind power plants will be electrical energy for which a demand exists and will increase.

i. A potential foreign market exists; Australia currently exports very small units. The size of the market is not known at this time.

7. Possible Incentives:

After test and analysis under federal funding, utility companies or other users may be provided incentives to continue operation of the experimental wind power systems for one to four years to gain experience and acceptance. Similar subsequent systems should be implementable under normal motivation with limited Federal R&D continuing on the possible question of public interest and futher advanced components and subsystems techniques.

C. Impacts of Implementation

1. The natural resources required, in addition to the wind itself, are land and the steel, concrete, fiber glass, copper, aluminum and other construction materials. Initial estimates of the quantities of materials involved do not appear excessive as compared to domestic production or relative to other advanced systems, and in addition are generally substitutable materials.

Approximately one acre of land per MWe is required, thus 10^5 MWe capacity or 1/3 the present U.S. capacity would use 156 square miles. In actuality, considerably more total land would be involved due to spacing requirements; however, intervening land use for agriculture, grazing, or other uses would not be impaired.

Only normal competition for materials from other construction programs would be expected.

Zoning and land-use regulations will affect siting availability. The legal issues of ownership of wind energy, similar to "water rights" are not well defined and require early research and possible Federal action.

2. The energy input required for implementing these systems consists primarily of processing raw materials into the structural materials to be used. While a technology assessment has not yet been performed, this energy is expected to be a small fraction of the energy produced during each systems lifetime.
3. An objective of this program is to be compatible with existing electrical distribution systems. The implementation of this objective requires that the wind power systems operate in a mode which permits direct interfacing with existing power grids or in some applications, the use of a storage subsystem which interfaces with existing power grids.
4. Environmental Impacts of Implementation:

   No significant adverse environmental impacts are expected. While silent, these systems would cause an aesthetic impact, the magnitude of which is presently unknown. While the effect on local weather due to the extraction of energy is expected to be minimal, it is a subject for early research in the SR&T program element. An environmental impact statement would probably be required to address problems typical of a comparable construction project.
5. Occupational Health and Safety Considerations:

   No adverse effects are expected.
6. Other Impacts:
   a. Impacts on future demography and land-use pattern. The simplicity and reliability, i.e., ease or lack of required

maintenance make wind power especially attractive for the development of energy deprived remote areas. Such uses could result in significant impact on agricultural patterns and consequently population densities and distribution in areas which are currently of lower value.

b. Social costs and benefits. No significant social costs are expected. Possible benefits are discussed in a, above, and would in general be commensurate with the benefits associated with any other new source of power.

c. Long term impacts of implementation. See a and b above.

SECTION 5 - BIOCONVERSION TO FUELS

I. SUBPROGRAM SUMMARY

A. Introduction

1. Bioconversion comprises three areas: the conversion of organic wastes to energy, the production and utilization of biomass for energy, and the production of hydrogen by photosynthetic and other photochemical systems.
2. The objectives of the bioconversion program are to assess the available technology for producing and utilizing organic materials for energy, to develop new technology, and to establish the feasibility of the various processes through pilot plant and full-scale demonstration plants. The optimum program would be capable of utilizing organic wastes in the near term and subsequently, biomass to produce synthetic fuels for heat for large scale utilization in lieu of fossil fuels. Ultimately, the program would provide means for the direct production of hydrogen as a significant source of energy.

B. R&D Programs

1. a. The accelerated orderly program will provide by 1980, 1) seven pilot plants of 1 ton/day capacity for converting urban solid wastes, animal wastes, and/or other organic materials to methane or higher hydrocarbons, 2) one demonstration plant of about 100 tons/day capacity for converting solid wastes to a useful fuel, 3) production of

hydrogen by photosynthetic and biophotochemical methods, and 4) development of high yield crops which can be harvested for energy production.

b. In the minimum viable program the number of pilot plants would be reduced from seven to three; the demonstration plant would not be planned until the 1980's and all other accelerated research would be reduced.

c. Crash Program:

Two bioconversion projects lend themselves to crash development because of their advanced status. They are 1) anaerobic conversion through the utilization of fermentation plants, and 2) urban solid waste conversion by pyrolysis and/or incineration. Several, single unit, feedlot fermentation plants for 10,000 head and larger could be initiated in 1975. Each plant would yield approximately 10^5 SCF/day of methane. Similarly, demonstration plants capable of disposing of solid waste from urban communities of 100,000 population could be built in 1975 to process 200 tons/day of solid wastes. These latter plants would be expected to yield approximately 2×10^9 BTU/day in the form of heat, low BTU gas and/or oil.

C. Implementation

1. Readily collectible wastes could provide methane equivalent to about six percent of the present natural gas use, or nearly two percent of present total U.S. energy consumption. Attaining goals in agriculture to produce raw materials might raise contributions to 10 percent of total energy.

2. Time Schedule:

In the accelerated program for bioconversion it is considered that economic and technical feasibility are presently established. Pilot plants would be established during the period 1976-78, and one or more demonstration plants would be established during 1977-78. For biomass production, economic feasibility would be established during 1975-1977, and technical feasibility would be established during 1978-1979. Then pilot plants would be established during 1979-1980 followed by a demonstration plant during the early 1980's. For biophotolysis the goal is to establish economic and technical feasibility. No pilot or demonstration plants are planned before 1985.

In the minimum viable program for bioconversion the pilot plant is planned but would be developed over a 2-year longer period than in the accelerated program. The demonstration plant is not planned until some time after 1978. The biomass program would be carried out at a slower rate with technical feasibility not being completed until 1980. A pilot plant is not scheduled until after 1979 and no demonstration plant is planned. For biophotolysis, the plans for the minimum viable program are to establish economic and technical feasibility by 1980 or later.

3. Few barriers are anticipated because the proposed technology would make better use of our natural resources without readily visible ill effects.

II. STATUS OF TECHNOLOGY

A. Present Status

1. Bioconversion - For use of urban and forest wastes the following projects are underway.

   a. EPA and San Diego County - Pyrolysis plant with a capacity of 100 tons/day producing low BTU gas and/or oil is ready for construction.

   b. EPA and Baltimore County - Pyrolysis plant with a capacity of 1000 tons/day producing low BTU gas is in design phase.

   c. NSF and Dynatech Corporation - Anaerobic digestion pilot plant (economic feasibility and design) to process 1 ton/day resulting in the production of methane.

   d. Bureau of Mines - Chemical reduction pilot plant processing wood chips with a capacity of 1 to 3 tons/day to produce low sulfur oil.

   e. NSF and University of California - Anaerobic digestion of algae is at the economic feasibility stage.

2. Production of Biomass - Feasibility studies are underway.

   a. NSF and Stanford Research Institute - Evaluation of species for production of biomass and economic feasibility is under study.

   b. Naval Undersea Center and Weapons Center - Feasibility studies to use large marine algae as a source of biomass have been initiated. An initial experimental plot of 7-14 acres is planned for 1974.

3. Photosynthetic Production of Hydrogen by Algae.

   NSF and Case Western Reserve University investigations are underway.

B. <u>Barriers to Implementation</u>

1. Research barriers - No research barriers are anticipated for anaerobic, pyrolytic and chemical conversion techniques for the production of biomass. Direct production of hydrogen by algae is in the initial research stage and potential barriers have not yet been identified.

2. Development barriers - No development barriers are anticipated for bioconversion of urban, agricultural or industrial wastes. For the direct production of hydrogen by algae, the work is still in the early stages and potential barriers are unknown.

3. Implementation barriers - No implementation barriers are anticipated for bioconversion or production by biomass. For the biological production of hydrogen, no evaluation can presently be made because research is still in initial stage. Technical problems do exist, however, for biomass production. Availability of land and water may be a limiting factor on the potential level of fuel production by the biological production of hydrogen. The research is in initial stages and implementation barriers are unknown.

C. <u>Ongoing R&D Efforts to Overcome Barriers</u>

1. The present level of funding is approximately $2.2M for all program areas.

2. Availability of results of foreign efforts. R&D efforts are underway in Canada, Australia, and several other foreign countries. Efforts to coordinate these programs are underway.

III. RATIONALE FOR FEDERAL INVOLVEMENT, AND INSTITUTIONAL ARRANGEMENTS FOR IMPLEMENTATION

A. Federal involvement - Private industry will not normally invest substantial sums of capital until the economic and technical feasibility is established. Therefore, federal involvement is warranted during the above stages and perhaps into the commercial stages.

B. Direct and Indirect Government Actions Warranted - Direct involvement is warranted to stimulate effective utilization of wastes for energy production to reduce environmental pollution problems. Tax write-offs and subsidies would offer incentives as commercial implementation begins.

C. Industry sensitivity to change will probably not be involved because the products of bioconversion are currently being used as fuel sources.

D. Other government actions to promote bioconversion could be the enactment of increasingly stringent regulations for the disposal of wastes and the development of a subsidy program for the production of biomass.

IV. CRITERIA AND PRIORITIES

A. <u>Criteria for Setting Priorities</u>

1. Bioconversion - Anaerobic fermentation and pyrolysis of urban and agricultural wastes are reaching the demonstration stage. These technologies should be given first priority. Chemical reduction is at the pilot plant stage and would represent a second priority rating. The biological production of hydrogen is in the initial

stages of investigation. Its possible contribution to a hydrogen economy warrants a continued program at the level indicated.

2. Biomass production - This program is currently selecting species and obtaining information for decisions on ocean fresh water and land production and determining the advantages of each. To meet projected milestones related to the stated goals, this work must be accelerated as shown from 1975 through 1978.

B. Application of Criteria

1. Several strategic considerations - The greatest effort possible is required in the conversion of agricultural and urban wastes to energy forms. The accelerated program will accomplish this goal. The minimal program will increase the time required for implementation of the plan; probably affecting the bioconversion of wastes more than the other subprograms.

2. Development of Priorities

   a. Implement bioconversion of organic wastes.

   b. Develop the technologies required for the implementation of oceanic, inland waterway, and land production of biomass.

   c. Begin pilot type production of biomass.

   d. Expand biomass production to operate a 100 ton/day bioconversion plant to develop full economic feasibility.

   e. Implement commercial production of biomass with the required incentives.

   f. Continue evaluation if the biological production of hydrogen is consistent with the probabilities for the development of a significant hydrogen economy.

V. ALTERNATIVE R&D PROGRAM

A. Accelerated Program

See Fig 15a.

B. Minimum Viable Program

See Fig. 15b.

C. Crash Program

Immediate implementation of available technology.

1. Schedules and Milestones:

Accelerated Program

a. Milestones - Four major milestones are indicated. These are shown as ranges in years to reflect the differences in technological development of the systems involved. Decisions on program direction should be by government agencies in the periods indicated. The estimated size for each plant stage is as follows:

1) Bioconversion

pilot plants 25 tons/day max

demonstration plants 100 tons/days

2) Biomass production

pilot plants - 1 sq. mile

demonstration plant - 100 sq. miles

3) Hydrogen production

none planned

b. Parallel programs will exist in the bioconversion element. Three methods of producing energy from biomass are under investigation as follows.

FIGURE 15a

ACCELERATED ORDERLY PROGRAM
MILESTONES AND AMOUNT OF 5 YEAR PROGRAM FUNDS
REQUIRED TO MEET EACH MILESTONE, $MILLIONS

Milestone	Bioconversion	Biomass Production	Biophotolysis
Economic Feasibility Cost	established	1975-1977 5.0	1980 plus 1.0
Technical Feasibility Cost	established	1978-1979 20.5	1980 plus 11.9
Pilot Plant Cost	1976-1978 25.0	1979-1980 7.0	1985 -
Demonstration Plant Cost	1977-1978 49.0 (thru '79)	1982-1984 4.5	- -

FIGURE 15b

MINIMUM VIABLE PROGRAM
MILESTONES AND AMOUNT OF 5 YEAR PROGRAM
FUNDS REQUIRED TO MEET EACH MILESTONE, $MILLIONS

Milestone	Bioconversion	Biomass Production	Biophotolysis
Economic Feasibility Cost	established -	1975-1977 5.0	1980 plus 1.0
Technical Feasibility Cost	established -	1977- 1980+ 13.0	1980 plus 6.0
Pilot Plant Cost	1976-1980 25.0	1979-plus 3.0	-
Demonstration Plant Not Cost	1978-plus 13.5 (thru '79)	- -	- -

1) Anaerobic digest

2) Pyrolysis combustion

3) chemical reduction

Each has the potential for particular applications. Where they are duplicative, decisions on which system(s) to be contunied will be made at the appropriate milestone.

c. The likelihood of success is nearly 100 percent with one or more of the conversion systems. Success in biomass production is also considered good. However, land and water area available for production and the development of the technology may place limits on the quantities available. Large scale hydrogen production by biophotolysis is long range and uncertain.

Minimum Viable Program

The milestones remain the same, but more time will be required to reach them. Pilot plants and demonstration plants will be reduced in number and size.

2. Cost and Budget Projections to Meet Each Milestone:

a. See Fig. 16 for the Accelerated Orderly Program and Fig. 17 for the Minimum Viable Program.

b. Development costs through the pilot plant stage are to be borne by the Federal Government. Demonstration plant development costs should be shared by the Federal Government and the private sector. With demonstration of the economic viability, no direct Federal Government funding would be expected.

FIGURE 16

ENERGY R&D PROGRAM BUDGET SUMMARY

SUBPROGRAM NAME: Bioconversion

PROGRAM ALTERNATIVE: Accelerated Orderly Program

FEDERAL OBLIGATIONS

$\$X10^6$

PROGRAM ELEMENT	1975	1976	1977	1978	1979	1980-1989
1) Conversion including fermentation, chemical reduction, pyrolysis, & combustion						
Research & Tech.	2.6	2.6	2.6	2.6	2.6	5.0
Engr. Dev.	2.0	2.0	2.0	1.0	1.0	2.0
Pilot Plants	2.0	4.0	6.0	5.0	3.0	4.0
Demonstration Plants		1.0	3.0	10.0	19.0	4.0
	6.6	9.6	13.6	18.6	25.6	15.0
2) Organic Material Prod.						
Research & Tech.	3.0	4.0	4.0	3.0	3.0	6.0
Engr. Dev.	1.0	2.0	3.0	2.0	2.0	2.0
Pilot Plants			1.0	2.5	2.0	2.0
Demonstration Plants				1.5	3.0	20.0
	4.0	6.0	8.0	9.0	10.0	30.0
3) Biophotolysis						
Research & Tech.	1.5	1.7	2.1	2.5	3.0	8.0
Engr. Dev.					1.0	2.0
	1.5	1.7	2.1	2.5	5.0	10.0
	12.1	17.3	23.7	30.1	40.6	55.0

Five Year Total = $123.8M

FIGURE 17

ENERGY R&D PROGRAM BUDGET SUMMARY

SUBPROGRAM NAME: Bioconversion PROGRAM ALTERNATIVE: Min. Viable Program

FEDERAL OBLIGATIONS

$\$X10^6$

PROGRAM ELEMENT	1975	1976	1977	1978	1979	1980-1989	
1) Conversion including fermentation, chemical reduction, pyrolysis, & combustion							
Research & Tech.	2.0	2.0	2.0	2.0	2.0	5.0	
Engr. Dev.	2.0	2.0	2.0	1.0	1.0	2.0	
Pilot Plant	2.0	3.0	1.5	1.5	1.5	1.5	
Demonstration Plants					1.0	33.0	
2) Organic Material Prod.							
Research & Tech.	1.0	1.5	2.0	2.0	1.0	5.0	
Eng. Dev.	0.5	1.0	2.0	2.0	1.0	5.0	
Pilot Plant				1.0	2.0	4.5	
Demonstration Plants						20.0	
3) Biophotolysis							
Research & Tech.	1.0	1.0	1.0	1.0	2.0	8.0	
Eng. Dev.					1.0	2.0	
	8.5	10.5	10.5	10.5	12.5	86.0	

Five Year Total = \$52.5M

c. Projected Federal outlays FY 1975 to FY 1979 are shown on Fig. 16 and 17.

d. Major uncertainties in the funding arrangements are the impact of continued inflation on estimated costs of the various parallel programs. Hydrogen production could conceivably progress faster than anticipated, resulting in the need for funds for pilot and demonstration plants.

