THE ECONOMICS OF SOLAR ENERGY

826

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THE ECONOMICS OF SOLAR ENERGY

MONDAY, APRIL 5, 1976

CONGRESS OF THE UNITED STATES,
JOINT ECONOMIC COMMITTEE,
Washington, D.C.

The committee met, pursuant to notice, at 10 a.m., in room 1202, Dirksen Senate Office Building, Hon. Paul J. Fannin (member of the committee) presiding.

Present: Senators Fannin, Percy, and Taft; and Representative Heckler.

Also present: William A. Cox, and George R. Tyler, professional staff members; Michael J. Runde, administrative assistant; and Charles H. Bradford and M. Catherine Miller, minority staff members.

OPENING STATEMENT OF SENATOR FANNIN

Senator FANNIN. The hearing will come to order. This morning the Joint Economic Committee is happy to welcome many distinguished authorities in the field of solar energy development. We are anxious to hear their testimony concerning the state-of-the-art and to receive their recommendations on how this country may achieve widespread solar utilization. We in Congress have expressed a sense of urgency in the vain of two solar energy acts. In my questioning, I will refer to legislation which Senator Humphrey and I and 19 of our colleagues introduced as the Solar Act of 1976. I realize you may not be familiar with this proposal so I will furnish appropriate figures in my questioning which will concern itself with capability.

We seek the advice of experts such as you to support the urgency for the development of this clean and abundant resource. We are very pleased this morning to welcome all of you to the hearings.

At this time I have two statements I would like to insert into the record. One from the chairman of our committee, Hubert Humphrey, and another by my colleague from New Mexico, Senator Joseph Montoya. Senator Humphrey has furnished a memorandum, by Lionel S. Johns, on S. 3227, which will also be made a part of the record.

[The information referred to follows:]

OPENING STATEMENT OF CHAIRMAN HUMPHREY

This is a Joint Economic Committee hearing on the economics of solar energy.

There is great dissatisfaction with our progress in developing solar energy. We've made some notable strides: for example, solar water heating is economically competitive in most regions now of the United States.

Yet, we've also seen reluctance on the part of the Administration to aggressively pursue solar energy development. Instead, a variety of nuclear and non-nuclear energy alternatives have been emphasized in funding requests—alternatives which in some cases are more remote technically and economically than solar energy.

In one word, we have failed to achieve a balance in promoting advanced energy research and development. And we have failed to achieve that balance at the expense of solar energy.

Solar energy is still a cottage industry; as a result, it cannot yet compete economically with fossil fuels. Despite being essentially fully developed technically in some forms, solar energy has not been able to achieve the economies of scale so necessary to price reductions and wide-scale public adoption. In fact, solar energy is a classic chicken-and-egg situation; it will not be widely utilized until costs decline, but costs will not fall without expanded demand and associated economies of scale in production.

So, solar energy is deeply intertwined with economics and that connection exists even with those solar energy forms where significant technological barriers remain to be overcome.

We will hear today from a number of public and private experts in solar energy, its economics and its technology, with a major focus on photovoltaics and solar powerplants:

What is the status of current technology in these two areas?

Are there technological breakthroughs occurring?

How soon (and for how much R & D funding) can we expect to see these two solar energy forms cost—competitive with fossil fuels or electricity?

We will explore these and other questions.

Leading off our hearing today is Congressman Runnels of New Mexico, whom I hope is willing to join the committee following his remarks.

He will be followed by a panel of businessmen and scientists with a broad background in solar photovoltaic research, development, and production.

CONGRESS OF THE UNITED STATES,
OFFICE OF TECHNOLOGY ASSESSMENT,
Washington, D.C.

Memorandum to: Hon. Hubert H. Humphrey.
Chairman, Joint Economic Committee.
From: Lionel S. Johns, Program Manager, Energy Assessment Program.
Subject: Classification of OTA Comparative Analysis Briefing Documents on the ERDA Solar Program and Budget.