3. Other Requirements:

a. Manpower needs to accomplish this program. The following manpower are needed for the 5-year period:

1. Accelerated Program

Scientific	1020
Technical	1020
Administrative	2060
Total	4100

2. Minimum Program

Scientific	437
Technical	483
Administrative	875
Total	1750

b. Facilities for storage of biomass, farming operations and expansion of laboratories will be required. These costs are accounted for in the cost projections.

4. Management Plan - The management will coordinate the efforts of the Federal Government with those of private industry, local and state governments and academic researchers with the goal of developing a viable and profitable bioconversion industry at the earliest possible time. Federal laboratories will be utilized in

the early stages to manage the individual projects of the bioconversion subprogram. These laboratories will conduct in-house research and manage extramural activities based on detailed program development plans. Coordination and involvement of the pertinent groups mentioned above is already underway, and it is expected that participation will be broadened. As demonstration and development projects mature, industry will assume an increasing share of the fiscal and management responsibilities, as discussed in other sections of this report.

5. Criteria Employed in Construction of the Proposed R&D Program:
   a. The present program embraces all bioconversion areas except direct combustion which received attention previously.
   b. The program attempts to balance the need for rapid results with the need to maintain a R&D base sufficient to permit a sound evaluation of the potential of the various bioconversion processes for full-system implementation.
6. Dependence of Other R&D to Progress of This Technology:
   a. The energy products of bioconversion can be used by present energy distribution systems. Development of hydrogen production by biophotolysis is dependent on an emerging hydrogen system.
   b. This R&D effort is independent of the progress of other R&D programs. Consequences of delays in the program would not be serious provided alternate energy systems emerge.

7. Possible adverse environmental or ecological effects could occur due to extensive usage of land, water, and ocean for biomass production. Questions of the Federal Government's right to farm the oceans may arise. Air and water pollution from bio-conversion plants have not been thoroughly investigated. Environmental Impact Statements will be required in some instances.

VI. IMPLEMENTATION

A. Direct Benefits of Implementation

1. Farming, urban, industrial, transportation, and storage sectors are involved in delivery of biomass to conversion centers. The conversion product will fit directly into existing energy distribution systems.
2. About 6% of natural gas requirements can be supplied from wastes alone. With agricultural material, about 50% of gas needs may be produced. Alternatively, liquid fuel from wastes plus agricultural materials may replace 40-50% of oil requirements in the early 2000's.
3. Sources are wholly domestic, and non-depelting. Methane produced would offset needs for imported liquified natural gas.
4. An agricultural energy source is dispersed--not vulnerable to attack. Conversion plants are vulnerable but no more than existing refineries. Use of wastes would decentralize methane production and tend to diminish disaster impact.
5. Systems efficiency is not the prime parameter. The main interest is capture and use of solar energy for fossil fuels supplements.

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B. Economics of Implementation

1. There have been few economic studies made on converting various forms of stored energy via photosythesis into commonly used fuels. There have been detailed engineering studies for present day technology on bioconversion processes used for disposal of municipal solid waste. However, the emphasis has been placed on disposal. Energy production is merely a by-product for the disposal systems. Yet, in these solid waste disposal systems it has been demonstrated that there is potential for obtaining a significant amount of energy. It appears that fuel can be produced in the future that will be within a competitive cost range. Cost estimates used by the NSF/NASA Solar Energy Panel in 1972 suggested that the fuel cost at a power plant using biomass would range from \$1.50 to \$2.00/10^6 BTU. The capital cost for an organic materials-steam electric plant would approximate that of a conventional coal-steam-electric plant or about \$250 per KW according to NASA projections. Biophotolysis systems are not as well defined, and therefore, economic projections are difficult. Detailed cost studies will be one of the major activities undertaken during early phases of this program as more data become available.

2. Incentives - Capital should be made available to industry at reduced rates. Taxes should be reduced or waived on investments. Farm subsidies should be employed to provide profit incentives until the viability of biomass farming is established.

C. Impacts of Implementation

1. Natural Resources Required:

a. For full implementation to provide for approximately 10 percent of the total energy requirements of the U.S., estimates indicate that approximately 200M acres of land and water would be required. This represents about the total area currently farmed in the United States. Thus, a considerable share of the acreage would be of necessity on water unless photosynthetic efficiency in energy conversion were doubled or tripled. This is an area requiring a considerable research investment.

b. When oceanic surfaces are considered, resources are certainly available, if the technology for ocean farming can be accomplished.

c. Competition for land acreages will be great for the production of fiber, food, and feed.

d. Legal restrictions on using oceans for biomass farming need to be determined.

2. Energy Inputs Required:

There are presently insufficient data to assess the energy inputs required. Presently funded research is working on this aspect of the program.

3. Compatibility with Existing Energy Systems:

Projected outputs may be methane--directly usable as pipeline gas; liquid hydrocarbon fuels which may require refining and processing, and low BTU gas suitable for direct use in power plants.

4. **Environmental Impacts of Implementation:**

Pryolytic or chemical conversion plants are analogous to coal gasification and liquefaction plants. Control of gaseous, liquid, solid, and thermal emissions is required. Fermentation yields liquid effluent and sludge which requires disposal. With full implementation large areas of land and water not presently used agriculturally would be converted to biomass production.

5. **Occupational Health and Safety Considerations:**

There are no anticipated unique occupational health or safety considerations. Bioconversion plant operations, farming, and hazards of sea duty are expected to be similar to those encountered in other industries.

6. **Other Factors:**

   a. **Full implementation of biomass production could drastically alter farming operations on up to a total of 100 million acres of farm land (principally grazing) and perhaps an equal amount of forest land. Erosion could occur; organic content of soils may be adversely affected and recreational waterways would be reduced.**

   b. **Small generating plants for local use on farms or small urban areas could aid in waste disposal and reduce energy requirements from conventional sources.**

c. The long-term impacts of implementation could:

1. Change patterns of recreational land and waterways in the U.S.
2. Make a significant contribution toward reducing the predicted energy gap.
3. Significantly reduce the organic waste problem in the U.S.
4. By-products from bioconversion could provide animal feed and fertilizer from sources that are now discarded.

SECTION 6 - OCEAN THERMAL ENERGY CONVERSION

I. SUBPROGRAM SUMMARY

A. Introduction

1. The oceans serve both to collect and store tremendous quantities of solar energy. By utilizing the natural temperature difference between the surface and deep ocean waters, a heat engine can be operated. Experiments by Claude have demonstrated the concept off Cuba, producing 22 Kw of electrical power. Studies indicate that significant amounts of energy (compared to total U.S. needs) can be economically harvested in this way from the ocean. Because the temperature difference (40° to 50°F) is small, the Carnot efficiency is about 5%. However, the available thermal energy is enormous. The process requires no fuel or fresh water and the associated power plant technology is straightforward, hence, the resulting electrical energy should be competitive in cost with that produced by present-day power plants.

2. This development program is intended to demonstrate the practical feasibility of converting ocean thermal energy into electricity. System reliability and economic viability will be determined, along with an associated assessment of the technology and environmental impacts. The potential for production of protein and fresh water as valuable by-products will be investigated. Engineering problems to be solved include the development of deep-water pipes of large (order of 50 foot) diameter (along with methods for their deployment) and the design of appropriate heat exchangers and

pumping systems. A selection must be made between an open or a closed thermodynamic cycle, and as to the transmission of energy from ocean locations to land. The legal questions associated with operations in international waters must also be examined.

B. R&D Programs

1. a. Accelerated orderly program

This program looks toward an early 1980's demonstration of technological feasibility, so that the immense thermal energy resources of the oceans would soon begin to be tapped. Advanced development and engineering will produce components and subsystems, overlapping in time the establishment of ocean-based and near-shore pilot plants and test facilities.

b. Minimum viable program

This program compromises on the above program by utilizing only a near-shore pilot plant/test facility in conjunction with the associated advanced development and engineering. The minimum viable (near-shore) program would not come to grips with many potential features associated with ocean-based operations. Consequently, feasibility determination and ultimate commercial implementation of ocean-thermal plants will be delayed several years.

c. Crash program

Because the basic technology for ocean-thermal plants exists today, the accelerated program is amenable to efficient conversion to a crash program. A crash program for this relatively low-level technology can be conducted at low technical risk and with high probability of successful completion within the time and funding allocated. The rate of advanced R&D would be doubled, and from two to four pilot plants constructed during the five-year period. A demonstration plant could be designed and constructed by the end of this decade, shortening the time to this milestone by almost three years.

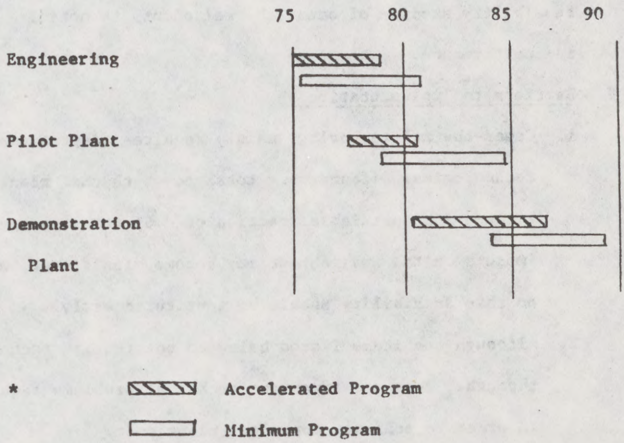
The accelerated orderly program calls for the completion of construction of two 5-10 Mw pilot plants by FY 1980. One will be located near shore, and the other will be ocean based. The minimum viable program provides for only one near-shore pilot plant, to be completed by FY 1984. Both programs include a demonstration plant, and their respective schedules are shown in Section I. C. 2. No major technical barriers are envisioned, but legal aspects of ocean-based plants may be a major problem.

C. Implementation

1. Projected size of the applications after implementation:
The solar energy impinging on the topical oceans averages 20 watts/ft^2 or 560,000 Kw/mi^2. Thus, for thermal equilibrim at 3% net conversion efficiency, a 500 Mwe plant would extract the heat supplied by the sun to 30 square miles of ocean surface. Since more than 30 million square miles of ocean have appropriate thermal conditions, as many as one million plants--each of 500 Mw output--could conceivably be operated (having a total

output of over one thousand times the current U.S. capacity for electrical energy generation). The output of the ocean-thermal plants would be transmitted to the user as electricity and/or by conversion to an intermediate fuel such as hydrogen. Thus, several thousand such plants could supply all current U.S. energy requirements.

2. Time scale for implementation:



3. Possible barriers to implementation:

The heat-exchanger and cold-water pipe designs represent possible technical problems, but are not expected to be barriers. Possible environmental impacts of large-scale implementation will require study. Possible institutional barriers to widespread implementation include lack of short-term private incentives and risk capital, and international legal questions.

II. STATUS OF THE TECHNOLOGY

A. Present Status

In 1929, Claude demonstrated an ocean-thermal plant off Cuba that generated 22 kilowatts of electricity. An assessment of this and other French efforts (prior to 1960) has been made. A workshop on ocean-thermal power plants was conducted in June 1973. Computer-based models and other approaches are currently being used for feasibility studies of ocean-thermal plants to optimize their design and performance.

B. Barriers to Implementation

1. Ocean-thermal technology mainly requires adaptations of existing technologies. If and when total ocean-thermal plant capacity becomes an appreciable fraction of U.S. total energy needs, possible impacts on the environment may become significant; hence research on this possibility should be instituted early.

2. Although the items listed below do not require technological breakthroughs, they are important technical problems requiring solution in order to achieve economical plant cost.

   - Cold water intake pipe; design and deployment of pipe having a diameter of about 50 feet, and a length of 2000 to 3000 feet.
   - Anchoring or station-keeping of pipe and power plant.
   - Biofouling of heat exchangers.
   - Turbine diffuser design and turbine seals.
   - Corrosion control and heat transfer degradation.
   - Large scale water pumps (30M gallons/min for 500 Mw plant).
   - Energy transmission.
   - Conversion of electrical energy to intermediate fuel.

C. Ongoing R&D Efforts to Overcome Barriers

1. Present U.S. efforts are funded at less than $50K and are mainly concerned with system design studies, not hardware. There has been some relevant private work on 10 foot diameter pipes for pumping condenser water to a 325 Mw steam unit.

2. The French company, Energie des Mers (dissolved in 1960), has done extensive studies and produced complete system designs and cost estimates for a 25 Kw ocean-thermal plant using the open-cycle Claude process.

III. RATIONALE FOR FEDERAL INVOLVEMENT AND INSTITUTIONAL ARRANGEMENTS

A. Federal Involvement

Private industry is heavily committed to present methods of generating power, and cannot be expected to share the research and development costs required in the short run for this unique, new system. Although the risk of technological failure in developing ocean-thermal technology is deemed negligible, it is still too great (and the investment too large) for private industry alone to assume. Moreover, the federal government is the logical sponsor of this development, since the U.S. public will be the recipient of the resulting benefits: a) reduction or elimination of power generation as a source of environmental pollution; b) conservation of the remaining U.S. fossil-fuel mineral resources; and c) U.S. self sufficiency in energy production.

B. Stimulation of Investment in R&D

Besides direct financial support, the Government could undoubtedly stimulate private investment in R&D by allowing tax write-offs. This procedure was successfully employed during World War II. The Government could also guarantee to buy (at attractive prices) future power generated by ocean-thermal plants. (Other incentives are summarized in VI. B. 6. i.)

C. Industrial Interest

The rising cost of competitive power plants will help focus industrial attention on the attractiveness of ocean-thermal systems. Increasing resistance to the exploitation of coal and nuclear energy may increase the interest of power companies in ocean-thermal and other alternative systems. Demonstration of ocean-thermal pilot plants will stimulate industrial interest.

D. Other Recommended Government Actions

- Provide special dispensation with regard to anti-trust laws so as to permit collaborative efforts among normally competiting companies.
- Clarify the legal status of ocean-thermal plants situated in international waters.
- Provide incentives as discussed in VI. B. 6. i. below.

IV. CRITERIA AND PRIORITIES

- Studies essential to the evaluation of ocean-thermal plants: Performance, economic viability, environmental impacts, potential for application, and institutional influences.
- Elements critical to demonstrating the technology: Cold water intake pipe, heat exchangers, and (especially) verification of system performance by means of a pilot plant.

- Commonality of the element to various ocean-thermal approaches (closed cycle, open cycle; near-shore plant or ocean-based plant). The cold water intake pipe is common to all alternatives, while the development of flash evaporators and deaeration systems relates only to open-cycle systems.
- Universality of the research and technology: Corrosion-prevention and anti-fouling techniques will be derivable from, and also of benefit to, other marine applications. The ocean-thermal technology will be applicable to bottoming cycles and to the increasing use of the ocean as a heat sink for nuclear and fossil power plants.

V. ALTERNATIVE R&D PROGRAMS

A. Accelerated Program

Includes engineering development and testing to establish component design and performance in conjunction with construction of two 5 to 10 Mw pilot plants based on two different concepts. These steps will be followed by construction and test of a 100 Mw demonstration plant. (See Fig. 18.)

B. Minimum Program

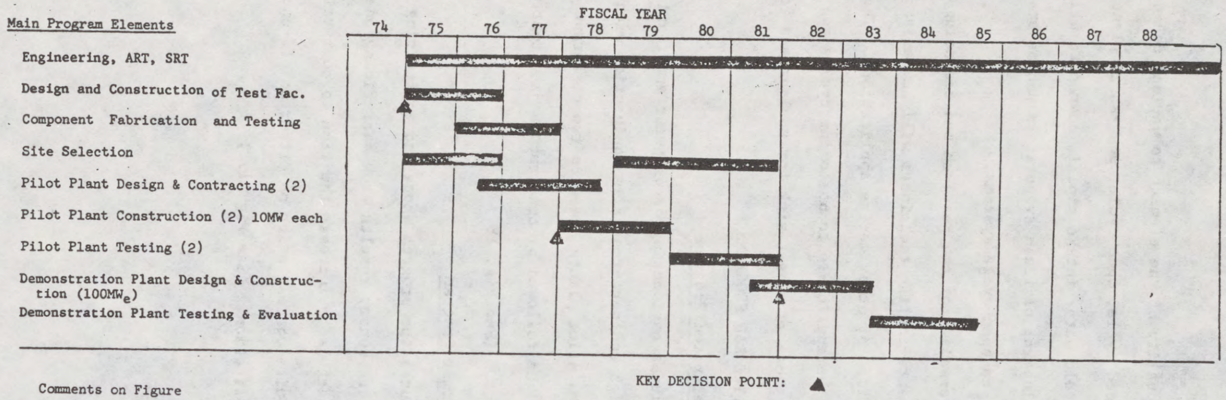
Reduces the program scope and engineering development effort. The major economy results from sacrificing one pilot plant. The net effect is to increase the time to commercial application and to require concentration on either an off-shore or ocean-based application. (See Fig. 19.)

FIGURE 18

PROGRAM FLOW CHART

OCEAN THERMAL CONVERSION SUBPROGRAM

ACCELERATED ORDERLY ALTERNATIVE



KEY DECISION POINT: ▲

Comments on Figure

(a) Three major milestones are indicated by ▲'s: Construction of test facilities - FY1974
Construction of pilot plants - FY1977 Demonstration plant construetion - FY1981
Decision as to the direction of the program should be made by the government at the indicated times.

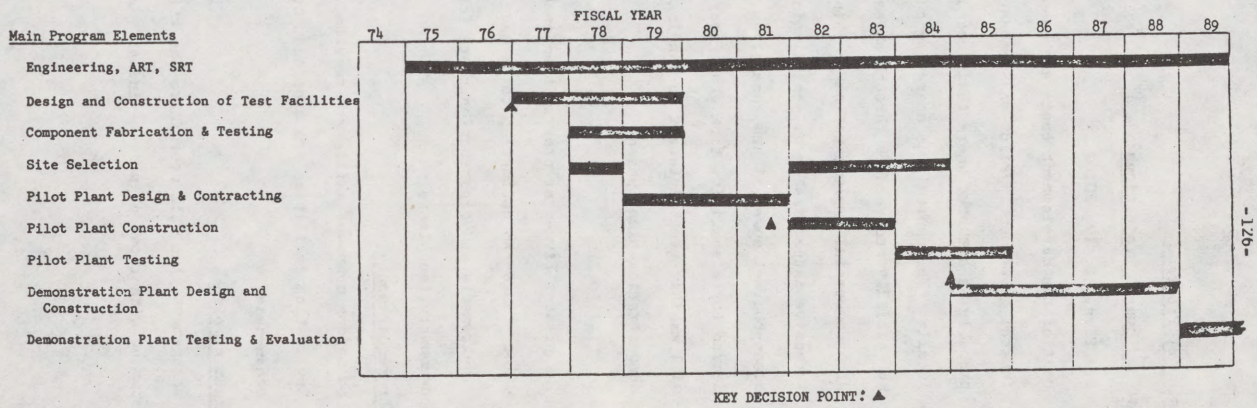
(b) Two pilot plants are proposed. One is to establish the design of an ocean-based plant, the other to establish the design of a near-shore plant.

FIGURE 19

PROGRAM FLOW CHART

OCEAN THERMAL CONVERSION SUBPROGRAM

MINIMUM VIABLE ALTERNATIVE



C. Discussion of Programs

1. Cost and budget projections:

a. See Figs. 18, 19, 20, 21.

b. Most of the development costs are assumed to be borne by the federal government. Pilot and demonstration plants will probably be situated where their output power is usable locally. The capital and operating costs of such plants may be partially recoverable through sales of their products. With commercial implementation of this technology, energy-intensive industries (e.g., the aluminum industry) may build ocean-thermal power plants themselves, thus relieving the demand for electricity from other sources. Private investors will exhibit great interest in funding plants following the demonstration-plant phase.

c. See Fig. 20.

d. The present five-year program plan enables--through use of pilot plants--an estimation to be made of engineering design requirements and construction costs for scaling up to demonstration plants.

2. Other requirements:

a. No unique manpower skills are required.

b. New testing facilities are proposed, both near-shore and ocean-based.

3. Management plan:

The management plan will coordinate the efforts of the federal government with those of private industry and academic researchers,

FIGURE 20

Budget Summary (Millions of $)

Ocean Thermal Conversion Sub-Program - Accelerated Alternative

	Fiscal Year									
	74	75	76	77	78	79	80-84	85-89	75-79	80-89
Engineering, ART, SRT		5.5	6.0	6.4	6.8	6.3	20.1	15.3	31.0	35.4
Design and Construction of Test Facilities		3.0	7.0				-	-	10.0	-
Component Fabrication and Testing			4.0	6.0			-	-	10.0	-
Site Selection		0.1	0.2			0.2	0.3	-	0.5	0.3
Pilot Plant Design and Contracting			2.0	4.0	2.0		-	-	8.0	-
Pilot Plant Construction					20.0	20.0	-	-	40.0	-
Pilot Plant Testing							8.0	-	-	8.0
Demonstration Plant Design and Construction							212.0	-	-	212.0
Demonstration Plant Testing							12.5	25.5	-	38.0
TOTALS		8.6	19.2	16.4	28.8	26.5	252.9	40.8	99.5	293.7

FIGURE 21

Budget Summary

Ocean Thermal Conversion Sub-Program - Minimum Alternative

	Fiscal Year									
	74	75	76	77	78	79	80-84	85-89	75-79	80-89
Engineering, ART, SRT		4.0	4.5	5.0	5.5	6.0	26.5	15.5	25.0	42.0
Design and Construction of Test Facilities				2.5	4.5	3.0	-	-	10.0	-
Component Fabrication and Testing					2.0	3.0	-	-	5.0	-
Site Selection				0.1	0.2		0.5	-	0.3	0.5
Pilot Plant Design and Contracting						1.0	3.0	-	1.0	3.0
Pilot Plant Construction							10.0	-	-	10.0
Pilot Plant Testing							3.0	3.0	-	6.0
Demonstration Plant Design and Construction							-	212.0	-	212.0
Demonstration Plant Testing							-	12.5	-	12.5
TOTALS		4.0	4.5	7.6	12.2	13.0	43.0	243.0	41.3	286.0

with the goal of turning over the commercialization of ocean-thermal energy to industry at the earliest possible time. Federal laboratories will be utilized in the early phases to manage the individual projects of the ocean-thermal subprogram. These laboratories will conduct in-house research and manage out-of-house activities, based on detailed program development plans. Coordination and involvement of the three major research groups mentioned above is already underway, and participation will be broadened. As demonstration and development projects mature, industry will assume an increasing share of the fiscal and management responsibilities, as discussed in other sections of this report.

During the initial implementation of ocean-thermal energy, the federal government could be both supplier and consumer. For example, DOD shore facilities and remote installations (Gaum, Hawaii, etc.) present requirements for small power plants. At these locations, ocean-thermal plants are strategically and economically justified in the near term.

4. <u>Criteria employed</u>:

a. Related R&D programs considered:

The ocean-thermal program is based on an extension of existing technology. However, alternative paths are available that would lead to a useful product. These involve the use of open or closed cycles for the heat engine, the design of ocean-based plants, and the construction of plants near shore. The accelerated program includes both a near-shore pilot plant and an ocean-based pilot plant. In the minimum program, only a near-shore pilot is proposed.

b. Criteria for program selection:

The program selected is designed to demonstrate the technical and economic feasibility of ocean thermal energy conversion. Accordingly, the program includes initial engineering design and tests to establish the detailed design of system components, meanwhile proceeding with pilot-plant design and operation to confirm expected performance. Pilot-plant experience then leads to the design and operation of a demonstration plant capable of commercial utilization. Emphasis in the program will be placed on achieving competitive capital cost without sacrificing durability and ease of maintenance.

5. Interdependence of R&D:

Basically, ocean-thermal systems will depend on adaptations of existing, relatively low-level, technology. In particular, unlike many forms of solar power--they do not require hardware for energy collection or energy storage. The ocean itself serves as a collection and storage medium for the energy provided by the sun so that the systems can operate continuously, day and night, year around. For fullest utilization of ocean-thermal energy, these systems may be remote from land and hence require the conversion of electricity to some intermediate form (such as hydrogen) for energy transmission.

Engineering developments of this program will contribute design data applicable to low pressure turbine technology, low temperature-gradient heat exchangers, and to specialized ocean platforms. Experience gained in this program will also be valuable in using the ocean as a heat sink for conventional power plants. Significant delays in this program would result in overlooking--during the near term--a substantial, clean energy source of great potential.

6. Acceptability of R&D program:

Public acceptability of this program will be very high, since the plants will be out of sight. Problems of the environment and of safety are expected to be minimal, compared to those involved with the development of almost every other energy source. Land usage will be largely avoided. The potential of ocean-thermal systems for providing a clean source of energy should promote general public and industrial support. Studies will be necessary to determine the possible effects on climate and biota of the thermal redistribution resulting from the operation of ocean-thermal plants. Implementation of this technology will help lead to national self sufficiency in energy production.

VI. IMPLEMENTATION PLANTS

A. Direct Benefits of Implementation

1. Both the civilian and military sectors can utilize the energy (along with protein and fresh water) resulting from implementation of ocean-thermal plants.

2. The potential energy market for ocean-thermal power plants will be comparable to the U.S. energy gap for the foreseeable future. In addition, such plants can supply needed protein and fresh water in large quantities.
3. The production of significant quantities of electricity and/or chemical fuel using ocean-thermal plants will help relieve U.S. dependence upon foreign sources of fossil fuels.
4. Ocean-thermal power plants--like the merchant marine--are vulnerable to acts of war and sabotage. Since a large number of ocean-thermal plants are envisioned, the loss of several such plants should not have a deleterious effect on the national energy system.
5. Ocean-thermal power plants can provide base load and peaking capacity directly or via chemical fuels such as hydrogen. This would improve the diversity and energy utilization efficiency of the national energy system.

B. Economics of Implementation

1. Projected delivery price of the ultimate product: The ocean-thermal plant could generate electricity at a cost preliminarily estimated at 5 to 10 mills/kwh.
2. As by-product of the conversion to electricity of ocean-thermal energy, protein and/or fresh water can be produced. The value of these resources might indeed be appreciable for some installations, perhaps exceeding the value of the associated energy. The net effect of the production of these additional commodities is to reduce the net price of the energy delivered to the user. If hydrogen is produced, halogens and metals may be additional by-products.

3. Capital costs for ocean-based thermal energy conversion plants are preliminarily estimated at about $400 per kilowatt of capacity. Operating costs (estimated at $10M per year for a 500 Mw plant) may be somewhat higher than those associated with conventional steam plants, because of the marine environment. However, some economy should result because of the benefit of boiler operation at low-temperatures. Thus, a cost trade-off, which could be favorable to the ocean-thermal plant, will be involved.
4. The ship building and turbine industries will be stimulated appreciably by the construction of a fleet of ocean-thermal power plants, and a new labor market will develop for operating them. Resource requirements for the ocean-thermal plants will be manifested in the aluminum industry.
5. The energy output of ocean-thermal plants can be used as electricity and/or converted into fuels such as hydrogen, so as to offset the need for importation of fossil fuels. The ocean-plant technology will be an exportable commodity, and certain subsystems and components of ocean-thermal plants will be patentable. The potential for exportation of energy-intensive products will be enhanced.
6. Assumptions underlying our projections:
   a. The required energy and material resources for the construction of ocean-thermal plants will be made available at present "real dollar" prices.

b. The R&D provided by the government (through the demonstration plant phase) is regarded literally, in this case, as pump-priming; i.e., as a subsidy not amortized in the price of the energy initially produced.

c. The costs of labor, expressed in "real dollars," will be comparable with those for other energy-production plants.

d. Capital will be made available at usual interest rates.

e. The date of commercial availability could be as early as 1985 for an accelerated program extending into that period, coupled with appropriate federal incentives (discussed below in i. and in III. B.).

f. The useful lifetime for a durably-built ocean-thermal system will exceed 30 years, with maintenance costs somewhat higher than for conventional steam plants. The costs of decommissioning such plants will be minimal.

g. The increased availability of high quality electrical and/or chemical energy can help satisfy the global and/or U.S. energy deficiency, since the relative potential magnitudes of the supply of ocean-thermal energy and of the world energy gap are comparable. Similarly, the possible by-product resources, protein and fresh water, will be in great demand.

h. As contemplated above, possible excess U.S. capacity for producing renewable ocean energy and the associated resources will find foreign markets.

i. Incentives should be provided by the federal government to speed the development of these ocean resources. Since this new industry will be enhancing U.S. resources, rather than depleting them, there should be an "allowance" to reward successful private participation in this effort. Taxes should be waived on investments in the associated R&D; capital gains exclusions should be offered on returns resulting from corporate investments in this area.

C. <u>Impacts of Implementation</u>

1. <u>Natural resources required</u>:

a. Investment in ocean-thermal plants will require significant quantities of resources per plant. However, these requirements are expected to be no greater than those needed for conventional steam power plants. For ocean-thermal plants, large heat exchangers (probably of aluminum) are required, but there is no need for fuel. The basic material needs are for plant flotation, water circulation and heat extraction. Considerable amounts of aluminum will probably be incorporated for components requiring corrosion resistance. There is no land required for most of the plants, inasmuch as they will be located in the ocean.

b. The ratios of required steel, plastic and aluminum to national total resources of these materials is inconsequential. Ocean sites for ocean-based plants are widely available.

c. Although other sectors will continue to require these resources, they are in plentiful supply, and we do not expect serious competition in meeting the needs for ocean-thermal facilities. Similarly, the abundance of offshore ocean sites should interpose no obstacles to exploitation, although the availability of sites near land is more limited.

d. The materials requirements can probably be satisfied without difficulty. On the other hand, the ocean resource could present international jurisdictional problems. If ocean-thermal plants were anchored, this potential problem might be more serious than if they were not. However, anchoring is unlikely, since technical considerations favor dynamic positioning as a means of station-keeping.

2. Inputs required:

a. Preliminary estimates of the capital investment for ocean-thermal plants is about $400 per kilowatt of capacity.

b. There is no fuel cost, except for the purpose of priming the pumps. Because of the absence of fuel and the high load factor (ca. 90%), the amortized capital costs lead to an electrical energy production cost (F.O.B. the plant) of about 8 mills per kwh. Intermediate fuels, such as hydrogen, could be produced at competitive prices.

3. Compatibility with existing energy system:

Ocean thermal plants will encounter the same sorts of problems of security and concentration-distribution of power posed by existing offshore activities. The forms of energy produced will be compatible with existing and contemplated energy distribution networks and systems.

4. Environmental impacts of implementation:

The global environmental impacts--on climate and biota--of large numbers of ocean-thermal plants could possibly be significant. Also, the possible local impacts of even a single plant need to be studied. The principal environmental concerns in exploiting the ocean-thermal resources are the possible consequences of the resulting redistribution of heat.

5. Occupational health and safety considerations:

Insofar as the ocean plants are seaworthy, durable, and well designed for maintenance, their health and safety characteristics will be comparable to conventional land-based plants, although their relative isolation presents a potential morale problem for their staff.