As you know, the OTA Board approved use of the information developed in the OTA Comparative Analysis of the ERDA 1977 Budget and revised Plan and Program as a basis for briefing information to meet the time constraints of the authorization and appropriation committees. This comparative analysis is still in the preparation and review stage. At the time of its completion it will be submitted to the Board for approval to release to the Congress and the public.

Your questions from the draft briefing papers as forwarded to me by Mr. George Tyler are repeated and answered below.

1). Is it OTA's intention to suggest that the solar electric program at ERDA should be de-emphasized?

It was never the feeling of the panels, both for the original OTA ERDA analysis and the Comparative Analysis, that the funding of the solar electric programs should be reduced. The panels felt that ERDA's treatment of Solar Heating and Cooling (SHAC) as a "underused mid-term technology" was inconsistent with the potential contribution of SHAC to the nation's energy supply, as estimated by ERDA, and that the funding of the SHAC programs should be increased more in line with this estimate. It was not meant to infer that the solar electric program was overfunded or that the SHAC funding should be increased by transfer from or reduction of solar electric projects.

2). Is it OTA's conclusion that both programs should be more aggressively funded than provided in the President's FY77 request, and that additional funding for one program should not be at the expense of the other?

The comparative analysis participants concluded that the Solar Heating and Cooling was inadequate to meet the Solar Heating and Cooling Act or achieve its objectives of rapid commercialization in the near-term. On solar electric programs ERDA improved their program between 1976 and 1977, however, some programs such as photovoltaic, total energy systems and decentralized solar power generation systems could be explored more aggressively.

STATEMENT OF HON. JOSEPH M. MONTOYA, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

I would like to express my appreciation to the committee and to the chairman for this opportunity to comment on the problem of solar energy research and development and its relation to our total energy program.

Recently the committee has heard comments by several of my colleagues on the administration's apparent neglect in promoting solar energy research and development programs. There has been a significant reduction in the budget request for solar energy development by the Office of Management and Budget. Specifically the Solar Division of the Energy Research and Development Administration requested approximately $230 million. This request was cut by senior ERDA officials and the Office of Management and Budget, and a new request was submitted for only $166 million.

I would like to be on record as agreeing with my distinguished colleague from Arizona, Senator Paul Fannin, who denounced the "Prejudice within the Administration which affected a sixty-two percent reduction" in this request for funds for solar energy programs.

It is obvious that this reduction would mean a further reduction in a vital new energy potential. A cut of this size in any energy producing area at this time is a serious mistake. Such a cut could only be contemplated in the situation in which we find ourselves: we do not have a total energy policy designed to fill our energy needs either in the immediate future or in the years ahead.

Apparently the need for a solid national energy policy which addresses our energy needs across the board is not yet recognized by the administration. Such a national policy would have to include an appropriate level of funding for the development of alternative energy sources such as solar energy. It is indeed most alarming to see that the administration has chosen to reduce funding in this very important area. Our sources of fossil fuels and other currently used energy will inevitably disappear, and I think all of us are aware that as that time approaches the pressure for alternatives will become ever more severe. Now is the time to take action in planning for research and development for those alternatives. We cannot wait, and we cannot allow any one alternative to be ignored while others are emphasized.

The development of solar energy deserves more, not less support—not only from the administration, but from the Congress as well. We cannot allow second class treatment of this very promising energy resource. The Solar Energy Act of 1976 would restore fiscal year 77 solar funding to the level requested by ERDA's Solar Division, and would provide an outlay of $238 million.

If the administration will not take action to give solar energy the emphasis it must have, the Congress must move to mandate that action. By passing the Solar Energy Act, we would begin to put the emphasis on solar energy research which it deserves and must have.

I strongly urge the passage of this legislation. It will help us to determine if solar energy, the most environmentally sound energy resource, will be an economically viable source in the future, and it will help us to determine how much of our future needs can be fulfilled through the use of solar energy.

I hope that the committee will agree with me that this legislation deserves the support of every member of the Congress this year.

Senator FANNIN. For too long, we here in America have taken energy and its use for granted. This attitude was manifested in the fact that at one time there was a bountiful supply of energy and it was cheap. But all of this has changed, or has it really?