6. Other factors:

   a. The utilization of the oceans for plant siting will free land sites that otherwise would be used for power plants. Rejected heat from those unbuilt, land-based power plants will then not be released to the atmosphere or to streams or lakes.

   b. There will be essentially no social costs, since ocean-thermal plants will have little interaction--even esthetic--with significant numbers of humans. The production of energy, along with food and water resources, will benefit society, which is experiencing increasing shortages in all three commodities.

c. The implementation of this technology has the potential for providing a significant contribution of energy to help bridge the energy gap, both domestically and internationally. Such implementation can be accomplished with minimal impact, while utilizing a renewable energy resource. Since the ocean will probably be increasingly needed as a heat sink in producing power by various means, the technology developed in this program will be useful for that application. From the standpoint of its producing valuable energy, protein and water resources, the implementation of this technology can help lead toward global, political, and social stability.

SECTION 7 - PHOTOVOLTAIC CONVERSION

I. SUBPROGRAM SUMMARY

A. Introduction

1. This research effort is directed at development of single crystal, thin film and other techniques to produce high efficiency low cost photovoltaic systems for terrestrial use. In contrast to the present labor intensive methods used to produce solar cells, the research will explore and develop processes and technology which will permit the production of enormous quantities of low cost photovoltaic arrays by automated processes such as those now employed in the production of photographic film.
2. The objectives of the research are to reduce the cost of terrestrial photovoltaic systems from the present $50 per peak watt to less than $1.50 per peak watt (eventual goal of $0.10/peak watt) so that it will be economically competitive with other methods of generating electricity for various uses in various regions of the country. The major problem is to develop the technology which will permit the continuous manufacture of large area arrays in quantities of hundreds of millions of square meters per year.

B. R&D Programs

1. The accelerated program would permit research to be conducted

along several lines in single crystal, thin film and new concept approaches permitting a high degree of confidence (80% or greater) in successfully accomplishing the goals. Then trade offs between approaches, e.g., single crystal silicon, thin film silicon, cadmium sufide, copper oxide, etc., could be made realistically. The minimum program would require earlier narrowing of approaches resulting in fewer available alternatives and could thereby delay the demonstration of practical systems.

2. The budgets for the accelerated and minimum programs, shown in Fig. 24 and 27, are seen to be about a factor of 5 different. The major milestones are given in Figs. 22, 23, 25, and 26.

C. <u>Implementation</u>

1. As indicated in Figs. 28, 29 of this writeup, the achievement of the cost goals of this program will result in the production of economically competitive electrical power (cost of 10 mils per KWH) by the year 1990. The projected rate of implementation of this solar energy concersion technology will produce more than 7% of the required U.S. electrical generating capacity by the year 2000.

2. The time schedule for implementation of the two primary applications are projected as follows:

   a. On-site electricity generation for homes, schools, shopping centers, etc. Installation of economic units is projected to begin by 1982 in the southwestern U.S. All new construction in that area can be expected to include photovoltaic systems by 1985.

FIGURE 22

PHOTOVOLTAIC CONVERSION
ACCELERATED ORDERLY
MILESTONE SCHEDULE

1975 . Solar Insolation data collection network established.

. Establish materials characterization and analysis la laboratory.

1976 . Set up and operate standards and calibration laboratory.

. Operate terrestrial environmental test facility.

. Determine maximum allowable costs of photovoltaic systems for on-site and central station application in several U.S. locations taking into account meteorological data and the effect of such systems on communities, environment and society.

1977 . On-site System design completed.

. Commence testing of cells and arrays.

. Attainment of $5/watt(peak) technology.

1979 . Attainment of $0.50/watt(peak) technology feasibility.

. On-site System installed and testing initiated.

. Central Station System design completed.

1981 . Completion of a pilot line to manufacture $0.50/watt (peak) solar arrays.

1982 . Integrate photovoltaic systems in the range of 0.01-1.0MW into new and existing building (homes, schools, shopping centers, etc.).

1985 . Integrate photovoltaic systems of about 10MW capacity into communities and large industrial plants.

1986 . Completion of pilot line to manufacture $0.30/watt(peak) solar arrays.

1990 . Integrate photovoltaic systems of greater than 100MW capacity into towns and power networks.

FIGURE 23a

PHOTOVOLTAIC R&D PROGRAM FLOW CHART

PROGRAM NAME: Photovoltaic Conversion

PROGRAM ALTERNATIVE: Accelerated Orderly

KEY DECISION POINT: 0
Array Research and Development

MAJOR MILESTONE OR CRITIAL PATH JUNCTURE
(e.g., technical feasibility demonstrated)

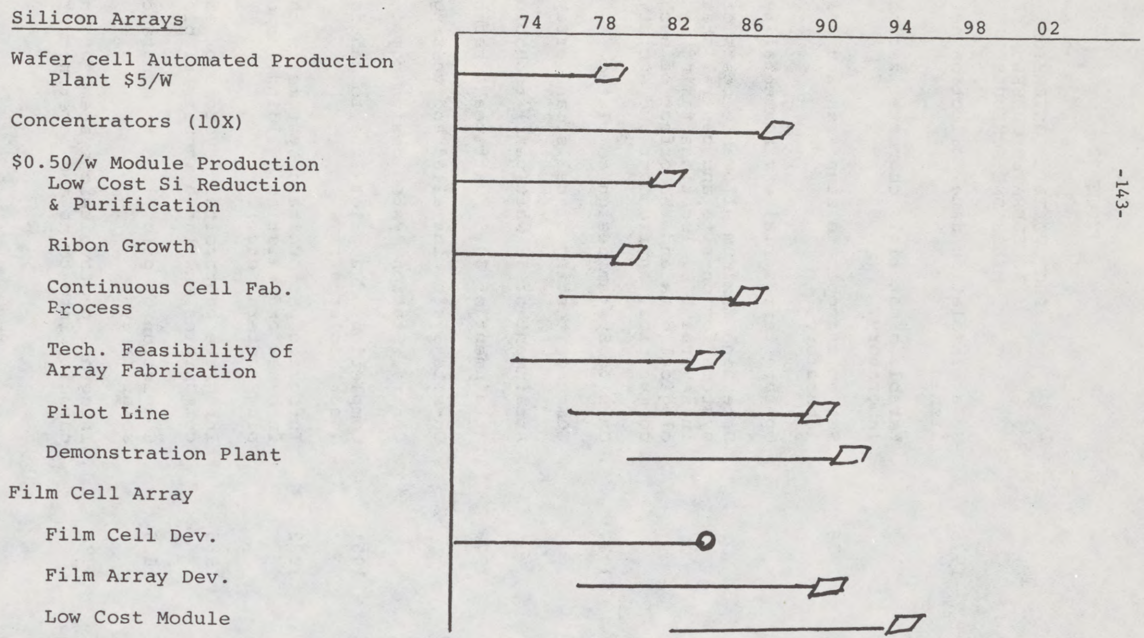


FIGURE 29

RATE OF IMPLEMENTATION - PHOTOVOLTAIC CONVERSION

The rate of implementation is based on estimates from learning curves projected for various rates of photovoltaic device research and development.

Year	Peak Power Output Capability of Arrays Produced One Year (MW)	Cumulative Output (MW)
1981	1	1
1983	10	13
1985	1000	1100
1990	5000	10,000
1995	10,000	40,000
2000	20,000	100,000*

* AUI Projected Electrical Generating Capacity (U.S.) Required in the year 2000 is 2000 mkw(e). This would then be (at peak output) 5% of U.S. requirements.

39-827 O - 74 - 22

FIGURE 23b

ENERGY R&D FLOW CHART

PROGRAM NAME: Photovoltaic Conversion

PROGRAM ALTERNATIVE: Accelerated Orderly

KEY DECISION POINT: 0

MAJOR MILESTONE OR CRITICAL PATH JUNCTURE ▱

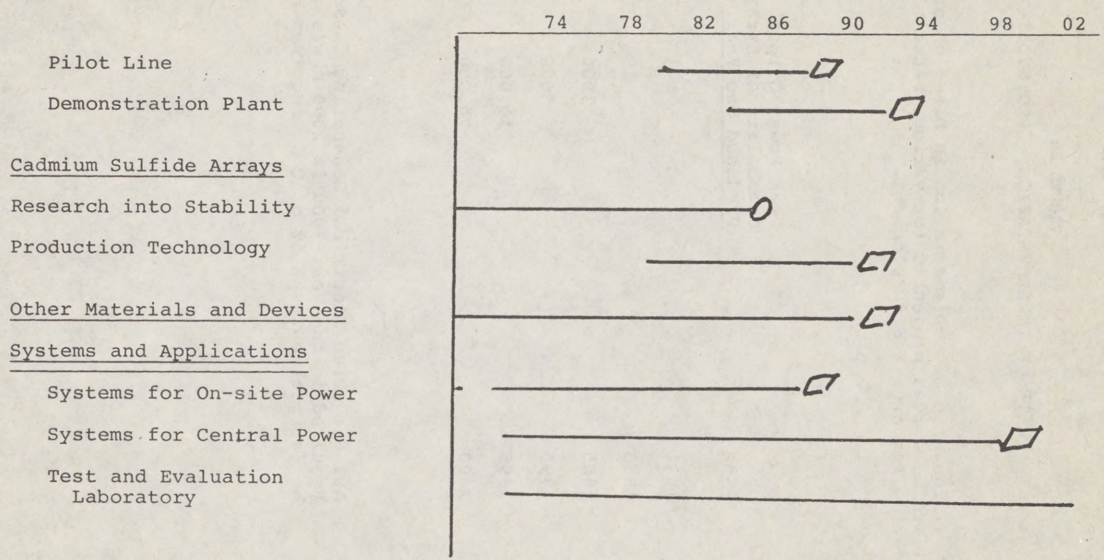


FIGURE 24

ENERGY R&D PROGRAM BUDGET SUMMARY

PROGRAM NAME: Photovoltaic Conversion

PROGRAM ALTERNATIVE: Accelerated Orderly

FEDERAL OBLIGATIONS
$\$X10^6$

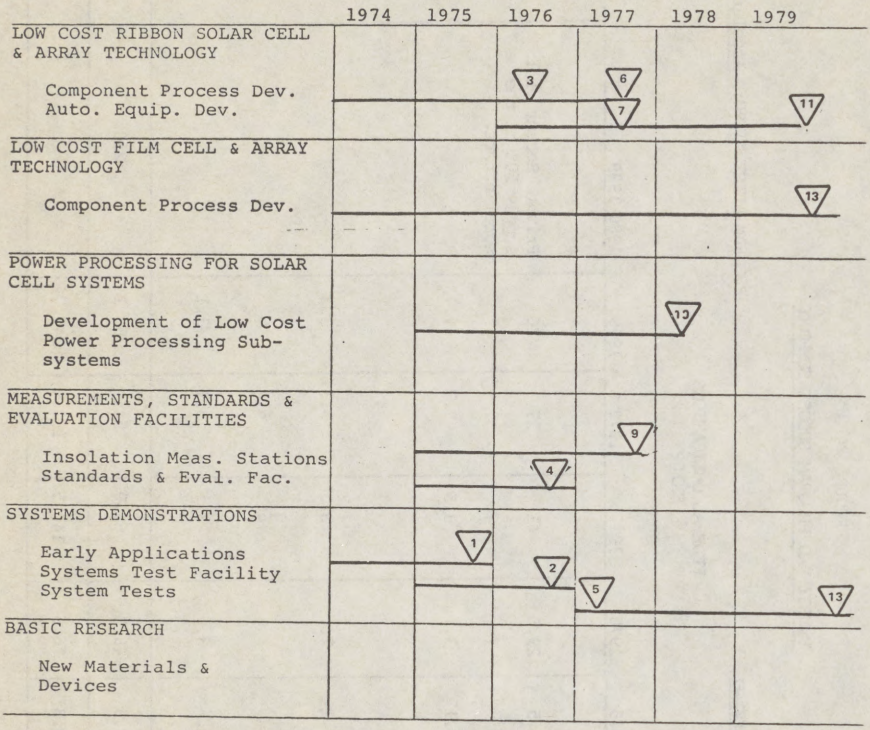
PROGRAM ELEMENT	1975	1976	1977	1978	1979	1980-1989	1990-1
AREA 1: Array Research & Development							
Subprogram 1: Silicon Solar Arrays	11.5	29.5	41	27	26	Private Sector will supply 50% of the total effort.	Private Sector will supply 90% of the effort.
Subprogram 2: Cadmium Sulfide Arrays	6	7	7	7	7		
Subprogram 3: Other Materials & Devices	3.1	3.1	3.5	7.7	7.7		
AREA 2: Systems & Applications							
Subprogram 4: Systems for Onsite Power Generation & Storage	2.1	2.1	3.3	3.3	3.3		
Subprogram 5: Systems for Central Power Generation & Storage	1	1	6	6	6		
Subprogram 6: Test & Evaluation Labs	4.6	3.6	3.1	3.1	3.1		
PROGRAM TOTAL	28.3	48.3	63.9	54.1	53.1	250.	50.
CUMULATIVE TOTAL	28.3	76.6	140.5	194.6	247.7		

Figure 25

PHOTOVOLTAIC R&D PROGRAM FLOW CHART

Terrestrial Photovoltaic 5 yr Minimum Viable Program

Major Milestones Minimum Viable Program



1 Numbers refer to milestones of table C.

FIGURE 26

TABLE C

Photovoltaic, Minimum Viable Programs

Milestones:

1975	1.	Complete ongoing (FY 73 & 74) studies of early applications of terrestrial photovoltaic power systems.
1976	2.	Terrestrial power system demonstration test facility in operation.
	3.	Development of processes for producing low-cost silicon ribons completed.
	4.	Set up and operate standards and calibration laboratory.
	5.	Begin operation of terrestrial environmental test facility.
1977	6.	Complete development of methods forprocessing low-cost semiconductor grade silicon from oxide raw materials.
	7.	Complete design and development of automated production equipment for making photovoltaic cells.
	8.	Complete development of low-cost concentrating/reflecting systems for photovoltaic arrays.
	9.	Complete establishment of solar insolation measuring stations network.
1978	10.	Complete development of low-cost power processing.
1979	11.	Complete design and development of production equipment for making photovoltaic cell modules.
	12.	Complete development of method for fabricating thin film polycrystalline photovoltaic cells.
	13.	Complete initial phase of investigation of alternate materials for low-cost photovoltaic cells.

FIGURE 27

ENERGY R&D PROGRAM BUDGET SUMMARY

PROGRAM NAME: Photovoltaic Conversion

PROGRAM ALTERNATIVE: Minimum Viable

PROGRAM ELEMENT	FUNDING, MILLIONS OF $					
FY	75	76	77	78	79	Total
Single Crystal Solar Cell and Array Technology	3.0	3.7	5.3	8.3	8.3	28.6
Thin Film Cell & Array Technology	1.3	1.3	1.8	2.0	2.2	8.6
Systems for Central Power	0	1.0	1.0	1.0	0	3.0
Test and Evaluation Laboratories	2.4	2.4	1.0	0	0	5.8
Systems for on-site Power	2.8	1.1	1.1	1.1	1.1	7.2
Basic Research on other Materials and Devices	0.8	0.8	0.8	0.8	0.8	4.0
TOTAL	10.3	10.3	11.0	13.2	12.4	57.2

b. Economic electricity generation in central stations is projected to begin by the year 1985 in the SW U.S.A.

3. There are no major barriers in implementation anticipated when the predicted cost figures are reached.

II. STATUS OF TECHNOLOGY - PHOTOVOLAIC CONVERSION

A. Present Status

Present arrays for terrestrial use are now sold at $50/watt (peak), and the manufacturers state they can supply these at $20/watt (peak) in large quantities. A reduction to $5/watt (peak) by automation of the present batch fabrication process appears likely. Continuous growth of single crystal silicon ribbon has been shown to be feasible, making highly automated, continuous cell and array fabrication processes a definite possibility. Improvement in cell efficiency is being pursued at several government, industrial and academic laboratories. Reduction of cost by continuous processes, to less than $0.50/watt (peak) is projected.

Such reductions in cost are not unreasonable based on the experience of the semi-conductor device industry. Thin film cells, now in the research stage, offer the promise of very low cost continuous production by less expensive processes and/or materials. The cost now projected for thin film cells is $0.10/watt (peak).*

*The ratio of peak to average power is approximately two for a system tracking the sun and about 5 for a fixed system.

B. Barriers to Implementation

1. Research barriers:

Current thin film cells require a better understanding of the degradation mechanism in $CdS-Cu_2S$ films and of processes interfering with efficient electron collection in polycrystalline silicon cells. Research is needed to identify low cost processes for large scale Si production. It is desirable to develop a better understanding of storage for use in conjunction with photovoltaics. The projection of energy storage capital costs by the Panel on Energy Storage for the year 2010 is $10/KWH. This low cost will increase the potential utilization of photovoltaic conversion.

2. Development barriers:

Systems at $3000/kilowatt average installed in buildings, can be expected to be produced by the Edge-defined Film-fed Growth (EFG) crystal growing process which has already proven feasible for Si ribbons, but needs intensive development before low cost high efficiency solar cells can be produced from the material. Mass production technology for doping and contacting, power conditioning equipment, and deployment technology must be developed.

3. Implementation barriers:

Economic solar cells will have to be made by mass production processes. A tax credit or other government subsidy may be needed to encourage the building of such a mass production facility.

C. Ongoing R&D Efforts to Overcome Barriers

1. Present levels - domestic

The major source of funding at the present time for research and development of photovoltaic conversion of solar energy for terrestrial applications is the Federal government. The Federal agencies primarily involved are listed below:

	FY '74	FY '73
NSF	$2600K (est)	$ 794K
NASA	$ 179K	$ 130K

Present NSF and NASA supported research includes fourteen active grants and contracts in the areas of: (1) single crystal solar cells (primarily ilicon); (2) thin film cells (primarily polycrystalline silicon and cadmium sulfide); (3) other materials and devices; and (4) systems and applications studies. Other federal agencies with an interest in photovoltaic conversion include DOD, AEC, and DOC (USCG, NOAA, NBS).

Private domestic funding of R&D is currently estimated at $300K. This includes work supported by three solar cell manufacturers to develop systems in the 10 watt to 1 kw range for a variety of terrestrial applications. Available photovoltaic arrays (at $50/watt peak) are competitive with other forms of available power in specialized applications, such as aids to navigation.

Known photovoltaic activities in foreign countries are listed below:

Country	Estimated R&D Costs	Principal Projects
France	-	Several companies and national laboratories are working on single crystal and film cell systems in the 10-100 watt range.
Russia	-	Research on advanced concepts such as vertical junction devices and new materials. Space program based on silicon and gallium arsenide cells. Development of kilowatt sized units for use in remote areas.
Netherlands	-	Development of large scale terrestrial program. Investigation of new materials.
Others	-	Several other countries have small programs (e.g. Poland Belgium, England, Israel).

2. Availability of results of foreign efforts. There is active interchange between scientists in the relevant major U.S. and European research centers through publications, workshops and conferences. However, a more thorough examination of foreign efforts is necessary for the development of the optimum national program.

III. RATIONALE FOR FEDERAL INVOLVEMENT AND INSTITUTIONAL ARRANGEMENT FOR IMPLEMENTATION

A. Why Federal Involvement is Warranted

The solar cell industry survives now only on the small and relatively level market of about $4M per year. The investment and risk required for this solar energy program is too great for private investment now. The terrestrial market is only starting to develop, and without the stimulus of federally-developed low cost arrays, it will not grow fast enough to justify private investment soon enough to impact the energy crisis.

B. Government actions which would stimulate private R&D to insure a dependable, growing market are

1. Guaranteeing an annual market for solar cells and arrays
2. Enacting uniform building codes for solar cell roofs
3. Providing tax advantages for solar cell power systems and production facilities

C. Sensitivity of attitudes to changing conditions

Obviously, increases in price or shortages of electricity from other energy sources will make solar cell systems more attractive and make the market more favorable.

D. Other government action

Requirements for special legislative, regulatory, patent or anti-trust actions have not been identified. Manpower training programs will be needed in the rapidly increasing cell and array manufacturing industry and in the new array installation and maintenance trades.

IV. CRITERIA AND PRIORITIES

A. The Following Criteria Were Used to Judge Subprogram Elements and Priorities

1. The maturity of technology in a given subprogram element e.g., commercial quality single crystal wafer cells have been made in batch process while thin film cells are at the laboratory stage.
2. The potential of the approach e.g., automated wafer cell production is limited in cost reduction potential while film cells offer the most potential for very low cost production.
3. The value of the application to the country e.g., economical production of large scale power is more important than special applications.
4. When the technology is needed for intended applications e.g., automated wafer cell production is needed early or not at all.
5. The options or backups provided e.g., film cells offer a somewhat delayed backup to ribbon cells.
6. The breadth of applicability e.g. supporting research and technology and facilities are needed for many program elements.

B. Application of Criteria

In this subprogram the alternate approaches available and their various levels of maturity and potential gains allow the construction of a strong, well-phased program. Alternate approaches to making low cost arrays are pursued concurrently but with staggered milestones so that as these activities succeed there will be a succession of improvements. Alternate approaches will be pursued within each subprogram element so as to increase the probability of achieving all milestones. There is little likelihood of total failure and very high probability of at least partial, yet significant, success. A strong research effort is expected to lead to even better approaches. System demonstrations will be initiated as soon as the availability of sufficiently low cost arrays can be projected. The pilot plants and earlier subsystems will be built prior to the availability of low cost arrays so as to identify all system problems at an early date. Supporting efforts such as insolation measurements, standards laboratories and systems test facilities are necessary to the entire program and are given high priority. Priorities and schedules for all but the supporting efforts will be reassessed regularly, in light of progress throughout the subprogram, and changed appropriately.

C. <u>Priorities</u>

The subprogram has been planned with the following priorities and early emphasis:

Priority 1. Supporting efforts (measurement, standards, test facilities) need for all parts of subprogram.

Priority 1. Ribbon cell array ($.50/w peak) and associated research Most likely to first achieve a cost that makes large application practical.

Priority 1. Low cost, large volume, high purity silicon and cadmium production processes. Essential for ultimate success of photovoltaic program.

Priority 2. Film cell array ($.10-.30/w peak) and associated research. More risk than ribbon approach but potentially lower cost.

Priority 3. Wafer cells ($5/w peak).

Will stimulate market for special applications and expand the industry early. Not suitable for very large applications.

Priority 3. Research for other materials, processes and storage devices. Strengthens programs, provides further improvements. Milestones cannot be established now.

When low cost cells are available:

Priority 1* On site power demonstration. Most likely first successful large application. (1kw)

Priority 2* Central station demonstration. Very significant impact if successful, but further off. (10 MW)

*Would be given lower priority if low cost array development delayed.

V. ALTERNATIVE R&D PROGRAM

A. Accelerated R&D Program - Milestones and Schedule

The milestones and schedule for the development of photovoltaic systems are shown in Fig. 22. The R&D flow chart is shown in

Figure 23. The first building installations on the order of 0.01 to 1 MW will occur about 1982 and community and industrial plants of about 10 MW will be seen by 1985. The early development of photovoltaics (into the 1980's) will be mostly government supported but as a significant ($100 million/year) market develops, more funding will be provided by the private sector. The first 5 years of development will proceed along parallel lines including single crystal, thin film and the exploration of new materials and processes to reduce costs more than 100 times. It is too early at this time to say whether single crystal silicon, for example, will be more economical and be more advantageous than cadium sulphide thin films. The likelihood of success of the early milestones being reached are high, especially an order of magnitude in cost reduction of photovoltaics, but become increasingly lower as efforts are pushed to cost reductions of 300. Even if the latter is not attained a large market in photovoltaics for building and remote site applications is assured.

1. Cost and Budget Projections

Cost and budget projections are shown in Fig. 24. When demonstrations units become integrated into buildings in the early 1980's, cost sharing by the private sector is envisioned. This funding would come from industrial sources interested in embarking in a new field and may be from both existing and new corporations. Early production of low cost solar arrays may require a guaranteed procurement on the part of the government to attract private capital.

Studies are now underway to get a better estimate of the cost of developing mass produced solar arrays and the funding required to build plants to produce them. The projected Federal outlays in FY 75 thru 79 are shown in Fig. 24. Manpower needs to carry out the intended R&D are small and not considered to be a major impact on the labor market. Facilities needed are laboratory and production lines through the duration of this program. Extensive production would require new manufacturing facilities and expansion of certain materials production capacity such as for silicon, cadmium, copper, plastics, and glass.

2. Other Requirements

All requirements are discussed in 1 above.

3. Management Plan

Management of the photovoltaic development would be by government agencies overseeing work in academic, government and industrial laboratories and facilities. Those government agencies best suited to monitor and direct the research would be used under the overall surveillance of a central agency.

4. Criteria Employed to Construct Program

Due to the current state of the art, various alternative R&D program options have been left open and will be carefully monitored until dropped in favor of more promising approaches. A good deal of experience in photovoltaics has been gained from the space program and this has been used to guide the initial terrestrial program.

5. Dependence on Other R&D Progress

Development of low cost electrical power storage is essential for the use of solar-generated electricity around the clock. Until low cost electrochemical or other methods are available, photovoltaic systems must be limited to peaking or daytime operation to be economically competitive. The projected capital cost of electrical storage for the year 2010 at $10/KWH by the Energy Storage Panel suggests that around-the-clock use of electricity produced by direct conversion will become economical.

6. Acceptability of R&D Program

The successful implementation of photovoltaic power systems will have minimal direct adverse environmental, health or safety effects on animal or plant life. No other programs are dependent upon the success of this program. In contrast to problems incurred by nuclear power plants, photovoltaic systems would find wide public acceptance because of their minimal impact on the environment.

B. Minimum Viable Program

The alternate, minimum viable program plan takes generally the same approach as the first years of the accelerated plan. The program schedule has been laid out for the first five years. In this plan the technology will be developed up to the point where large investments are needed. An automatic wafer cell production plant is excluded, and pilot plants for low cost array production and demonstration systems would be built in later years.

The subprogram elements are essentially the same in both plans, but the minimum plan does not allow pursuing as many alternate approaches within each subprogram element, resulting in a lower probability of success. The probability of substantial reprogramming and program stretchout is significantly higher than for the larger plan.

The schedule is shown in Figure 25 with the milestones described in Fig. 26. Funding levels are shown in Fig. 27. The funding levels beyond 1979 will have to climb to near those of the accelerated program. If not, the later milestones will have to be delayed so long that photovoltaics will not impact the energy crisis impending in the 1990's.

The role of the Federal and private sectors management dependence on other R&D and public acceptability will be the same as for the accelerated plan.

VI. A. <u>Direct Benefits of Implementation</u>

1. Supply, marketing and consuming sectors involvement.

Substantial involvement of these sectors in the production of electricity by photovoltaic conversion is anticipated. In order to achieve 1% of the electrical generating capacity by the year 2000 and more than 10% of the electrical generating capacity by the year 2020 it will be necessary to increase the production of solar cells by more than 10^6 times current production rates. In addition, photovoltaic systems implemented on this scale will require significant supplies of mass produced components for support structures, power conditioning and storage.

2. Size of ultimate market.

The anticipated U.S. demand for electric power in the year 2000 will require 2000 MKW(e) generating capacity. The production of 1% of that amount by photovoltaic conversion in that year would represent a market cost of $1B while the production of 10% of the requirements for the year 2020 would near $36B. The latter figure would require the importation of approximately $100B of crude oil to generate the same amount of electricity if domestic sources were not available.

3. Foreign dependence

The production of electricity by solar energy will result in a one-to-one reduction in the dependence upon foreign sources of fuel. Thus, in the year 2020, a substantial reduction in fuel imports ($100B) would be expected.

4. Reliability

Implementation of national solar photovoltaic systems increases reliability and national security due to the dispersed nature of the solar collection schemes. A large photovoltaic system is easily modularized so that even if sections of the system are destroyed, useful power will still be produced. Furthermore, the system in full sunshine can be switched into service rapidly to meet emergency demand at minimum cost. Also destruction of such a large scale system would not result in the release of toxic materials.

5. Efficiency

National energy utilization efficiency should be increased by the following steps:

a. Reduction in energy transportation losses as a result of local production and utilization of power.

b. Elimination of costly plants to meet peak daily demand which corresponds to maximum solar isolation.

B. Economics of Implementation

Projected costs of two representative systems with high efficiency low cost arrays that are the goals of this subprogram are listed in Fig. 28. The annual cost of capital (interest, taxes, depreciation, maintenance, insurance) was assumed to be 15.5% of investment over a twenty year period. The projected rate of implementation is given in Fig. 29.

FIGURE 28

ECONOMICS OF IMPLEMENTATION - PHOTOVOLTAIC CONVERSION

Type/Time	Average* Power KW	Area $(ft)^2$	Array $ 1 watt (peak)	System $(\$)X10^3$	Operating $\$X10^3/yr)$	Life (yr)	Power Cost (¢/kwh)	Life (yr)	Power Cost (¢/kwh)
Residence/1985	1	420	$0.50	3	0	20	7	30	5
Central Station /1990	10,000	$4.2X10^6$	0.10	7000	100	20	1.8	30	1.2
Residence/1990	1	420	0.10	1	0	20	1.6	30	1.0

* Average output power = Integrated Peak Insolation X (Duty Factor) X (System+Efficiency)
= (constant over 6 hours) X 1/5 X (14%)

\+ System efficiency = (Basic Cell Conversion Eff) X (Packing Factor) X (Power Condition Eff) X (Overall Loss Eff)
= (21%) (85%) (90%) (90%) = 14%

Solar array systems will be capital intensive but have low operating and no fuel costs. Investment costs will eventually be below $1000/kw of installed average generating capacity, and operating costs on the order of those for hydroelectric installations.

A photovoltaic* power plant can come on line in segments during its construction while other systems must be completely built. This means it can start earning sooner. The solar energy industry will have a modest impact on the labor market amounting to no more than a few percent. By the turn of the century, photovoltaic processes could produce a percent or two of the nation's electrical needs saving several billion dollars in fossil fuels per year, much of which would represent imports. This would help in reducing balance of payments deficit. Also the U.S. might export multimillion dollar solar cell systems. Foreign markets should be extensive, especially in regions of abundant sunshine. By the 1990's as fossil fuel supplies become critical, world wide billion dollar markets will develop.

Large scale photovoltaic systems should be technology ready by the early 1980's and available in huge amounts by 1990. Useful lifetime of a system should be between 20 and 30 years and maintenance should be as minimal as the use of hydroelectirc power.

*Photovoltaic systems contain no moving parts. Their lifetime is conservatively estimated at 30 years.

Incentives to help instigate the use of photovoltaics might be done with reduction in taxes because of pollution reduction and savings due to lower transmission line requirements. Also low interest capital would encourage the use of photovoltaic systems for building and central station installations.

Incentives for using photovoltaics will include conservation of limited energy resources (fossil, fissile, water), lower pollution (both particulate and thermal), and reduced dependence on foreign resources and perhaps less vulnerability through dispersed power generation.

C. Impacts of Implementation

1. Natural Resources Required

Sand, the source of silicon, is so abundant as to present no resource limitation. However, the silicon reduction and refinement industry will have to be expanded by two or three orders of magniture to provide for photovoltaics as well as the greatly expanding electronic device industry.

If CdS cells are used predominantly, then about 150,000 tons of cadmium would be needed to generate 1% of the year 2000 U.S. electric power needs exceeding the known U.S. reserves of 130,000 tons available at 1971 prices. The plating industry would be a major competitor for cadmium. Plastics are likely to be the encapsulants and perhaps structural elements of arrays.

The amount of hydrocarbons needed to manufacture the plastic has not been estimated. Aluminum and steel are likely other structural materials and will not be a significant portion of reserves.

2. Energy Inputs Required

   a. Capital Investment

      Residence - $3000/KW avg (1985)/ $1000/kw avg (1990)

      Central Station - $1000/KW avg (1990)

   b. Operation

      The only energy input required is sunshine, for which there is no cost.

3. Compatibility with Existing Energy Systems

   Solar arrays generate DC power and electronic power processing equipment will make it compatible with the distribution network. Residences with photovoltaic systems would probably be tied to the network to draw power at night. For energy conservation and economics, excess photovoltaic power during the day should be fed into the network and the supplier credited. No major barriers to implementing feedback are foreseen; but electric utility companies must agree on the feasibility. In the case of large photovoltaic central stations, provisions will have to be made in the network to accommodate the changes in output due to variations in sunshine. Locally, conventional generating plants would have to adjust their capacity. Accurate, rapid weather forecasting may be needed to provide reaction time. Very efficient long distance transmission would allow averaging generating capacity and load over larger areas. Also, energy needs are usually greatest at solar maximum (summertime) and thus solar systems are in phase with the energy needs.

4. Environmental Impacts of Implementation
   a. Houses: The impact would mainly be esthetic.
   b. Central power stations require large land areas which will entail careful siting considerations.
5. Occupational Health and Safety Considerations

   Solar cells of $CdS-Cu_2S$ have to be carefully encapsulated. The danger of accidental release of Cd and S during a home fire (approx. 12.4 kg/home) must be considered.
6. Other Factors
   a. Impacts on future demography and land-use patterns. The Southwestern U.S. has the highest solar energy potential and presently the lowest land value. A shift of industry to the cheap solar energy source can be expected. One percent of the total land area could provide 75% of today's electrical demand. Fifteen percent of all land is used for agriculture. No significant impact on land use is expected.
   b. Socail costs and benefits

      Benefits: Photovoltaic electricity on houses would make a black-out of a whole region impossible.

c. **Long-term impacts of implementation.** Less dependence upon exhaustible supplies of energy would be a major advantage when using solar energy.

SUBPANEL 9

SOLAR AND OTHER ENERGY SOURCES

APPENDIX A

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SUBPANEL 9

SOLAR AND OTHER ENERGY SOURCES

APPENDIX B

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SUBPANEL 9

SOLAR AND OTHER ENERGY SOURCES

APPENDIX C

BUDGET FACT SHEETS

SUBPANEL 9

SOLAR AND OTHER ENERGY SOURCES

APPENDIX D

PROJECT PROPOSALS CONSIDERED

PROPOSALS

SUBPANEL 9 Sub-Program: Solar

Sub-Program Title	Identification Number	Proponent
1. Measurements and Standards Contributing to the Development of Solar Devices	0903-6608-205500102-0794	DOC
2. Power Production from Solar Energy using Low-Cost Solar Cells	0933-6605-1055-0302-0923	DOD
3. Process Development (Malten Salt)	0932-8309-1280-0202-0825	DOD
4. GUAM Self-Sufficient 150 Megawatt Ponding Thermal Gradient	0932-0407-1179-0202-0827	DOD
5. Solar Energy Research/Photochemical Production of Energetic Compounds	0932-6607-1055-0302-0834	DOD
6. Metal Combustion System for a Thermal Energy Source	0932-0007-1055-5502-0835	DOD
7. Solar Energy Research/Solar Chemical Reactor	0932-6607-1055-0202-0832	DOD
8. Solar Energy Research/Photochemical Storage of Solar Energy	0932-6607-1055-0202-0833	DOD
9. Solar Energy Research/Ocean Thermals and Ocean Currents	0932-6407-1055-0102-0831	DOD
10. Solar Energy Research/Gas Dissociation Solar Power	0932-6607-1055-0202-0830	DOD
11. Solar Energy Research/Improved Gallium Arsenide Solar Cells	0932-6107-1055-0202-0829	DOD
12. Solar Energy Research Solar Energy Collection and Conversion	0932-6107-2055-0202-0828	DOD
13. Advanced Research and Technology	0908-6105-1055-0103-0807	NSF
14. Solar Thermal Conversion Project - Total Energy System for an Industrial Load Center Supplying Process Heat and Electricity	0908-6105-1282-5501-0806	NSF

SUBPANEL 9

Sub-Program Title	Identification Number	Proponent
15. Independent STEC Plant, Energy Displacement Mode	0908-6105-1155-0103-0805	NSF
16. Solar Thermal Conversion Project - Total Energy System for Community or Military Base Applications	0908-6105-1282-5501-0804	NSF
17. Optical Transmission Solar Thermal/Fossil Fuel Hybrid Powerplant Project	0908-6605-1283-5501-0803	NSF
18. Advanced Research and Technology/Supporting Research and Technology	0908-6507-1055-5503-0802	NSF
19. Systems Demonstration Pro-Proof-of-Concept Experiments	0908-6507-1280-5502-0801	NSF
20. Power Generation from the Wind (1) Process or Product Development	0905-6205-1283-0102-0800	EPA
21. (1) Process or Product Development-Power Generation from Tidal or Wave Action of the Ocean	0905-6305-1281-0102-0799	EPA
22. Alternate Energy Sources Solar Generation, Individual Homes	0905-6507-1281-5502-0798	EPA
23. Solar Energy Conversion, Storage, and Utilization	0932-6605-1255-0103-0796	DOD
24. Conversion of Organic Material to Synthetic Fuel	0932-8305-1281-0101-0795	DOD
25. Program Development and Technology	0908-6207-1055-5502-0817	NSF
26. Ocean-Based Pilot Plant	0908-6405-1155-0102-0818	NSF
27. Near-Shore Pilot Plant	0908-6405-1155-0102-0819	NSF
28. Advanced Research and Technology	0908-6405-1155-5502-0820	NSF

SUBPANEL 9

Sub-Program Title	Identification Number	Proponent
29. Conversion of Organic Materials to Energy and Fuel Sources	0908-0005-1283-0101-0821	NSF
30. Photosynthetic Production or Organic Material	0908-6605-1155-0103-0823	NSF
31. Photosynthetic and Biophotochemical Methods to Produce Hydrogen	0908-6610-1055-0102-0824	NSF
32. Manufacture of Vast Quantities of Large Area Polycrystalline Silicon Solar Cells	0933-6107-1055-0302-0772	DOD
33. Photovoltaic Systems for Central Power	0908-6105-1290-0101-0812	NSF
34. Photovoltaic Systems for On-Site Power	0908-6105-1282-0101-8011	NSF
35. Other Materials and Devices	0908-6610-1055-0103-0810	NSF
36. Cadmium Sulfide Solar Cell Arrays	0908-6105-1285-5502-0809	NSF
37. Silicon Solar Cell Arrays	0908-6105-1286-0103-0808	NSF
38. Application of Solar Energy to Production of Synthetic Fuels from Coal	0922-1103-1155-0101-0378	DOI
39. Solar Energy Heat Pump System for Space Heating and Air Conditioning of Buildings	0931-6507-1278-5503-0380	DOD
40. Development and Demonstration of Solar Energy Utilization for Heating and Cooling of Buildings	0931-6507-1255-5502-0382	DOD
41. Terrestrial Photovoltaic Electric Power Generation	0904-6105-1285-5502-0383	NASA
42. Product Development and Testing	0933-0010-1055-3302-0771	DOD
43. Test and Evaluation Laboratories	0908-6110-1077-5502-0813	NSF

SUBPANEL 9

Sub-Program Title	Identification Number	Proponent
44. Small-Scale Wind Generator System (100KWe)	0908-6210-1055-5501-0814	NSF
45. MW-Scale Wind Conversion Systems (.5-2 MWe)	0908-6210-1055-0103-0815	NSF
46. Large Multiple Unit Systems (10MWe and 100MWe Scale)	0908-6205-1281-5501-0816	NSF
47. a. Pilot-Plant Design, Construction, and Testing b. Materials Technology c. Component Design Testing	0935-6607-1285-5501-0384	DOD
48. Solar Energy for Air Force Requirements	0933-6610-1055-0302-0765	DOD
49. Improve Solar Cell Technology to Reduce the Weight and Cube Requirements per Kw	0931-6607-1255-0103-0379	DOD
50. Residential and Commercial Utilization of Solar, Wind, and Waste Product Energy Sources	0916-6207-1055-0502-0386	College of Engineering, Kansas State University
51. Solar Augmentation of Heat Pump Performance for Space Heating and Cooling	0955-6507-1276-5501-0396	Aerojet Nuclear University of Utah
52. Conversion of Organic Wastes to Fuel Gases or Oil	0922-8303-1255-0102-0375	DOI
53. Solar-Thermal Electric Power Generating System	0904-6105-1183-0101-0376	NASA
54. Materials Research on Solar Energy	0922-6105-1189-0101-0377	DOI
55. Tidal Power, Thermal Gradients, Wind Power	0922-5503-1155-0101-0385	DOI
56. Definition of a Technology Development and Verification Program for the Satellite Solar Power Station	0914-6105-2055-5502-0387	Arthur D. Little Grumman Aerospace Corporation Raytheon Company Textron, Inc.

SUBPANEL 9

Sub-Program Title	Identification Number	Proponent
57. No Title	0931-6607-1185-0102-0389	DOD
58. Central Station Solar Power System	0914-6105-1283-0301-0394	Atomics Internati
59. Solar House Heater with MgO/ $Mg(OH)_2$ for Heat Storage	0914-6506-1279-0302-0395	Atomics Internati
60. Solar Heating and Cooling of Buildings	0904-6508-1280-0102-0390	NASA
61. Conversion of Speciality Grown Crops to Clean Gaseous Liquid and Solid Fuels	0904-6605-1285-5502-0391	NASA
62. Wind-Driven Electric Power Generating Systems	0904-6205-1179-5501-0392	NASA
63. Ocean-Thermal-Gradient Electric Power Generating Systems	0904-6405-1283-0102-0393	NASA
64. Biological Conversion of Solar Energy	0901-6607-1281-5501-0403	AEC
65. Solar Total Energy Program "SOLAR COMMUNITY"	0901-6607-1280-0201-0404	AEC
66. Development of the Biogas Process for Conversion of Waste to Fuel Gas and By-Products	0916-8309-1280-0501-0402	Institute of Gas Technology
67. Pilot Process for the Low Pressure Flash Pyrolysis of Organic Wastes	0915-8302-1182-0403-0401	W. P. Walawender and L. T. Fan Engineering Depar ment, Kansas St University
68. Production of SNG and Low-BTU Gas from Non-Fossil Renewable Organic Carbon	0916-3203-1290-0501-0400	IGT
69. Heat Recovery from the Disposal of Municipal Waste	0904-8109-1283-0301-0399	Atomics Internati
70. Solar Augmentation (Super Heating) for Geothermal Power Plant	0955-6655-1280-5501-0398	Aerojet Nuclear Idaho State University

SUBPANEL 9

Sub-Program Title	Identification Number	Proponent
71. Development of a Solar-Powered Environmental Control Unit	0916-6508-1280-0502-0397	Institute of Gas Technology
72. Program Definition, Preliminary System Design, Critical Component Development, and System Design, Fabrication and Demonstration	0916-6508-1055-0403-0976	ANS
73. Solar Energy Installation for the Heating and Cooling of Demonstration Office Buildings, and Preparation for Evaluation of Environmental and Energy Conservation Features	0913-6108-1255-0102-1133	GSA
74. Solar Energy System for Use in Cold Regions	0931-6507-1255-0103-0381	DOD
75. Demonstration Plant	0932-6105-1185-0203-1079	DOD
76. High Efficiency Solar and Thermal Static Energy Conversion	0931-6105-1185-0203-1079	DOD
77. Refuse Preparation and Burning	0914-6605-1055-0302-1087	AIF
78. Alternative Energy Source Biochemical Conversion on Municipal Wastes and Sewage Sludge to a Clean Burning Liquid Fuel	0905-8109-1279-5501-0843	EPA
79. Materials Research on Development	0932-0010-1053-0202-0530	DOD
80. Alternative Energy Source-Parolysis Conversion of Solid Wastes to Clean Burning Gaseous of Liquid Fuels	0905-8309-1279-5501-0845	EPA
81. Alternative Energy Source Development of Solar Energy Plantation Concept	0905-6609-1280-0102-0847	EPA

SUBPANEL 9

Sub-Program Title	Identification Number	Proponent
82. Alternative Energy Source-Energy Conversion and Environmental Improvement by Conversion of Cattle Feed Lot Waste to Ammonia Synthesis Gas	0905-8309-1279-5501-0844	EPA
83. Utilization of Waste Products	0901-8103-1255-0202-0184	AEC
84. Hanford Area Power Produced from Waste - An Engineering Demonstration Program Energy from Solid Waste by Pyrolysis Incineration	0901-8205-1278-0203-0426	AEC
85. Economic Utilization of Wood Wastes and Other Renewable Resources	0901-8205-1280-5503-0247	AEC
86. Process Development - Materials Recovery from Municipal Refuse Followed by Energy Recovery from Burning Combustible Fraction in a Cyclone Furnace at the Allin Steam Plant	0907-8209-1280-0103-0842	TVA
87. Alternate Energy Source	0905-8309-1282-5501-0846	EPA
88. Marine Environment Powered Energy Sources	0917-0007-1279-0302-1119	DOT
89. Conversion of Manure to Natural Gas	0914-8309-2055-0302-1103	L. B. Associates
90. Alternate Energy Source Development and Demonstration of Technologies Needed for Use of Urban Wastes as Supplemental Fuels in Fossil-Fuel Fired Boilers	0905-8109-1282-0103-0719	EPA
91. Extraction and Reclamation Technology - Energy from Oil Spill Cleanup Products	0905-2409-1281-0103-0848	EPA
92. Process Development (Wet Air)	0932-8307-1280-0302-0836	DOD
93. Water Pollution Control Technology Process of Development for Utilization of Waste Oils	0905-2409-1278-5503-0849	EPA

Sub-Program Title	Identification Number	Proponent
94. Supplementary Energy Source/ Wind Power	0901-6205-1179-0201-1155	AEC
95. Development, construction and demonstration of an ocean thermal gradient power plant for production and utilization of hydrogen as an energy carrier.	0915-6305-1179-0302-1154	Johns Hopkins University
96. Low temperature energy storage for space heating and absorptive air conditioning	0911-6506-2055-0103-1153	DOD
97. Systems design, testing and demonstration of solar heating and cooling of greenhouses for production of ornamentals and vegetables	0919-6105-1055-0103-1156	USDA

The attached listing includes the project titles and submitting organization of the proposals considered by the panel.

Each recommended subprogram contains research and development projects comparable to those identified below although in many cases, the timing, magnitude, or prime emphasis of the proposed projects will require modification to fit the subprogram. No effort has been made to choose between comparable or overlapping projects.

The distribution of the proposals among the subprograms is summarized below. The numbers refer to entries in the attached listing of titles.

1. Heating and Cooling of Buildings - 1, 22, 39, 40, 42, 48, 50, 51, 59, 60, 65, 71, 72, 73, 74
2. Solar Thermal - 5, 7, 8, 10, 12, 13, 14, 15, 16, 17, 18, 19, 23, 38, 47, 53, 54, 56, 57, 58, 70, 76, 79, 96, 97
3. Wind - 20, 25, 44, 45, 46, 55, 62, 94
4. Bio-conversion - 3, 24, 29, 30, 31, 52, 61, 64, 66, 67, 68, 69, 75, 77, 78, 80, 81, 82, 83, 84, 85, 86, 87, 89, 90, 92
5. Ocean Thermal - 4, 9, 26, 27, 28, 54, 63, 95
6. Photovoltaic - 1, 2, 11, 32, 33, 34, 35, 36, 37, 41, 43, 49

In addition to the above proposals, the following proposals were dealt with as noted:

Proposal #6 deals with a metal to metal-oxide combustion energy source. As the proposal points out, this has applications in specialized transportation situations (submarines) but the process does not appear to have a large impact on the total national energy production and was not considered further.

Proposals 21, 55, and 88 discuss the possibility of using tides and/or waves as energy sources both for general needs and for specialized marine applications (buoys, remote stations). The amount of energy available from tides or waves in ocean regions adjacent to the U. S. does not appear to be significant relative to the total national energy need and these proposals were not considered further. The panel noted that photovoltaic devices might provide an alternative in some of the suggested application areas.

Proposals 91, 93 discuss the combustion of oil wastes and the cleanup products from oil spillages as possible energy sources. While important environmentally, oil waste and oil spillage does not appear to be significant relative to the total national energy need and the proposal was not considered further. Such a process might easily be incorporated as an alternate sub system within a bio-conversion energy system.

Mr. McCormack. Our next witness is Dr. Fletcher.

STATEMENT OF DR. JAMES C. FLETCHER, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY HARRISON H. SCHMITT, ASSISTANT ADMINISTRATOR FOR ENERGY PROGRAMS

Mr. McCormack. Would you care to insert your statement in the record?

Dr. Fletcher. Yes, Mr. Chairman.

Mr. McCormack. With no objection, your statement will be included in the record at this point in its entirety, and you may proceed as you wish.

[The statement follows:]

Statement of

Dr. James C. Fletcher
Administrator

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Energy
Committee on Science and Astronautics
House of Representatives

Mr. Chairman and Members of the Subcommittee:

I am pleased to have this opportunity to present the views of the National Aeronautics and Space Administration on H.R. 15612, the "Solar Energy Research, Development and Demonstration Act of 1974."

This bill would establish an administrative structure and funding arrangement for the United States to conduct a timely and effective solar energy research, development and demonstration program.

NASA strongly supports the purposes of H.R. 15612. As we have testified previously, we are convinced that solar energy, in all its forms, has the potential for becoming a significant and economically competitive element of our total national energy supply. A well-planned and aggressive research and demonstration program, of course, will be necessary to realize the potential of this energy source.

During the past year or more, NASA has actively supported National energy planning, with such efforts as last year's initial Solar Energy Report, jointly supported by NSF and NASA. Last fall, NASA provided technical support to the formulation of the President's Five-Year Energy R&D Plan prepared under the leadership of Chairman Ray of the Atomic Energy Commission. And, as you know, NASA has been working for some time in cooperation with the National Science Foundation (NSF) to assist them in broad areas of their solar energy programs. Using funds transferred from NSF, NASA already has initiated work in the conversion of wind energy to power. Our first wind energy contracts should be awarded in the near future, and a comprehensive program plan has been drafted which outlines objectives for the NASA portion of the wind energy project. We also are working actively with the NSF to define appropriate NASA Project responsibilities in the areas of low cost solar cell systems. An additional number of project proposals have been submitted to NSF for inclusion in the President's Five-Year Program plans for the solar energy program area. These projects are currently being reviewed, and we are hopeful that we can begin to implement them soon.

In an area related in important ways to solar energy, NASA is developing selected energy storage research projects to be conducted during FY 1976 for the AEC as part of the President's Five-year Program Plan in Energy Storage. Energy storage, as you know, is a very critical element in the eventual success and commercial viability of most solar energy-use concepts.

On its own, NASA has several active projects related to solar energy. Summaries of these projects are contained in our report to the Senate Committee on Aeronautical and Space Sciences. This work includes both the terrestrial applications of our technology base in energy conversion and environmental control and the examination of critical technologies related to satellite solar power.

This brief review of our current efforts in solar energy underlines the importance NASA attaches to the eventual development and demonstration of this abundant resource. NASA fully supports the need for a comprehensive, effectively managed, solar energy research, development and demonstration program.

With regard to H.R. 15612 specifically, I would make the following observations:

NASA favors the general management intent of this bill. I would, however, like to remark on certain provisions of the bill which we feel require clarification or possibly changes to increase the effectiveness of this legislation.

As written, this bill would establish a Solar Energy Coordination and Management Project. The project would be composed of six members: the Administrator of the Federal Energy Administration (FEA), who would serve as Chairman;

an Assistant Director of the National Science Foundation (NSF); an Assistant Secretary of Housing and Urban Development (HUD); a member of the Federal Power Commission (FPC); an Associate Administrator of the National Aeronautics and Space Administration (NASA); and, the General Manager of the Atomic Energy Commission (AEC).

This body would be instrumental in shaping critical national policy regarding use of an important energy resource. It is vital that the leadership reflect a coordinated national energy organization policy. I would recommend, therefore, that the Chairman of this Project be appointed by the President rather than designated by statute.

Under the provisions of this legislation, NASA would be responsible for "the provision of management capability" and for developing necessary technologies. The AEC would also be responsible for developing necessary technologies requested by the Project.

Both agencies are well qualified to perform this general role. However, efforts of this kind are most efficiently implemented through one agency, usually the one with the most applicable experience, assuming the overall implementation responsibility.

Section 5 of this bill states that, "Upon request of the Project, the head of any such agency shall detail or assign, on a reimbursable basis or otherwise, any of the personnel of such energy to the Project to assist it in carrying out its responsibilities under this Act." This would appear to give the interagency Project a certain amount of direct line authority over NASA and the other agencies involved. I am sure that this is not the intent of the bill. Obviously, the head of each agency must retain the power to assign personnel in a manner reflecting the responsibilities and priorities of his agency. I would recommend that this interagency Project be a coordinating body without direct line authority over NASA and the other agencies. However, if the Project were to have line management authority, funding should be direct and not through another agency as presently called for in this legislation.

I note that procedures by which the Project would rule itself or arrive at its decisions are not specified. For instance, it is not clear whether the Project would act only unanimously or by majority; or whether the Chairman would have the power to make unilateral decisions.

This bill would authorize $2 million to be appropriated to NSF for Fiscal Year 1976 for "use in the preparation of the comprehensive program definition under Section 18." At this time, NASA is not in a position to estimate accurately the dollar resources required to perform the comprehensive program definition.

Under the provisions of H.R. 15612, the Project management personnel would be drawn from senior personnel of several agencies. While I am sure all these representatives would perform their duties conscientiously and in good faith, they would reasonably be expected to have responsibilities to their individual agencies. The importance and complexity of the solar energy program envisaged in H.R. 15612 requires a centralized program management structure with direct authority over responsible project management. This would permit competing technologies, approaches and problems to be efficiently and satisfactorily reconciled within a framework responsive to National needs. Competent experienced and dedicated program management personnel would need eventually to be assigned full-time. These program management personnel should be broadly experienced in both management and in the scientific and technological disciplines relevant to solar energy research and demonstration programs. They should have full-time responsibility for overseeing these research and demonstration programs and have authority over at least the policy and budgetary aspects of major program elements.

We therefore agree with the provision in H.R. 15612 which would transfer management responsibility for solar energy R&D to the Energy Research and Development Administration (ERDA) once it is established. Section 16 of the bill would provide for the transfer of all R&D functions to ERDA within 60 days after its creation. NASA believes that a general transfer provision such as this is essential; however, it is important that this transfer occur without major disruption of on-going projects.

NASA fully supports the goals described by H.R. 15612. Solar energy appears to offer great potential for reducing the Nation's dependence on other less desirable or less available forms of energy. We also agree that once ERDA is established it should have the responsibility of overseeing the comprehensive program necessary to exploit the potential of solar energy.

Mr. Chairman, this concludes my testimony.

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Dr. FLETCHER. I would like to introduce Jack Schmitt, my Assistant Administrator for Energy Programs. He will help me if we get into some technical difficulties.

Mr. McCORMACK. Dr. Schmitt is always welcome.

Dr. FLETCHER. Mr. Chairman, I would like to skip the part of my testimony which deals with NASA capabilities in the solar energy field, since they are well known to the committee and we have been involved with this principal source of energy for 15 years.

I think most of the things that we are doing are well known. I will skip right to the material on the bottom of page 3, which discusses the observations on the bill itself.

As written, this bill would establish a solar energy coordination and management project. The project would be composed of six members: The Administrator of the Federal Energy Administration (FEA), who would serve as Chairman; an Assistant Director of the National Science Foundation (NSF); an Assistant Secretary of Housing and Urban Development (HUD); a member of the Federal Power Commission (FPC); an Associate Administrator of the National Aeronautics and Space Administration (NASA); and the general manager of the Atomic Energy Commission (AEC).

This body would be instrumental in shaping critical national policy regarding use of an important energy resource. It is vital that the leadership reflect a coordinated national energy organization policy. I would recommend, therefore, that the chairman of this project be appointed by the President rather than designated by statute.

Under the provisions of this legislation, NASA would be responsible for "the provision of management capability" and for developing necessary technologies. The AEC would also be responsible for developing necessary technologies requested by the project.

Both agencies are well qualified to perform this general role. However, efforts of this kind are most efficiently implemented through one agency, usually the one with the most applicable experience, assuming the overall implementation responsibility.

Section 5 of this bill states that: "Upon request of the project, the head of any such agency shall detail or assign, on a reimbursable basis or otherwise, any of the personnel of such energy to the project to assist it in carrying out its responsibilities under this act." This would appear to give the interagency project a certain amount of direct line authority over NASA and the other agencies involved. I am sure that this is not the intent of the bill.

Obviously, the head of each agency must retain the power to assign personnel in a manner reflecting the responsibilities and priorities of his agency. I would recommend that this interagency project be a coordinating body without direct line authority over NASA and the other agencies. However, if the project were to have line management authority, funding should be direct and not through another agency as presently called for in this legislation.

I would like to move to the project management personnel on page 6.

Under the provisions of H.R. 15612, the project management personnel would be drawn from senior personnel of several agencies. While I am sure all these representatives would perform their duties conscientiously and in good faith, they would reasonably be expected to have responsibilities to their individual agencies. The importance and complexity of the solar energy program envisaged in H.R. 15612 requires a centralized program management structure with direct authority over responsible project management. This would permit competing technologies, approaches, and problems to be efficiently and satisfactorily reconciled within a framework responsive to national needs.

Competent experienced and dedicated program management personnel would eventually need to be assigned full time. These program managment personnel should be broadly experienced in both management and in the scientific and technological disciplines relevant to solar energy research and demonstration programs. They should have full-time responsibility for overseeing these research and demonstration programs and have authority over at least the policy and budgetary aspects of major program elements.

We therefore agree with the provision in H.R. 15612 which would transfer management responsibility for solar energy R. & D. to the Energy Research and Development Administration (ERDA) once it is established. Section 16 of the bill would provide for the transfer of all R. & D. functions to ERDA within 60 days after its creation. NASA believes that a general transfer provision such as this is essential; however, it is important that this transfer occur without major disruption of ongoing projects.

NASA fully supports the goals described by H.R. 15612. Solar energy appears to offer great potential for reducing the Nation's dependence on other less desirable or less available forms of energy. We also agree that once ERDA is established, it should have the responsibility of overseeing the comprehensive program necessary to exploit the potential of solar energy.

Mr. Chairman, this concludes my testimony.

Mr. McCormack. Thank you, Dr. Fletcher.

I am going to try to ask questions of any one of you or all together.

Mr. Brown, would you like to go first?

If not, first of all, I want to thank the three of you for your testimony. I particularly want to thank you for the constructive recommendations that you have made and the points that you have raised with respect to organizational and structural problems that you foresee.

Your testimony, along with that that we have already received, particularly from Chairman Nassikas, is going to be helpful to us as we try to write this bill in final form.

I have several questions I would like to ask, if I can collect them from the three statements here. First of all, Dr. Bisplinghoff, the concept of this bill now is to combine participation of five agencies; three involved in research and development and demonstration, NASA, NSF, and AEC, and two that are user groups, HUD and Federal Power Commission. We are trying to take advantage of the competence of each. We are doing this, particularly if we go along with the recommendation of OMB, without changing the organic acts.

Then, we are working within the existing statutory authority of each of the agencies. Do you see this as any problem? Do you think this will work? We recognize the fact that the NSF has responsibility for research and development through this concept. This limitation does not apply to NASA or AEC. We are aware of the outstanding basic research that NSF has done and is carrying forward in many areas, specifically this one.

Do you think this is a workable arrangment, assuming that we have a chairman appointed by the President?

Dr. BISPLINGHOFF. Mr. Chairman, as you pointed out, the NSF does not have a development and demonstration authority nor do we seek such authority. We believe that we can work most effectively in the basic and applied research areas. There is one thing to consider. It would be useless to funnel money through NSF for development and demonstration projects unless NSF has development and demonstration authority; otherwise, the money for such programs would be authorized and appropriated to an agency that does not have the necessary development authority. It is my recollection that one of the provisions that the bill now has is that the money would be funneled through the National Science Foundation. We believe it would be more workable to appropriate the money directly to the agencies that would be doing the development and demonstration, rather than funneling it through the NSF.

Mr. MCCORMACK. I appreciate that comment, particularly coming from you. As you are all aware, it has not been easy to put this thing together. We are trying to assemble what is really an interim functioning agency to get the show on the road while still trying to live within the existing constraints that we have, designation of NSF as the lead agency in solar energy, the fact that AEC and NASA are extremely valuable and operative in this field, and the fact that we have programs for authorizing funds in the future. Clearly, you recognize, we have not tried to authorize any funds ourselves in this bill. We have recognized this as something that has to be done on a year-to-year basis. It depends somewhat on the structure that does evolve, and thus your recommendation could be extremely valuable. It may be that we could work this out, having progressed as far as we have now progressed, from the writing of this bill to these hearings we have had today and the discussions that we have had surrounding them. It could be an extremely valuable suggestion, and I appreciate that.

I want to congratulate you. I am sure that we are all expressing our regrets that you are leaving us, but I know all of us here want to congratulate you on your appointment to the presidency of the University of Missouri. It is the University of Missouri?

Dr. BISPLINGHOFF. Yes, sir.

Mr. MCCORMACK. We all wish you well and congratulate you for an outstanding career in Government and hope that you will have an equally outstanding one in more tranquil surroundings; we hope they are more tranquil on the college campus.

Dr. BISPLINGHOFF. Thank you very much, sir.

Mr. MCCORMACK. If I may, I will turn for a moment to Commissioner Ray. First, I have a specific question above and beyond the others I asked. You mentioned in your commentary that flat-plate research was being carried out at Los Alamos, research on flat-plate collectors. The last time I was there, there was a plan to use solar heating and cooling for the new convention center and library authorized for construction. Are we going to go through with this plan to solar heat that building or not?

Dr. RAY. In the fiscal year 1975 appropriation bill which just passed the Senate yesterday, funds are included for starting the construction of that particular building. To the best of my knowledge, the plans still include the solar heating provision, but I might ask one of our technical people if that is correct.

Dr. VANDERRYN. Yes, we still are looking at the building design but present plans are that we would hope to include these flat-plate collectors in the building design.

Dr. RAY. That gives them onsite location for the testing, and people who work in the building would be very good experimental subjects to try out the new procedures on.

Mr. MCCORMACK. I want to say that I am glad. I fought pretty hard for that particular authorization and that specific line item in the bill. I saw the concept, and I hope it works out well. You will be publishing cost information on these in very early reports?

Dr. RAY. We will give them all support in this program.

Mr. MCCORMACK. I want to pick up the points Dr. Fletcher made here. I am not sure I will be able to remember them now.

You were not here perhaps when Mr. Zarb talked, in his testimony, about the President's appointing the chairman rather than our designating him in the bill. I am sure the committee will consider this. In your testimony you commented on what I guess I would describe as an ambiguity or potential ambiguity in the bill. You say, with respect to the responsibilities of NASA and AEC, that technology development should be implemented through one agency. Here again, we clearly are floundering, trying to accomplish a goal and not being absolutely certain how to do it.

In many instances, one leaves a gray area on the interface and does not try to define sharply certain areas of jurisdictional responsibility. I think there is some wisdom in not trying to be too specific, but we are flexible there, and it seems to me it should be possible to work these problems out under this so they would function under a chairman of the project.

I wonder if you can recommend language that would clarify the situation and would still give the functioning organization the opportunity and flexibility to take advantage of the obvious expertise of both AEC and NASA.

Dr. FLETCHER. We would be happy to recommend such langauge.

Mr. MCCORMACK. When one writes legislation, one does the best he can and realizes it is always going to be far from perfect. We are not frozen on the language. We certainly would welcome any constructive suggestion or criticism that you can make. We have had a great deal of criticism from Mr. Nassikas. He analyzed the legislation carefully and recommended a number of changes that we are seriously considering.

You mentioned on page 6 of your testimony the problem of direct authority. This was already raised before, and we intend to try to clean that up so there will be ambiguity in the language. We welcome that criticism and intend to try to straighten it out. If you have any specific suggestion as to language, it would be a help to us.

I want to express my appreciation for the work that Dr. Schmitt did on the geothermal bill in this particular area, and any contribution that you can make will be appreciated.

Mr. McCormack. Mr. Brown?

Mr. Brown. Thank you, Mr. Chairman.

I have an item for discussion rather than a question. I have a sense that all three of our distinguished witnesses here have certain information indicating that this legislation represents an unnecessary movement in areas which are handled adequately administratively. You may well be correct. I won't vouch for that, but I want to suggest one reason you might not be correct, even though there is no basic disagreement between this subcommittee or the full committee or the Congress and your agencies with regard to the importance of solar energy or even the level of funding. One of our primary problems as a Nation now is to gain national recognition of the importance of moving in certain directions with regard to solutions to the energy problem, including the direction of solar energy.

The role of the Congress can be extremely important in creating a climate within the various communities which will have to be moved—the industrial community, the labor community, and professionals in the fields of energy and building, and all other energy-consuming industries.

One way you prove to them that action is needed is by demonstrating an aggressive concern at the highest level. I would say that the action of this Congress, particularly the leadership of Mr. McCormack, is demonstrating this kind of concern, and it is indicating to the public as a whole the Congress has this kind of concern.

We don't want to pass legislation that is going to do any harm to any of the agencies that you represent, I don't think that you have to worry about that. This committee is very friendly to all of your agencies. We are not quite so friendly to OMB. But since Mr. Zarb has left, we don't have to worry about that.

What we want to do is move forward in a visible, aggressive way with a demonstration of our concern to keep this program going on the right track. We need your help in making sure that we don't make mistakes, but I don't think that you need to temper your enthusiasm with a fear that we are going to try to do harm to any of you.

I sense this in all of your testimony. I hope that you will not carry that away from this witness room.

Dr. Ray. If I might respond quickly to say that if there was any connotation of worry or fear on the part of AEC, I want to remove that. Our greatest concern or worry is that we won't be able to devote enough of our efforts to solar research. We certainly want to do whatever is proper and appropriate to use the kind of capability that AEC possesses. We do feel that the emphasis on solar energy, which is coming as a result of these hearings and this legislation, is a loud and clear signal that the country needs to get the support and to move forward with this type of research.

A lot of people have the simplistic feeling that the role of the Federal Government is to provide the money, not ask any questions and let others do the work. It is not true. The agencies will respond to the guidance, the expression of intent and concern on the part of the Congress that I think is stimulating not only to Federal agencies but to the country at large. We are very much in favor of that.

Mr. Brown. There will always be a certain amount of competition, shall we say, between agencies as to who gets what part of some developing program. To a degree this is a healthy situation, but I can assure all of you that without regard to whether this legislation is passed, this committee and other committees of the Congress are going to be on your back all the time through the oversight function, and other ways, to make sure that you are moving in a way which reflects congressional intent as enacted in legislation and which accomplishes the goals that we have set in the most efficient way.

That is a separate worry which I don't think we need have.

Mr. McCormack. Do you wish to comment?

Dr. Fletcher. I was going to say essentially, Mr. Chairman, what Dr. Ray said. If there were any indication of worry on our part, and I suspect Dr. Bisplinghoff would have the same statement, it was not intended.

One of the problems we get into when we start to summarize is that we sometimes pick out the points that are critical of the bill, and we leave out the points that are favorable to the bill. That was not our intent.

Mr. Brown. There are ways that we can go wrong. Obviously, we expect all of you to point out any mistakes. I would not want in any legislation here to convert the NSF into something different from what it is today, basically the backbone of our Federal effort in basic science. I think it should remain that, not become an agency for development of particular projects or things of that sort.

These are critical times in moving toward solutions of the energy field, and I wouldn't be too unhappy if NSF is compromised a tiny bit at this stage to get things moving. I wouldn't want it on a long-term basis.

Dr. Bisplinghoff. Could I comment on that? I think we are getting to be old hands at this in the NSF. We have been getting things started from the promise of science, things that we think have a lot of promise, and can be applied to help the country's problems. Then, NSF has been passing these off to other agencies and to industry. We think this is a perfectly normal mode of activity for us.

Twenty years ago, we started to roll this little snowball called solar energy, and now it is a huge snowball, and we need help in moving it into practical application. We support completely what you are trying to do, and we would like to help you.

Mr. Brown. We appreciate that, and my comments were not in any way meant to disparage the real help all of you have given us this morning in putting this bill into shape so it will meet all our needs and contribute to the solution of national problems.

I have no further comments.

Mr. McCormack. Thank you, Mr. Chairman. Mr. Pickle?

Mr. Pickle. First, Dr. Bisplinghoff, I was impressed with your analogy relating our energy problems to a snowball. I wanted to ask you and the panel two or three questions, one of which was asked yesterday in hearings. I want to ask it again for comments.

In the Housing Act, title 7, specific provision was made for innovation with respect to new communities. HUD testified yesterday, I believe, that this is a logical place for a lot of innovation to take place. Assuming that would be your intent, or rather, in addition, assuming the normal application or mission that ran a plow through this general program, what additional steps, if any, could be taken with respect to innovation in new communities?

Mr. BISPLINGHOFF. Are you directing that to me?

Mr. PICKLE. I guess you would be the logical one. I aim at you.

Mr. BISPLINGHOFF. I am not familiar with all the details of that program, Congressman Pickle, but I would like to say that we in the NSF believe that it is very important for us to work with HUD in connection with bringing the technology of heating and cooling of buildings to practical fruition. We believe that HUD is the mission agency in the Federal Government that fully understands the environment in which buildings are constructed and developments take place, and we feel very strongly that it is quite important in any activity such as the bill you are now working on, or in the present mode of activity of the administration, to work closely with HUD.

We have done this in our program. HUD has been involved in those activities right from the very beginning.

Mr. PICKLE. Then we are limited by our available funds as much as any one factor?

Dr. BISPLINGHOFF. Yes, sir.

Mr. PICKLE. Aside from that and assuming we have the funds, would it be your feeling that we ought to be as bold in this field as we can?

Dr. BISPLINGHOFF. It is my feeling; yes, sir.

Mr. PICKLE. Thank you, Dr. Bisplinghoff.

Let me ask another question of the group. This was asked a few minutes earlier. We have, it seems to me, certain nontechnical barriers in this overall problem making it practical and making it possible to install a solar energy project.

I raised this question with the OMB representative, and he referred me to a part of the bill which was in the innovation section. This section referred to utilization on page 19. I read that again. It seemed to me that the emphasis is being placed on commercial application of solar energy technology and research. At least this section makes specific reference to the commercial application. It would seem to me that we ought to broaden that section and include a wider spectrum. Is that your feeling, or do you want to comment?

Dr. FLETCHER. Mr. Chairman.

Mr. MCCORMACK. Go ahead.

Dr. FLETCHER. I would like to comment on that. Probably Mr. McCormack was going to. We do have another bill, which is called the Solar Heating and Cooling Demonstration Act of 1974, H.R. 11864. It is a very important bill, and the intent of that bill is to do just what you say; namely, emphasize the housing aspects of or potential of solar heating and cooling, and to gradually get a customer interest in building homes with solar heating and cooling units. I think the reason this perhaps emphasizes the commercial part of it is because that was not emphasized in the previous bill.

I think the chairman could indicate the intent better than I could.

Mr. MCCORMACK. If the gentleman would yield.

I believe we put a wrong connotation on the word "commercial." Here we mean commercialization of energy and talking about taking these various concepts for converting solar energy into useful sources of energy, useful forms of energy, and using them commercially. That is, to heat homes and buildings, generate electricity, make fuel, and this sort of thing, in the commerce of this country, rather than talking about commercial facilities.

Mr. Pickle. I would hope we might have a broader language in this particular section to make that a little clearer. My reaction is that, as it stands, we are talking about commercial buildings, and I don't think that altogether relates to the problem I raise—the problem of initial capital investment.

I think that is something the committee ought to consider as we consider the final markup of this bill.

The last question I want to ask you is this:

There is a section in the bill that establishes the Solar Energy Research Institute. That is a short section, and I am glad to see it in there. I am concerned about what this type of facility would be. You say there is a solar research institute. Do you mean as far as your views are concerned it would be a single institution—only one? Could we have others?

The bill says it may be located at any new or existing Federal laboratory. Do you refer to national laboratories? What do you envision as the best way to create that institute so that at a place or places in the United States we may have an institute or several institutes emphasizing solar research?

Dr. Fletcher. Of course, I do not know what the intent of the bill was, but in my judgment you ought to start out with a place that can focus the research. This can later become a lead institute or something of that sort if you wish.

My way of looking at it is that you should establish an institute, hopefully at an existing facility somewhere in the Federal Government since it would save on facility costs and save the trouble of setting up a new one, but not necessarily an existing institute. It would be the focal point for all solar energy research. That does not mean universities and Government agencies would not also do research.

This institute, though, would tend to focus that research.

Mr. Pickle. Under the present language, I have the feeling that certain non-profit facilities such as the university or foundation might not be eligible to be so designated.

Mr. McCormack. Mr. Pickle, if I may comment on your question, the concept of a solar research institute is to create literally a critical mass of technical and scientific expertise and manpower in one place so that they could move forward with the various research and development programs and concepts that normally do not evolve and cannot be handled by individuals working by themselves or even small groups of people and that frequently cannot be handled at most universities because they do not have the facilities or the equipment.

When you get right down to it, solar energy research and development is a great deal of materials testing. It is not unsimilar to a great deal of work that is done in AEC or NASA laboratories today. So what we are talking about is having at least one place in this country today that is the lead institution for developing solar energy concepts, for doing the research and development work that cannot be done in smaller institutions or by individuals themselves—a place that has the competence and equipment, the very large array of expensive equipment that is required today to do this kind of work. One cannot tell where it might be. It may easily be a part of one of the existing laboratories, or it could be started from scratch.

It should be up to the project to determine.

Mr. PICKLE. The language makes reference to any new or existing Federal laboratory. I do not want to exclude any region or area or site. If they think the AEC has the capability to handle it, that is something, but I hope the language can be broadened so at least not to preclude them from being considered. The chairman knows of my interest in this particular field. I introduced a bill at one time that would have designated certain institutions of higher education or learning as energy research centers.

I think there is a great deal to be said for that approach. While I would not argue that we ought not to have a place in the United States as an institute, I surely do not think that it ought to be the only place for doing this or similar work. I think we ought to have more discussion on that.

Mr. MCCORMACK. Are there any more questions?

Thank you very much. Time has run out on us today. I want to say that I very much appreciate the testimony that our witnesses have given this morning. Now each of you have given constructive points of criticism, and each of you have raised questions in your testimony about what you see as potential problem areas in the language of the bill as written. I do want to observe that we are going to try to move rather rapidly with this legislation.

This bill is really part of a package. There are a number of bills that we anticipate will be moving together. Markup next week is not out of the question. This will mean that your contribution, your specific contribution to specific language, would be very welcome.

The staff is going to be working on this conscientiously to try to work the bugs out of this that have been suggested or pointed out in the testimony that we have received in these 2 days of hearings. So any contribution you can make, whether it is raising a specific question or indicating that something is vague or internally contradictory or might raise potential problems. If you have specific language that you would recomend, or even if you have specific recommendations without language that you would like to provide, we would appreciate them very sincerely. I can assure you the staff will be working very hard in the near future putting them together to try to get the new bill drafted for consideration by the committee very quickly.

I want to thank you all very much for coming today.

STATEMENT BY THE HONORABLE BILL GUNTER (D-FLA.), BEFORE THE SUBCOMMITTEE ON ENERGY OF THE HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS, AUG. 2, 1974

Mr. Chairman, I appreciate the opportunity to submit this statement to the subcommittee in support of H.R. 15612, the "Solar Energy Research, Development, and Demonstration Act of 1974", which you have introduced and which I have co-sponsored with enthusiasm. This piece of legislation marks a step forward for the cause of solar energy and the beginning of the implementation of a vigorous policy of government planning in this important field.

For several years now, the National Science Foundation, the National Aeronautics and Space Administration, and various private corporations and research firms have been investigating the feasibility of solar and environmental energy. All of these have, with varying degrees of enthusiasm, supported the cause of solar energy. As the TRW Systems Group report to the National Science Foundation stated: "The Solar Energy System industry will approach or even exceed a multibillion dollar-a-year industry by the year 2000, even with our conservative market capture analyses and use of 1974 dollars as a yardstick." The General Electric project report has predicted that by the end of the century solar energy could save the United States as much electricity as is currently generated throughout the country.

Clearly, then, the time has come to collate the evidence and coordinate research on a national level. To this end the Solar Energy Coordination and Management Project, incorporating a permanent, executive, Solar Energy Research Institute, is directed. This project, designed as it is to assess solar energy resources throughout the country, resolve remaining technical problems, and demonstrate solar energy practicability on a nationwide basis, is a concrete step forward into the next century. It represents the absolutely necessary assumption by the federal government of the responsibility for initiating national involvement in solar energy technology and provides for the institutionalization of this effort.

But above and beyond the concrete benefits to be accrued from such a project are the intangible, but equally important, psychological benefits that this institutionalization provides. For a great part of the public, solar energy represents an unrealizable, although desirable, dream. Federal involvement would signify to many the coming of age of that dream. It would stimulate interest and market potential for existing solar heating systems and thus encourage cost reduction by providing private enterprise with an incentive for going forward on solar energy.

Solar energy is still an infant industry. While the oil and atomic energy industries' interests are amply represented by various federal agencies, solar systems manufacturers must go unheard. The creation of a central institute will not only provide Congress with easy and reliable access to information on the state of the art, but will provide the pioneers in this field with a pathway into the councils of government.

All of these factors seem to me to indicate very strongly the need for supporting H.R. 15612. But beyond this, they indicate the need for maintaining a vigorous interest by Congress and more particularly by this committee in the fate of the Solar Energy Coordination Project and Institute. All too often a great leap forward is impaled upon the horn of bureaucratization. It is against this that we must guard. We must insure that the Institute is continually heard and we must recognize that we have only begun on the road toward development of a solar energy technology that will serve as our power source for the future.

This road will not be the easiest to travel. Besides facing the critical problem of cost competitiveness (which I believe will be overcome within the next decade, especially in view of rising oil prices), we must deal with a variety of legal, institutional, and social questions. The concept of sun rights will have to be incorporated into the law. Zoning regulations will have to be studied and financial institutions will have to deal with new innovations in building and fueling and support those innovations with credit. Finally, and perhaps most importantly, the nation's consciousness will have to be expanded to include the understanding that solar power is not primitive or somehow unprestigious, but sophisticated and forward looking.

This expansion of consciousness must be accompanied by a corresponding expansion of the consciousness of legislators and government officials. We can stimulate this not only by passing H.R. 15612, but by encouraging federal agencies, whenever possible, to incorporate facilities for solar heating and power in designs for projected buildings. Nothing is more convincing than seeing a new technology put into practice.

So, Mr. Chairman, I wholeheartedly support this effort to expand the development of solar power, the energy source of the future. Its time is due. Let us say together (with apologies to Mr. Disraeli) that we will take a "leap in the light."

The committee is adjourned.

[Whereupon, at 12:03 p.m., the subcommittee adjourned.]

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