At the beginning of this decade, 23 out of every 100 barrels of oil we were consuming here in America came from foreign wells. That number jumped to 38 just before the Arab oil embargo began in October 1973.

You would think that the embargo would have made believers out of us, that we truly were facing a crisis in energy.

The first witness this morning will be Hon. Harold Runnels, Congressman from New Mexico. I appreciate your testimony. I trust you will have the time to sit with us during these hearings.

STATEMENT OF HON. HAROLD RUNNELS, A U.S. REPRESENTATIVE IN CONGRESS FROM THE SECOND CONGRESSIONAL DISTRICT OF THE STATE OF NEW MEXICO

Representative RUNNELS. Thank you, Mr. Chairman.

I appreciate the opportunity to be present today to testify before your committee in support of Senate bill 3227, the Solar Energy Act of 1976. I have represented the Second Congressional District in New Mexico since 1970 and besides this I have been associated with the oil industry for over 25 years as the owner of service companies for the industry.

It is through this association and now through my involvement as a U.S. Representative that I am fast coming to the conclusion that this Congress is unable to deal decisively with our energy problems. Our energy problems are real, but yet Congress continues to ignore it by playing appeasement politics, in my opinion.

If you will remember back then, people were lined up for blocks waiting their turn to get to the gas pumps. They were also clamoring on Congress to do something about this whole thing. When the crisis was ended by the OPEC nations, officials here in Washington vowed to make this country independent of foreign oil.

We were going to accomplish this by 1985 through project independence. We started to drive our cars at 55 miles an hour. We saw a push for smaller automobiles and so conservation efforts began growing across the country. By April 1975, oil imports had dropped to a low of 31 barrels out of every 100 barrels consumed in America.

But today all of that seems to be forgotten again. In a 4-week period beginning and ending in mid-March, we found ourselves importing 44 barrels out of every 100 barrels of oil we were consuming.

In fact, for the first time in this country's history we found ourselves importing more oil than we actually produced here in the United States. In addition, earlier this year, the Russians for the first time outproduced us in crude oil. If we continue to depend upon the OPEC nations for oil we will find that by 1980 we will look to them for over half of our total needs. On the home front, production continues on its downward trend. In 1975 there was an overall drop of 3 percent in the production of oil, natural gas and coal.

These fuels make up 95 percent of this country's total energy.

The oil industry here in America has lost any incentive to explore and develop our own oil and gas reserves. What we have done, we have had the elimination of the depletion allowance, the incentive to drill for domestic oil and gas in the United States. Then Congress took almost 12 months to come up with a so-called comprehensive energy bill which not only continued the tight price control over domestic oil but rolled back a price for a barrel of oil from about $8.75 to $7.66 and this compares somewhere to near $12 to $14 for imported oil.

Nothing could have been more detrimental to the incentive of exploring and drilling activities. Oil companies are saying they are not making a sufficient profit on domestic oil and they will make less as the law takes full effect. But Congress did not stop there. In early February, the House killed the deregulation bill almost surely for this year. Congress inability to cope with the energy crisis, displayed through the type of legislation, they managed to give their stamp of approval to, is already having effects in many States.

Take my own State of New Mexico where the mineral wealth is abundant. In 1974, we were the sixth leading producer of oil in the Nation and also ranked fourth in the Nation on gas production. Most of the oil and gas produced in New Mexico comes from the Permian Basin. An area which includes Texas and New Mexico.

Last year, a producer would have to wait 4 to 6 weeks to acquire an oil rig. If you were to drive through the Permian Basin of the United States, you would count 100 drilling rigs that are lying idle today. This, Mr. Chairman, is only the beginning of what is yet to happen to the industry if Congress does not come to grips with our energy problems and adopt meaningful legislation.

In the past we have been able to undergo a gradual shift from one source of energy to another. If you will recall, it took about 60 years each time when we changed from wood to coal and from coal to oil.

But now we are faced with finding an answer to our energy needs in a much shorter time. Everything has a time and a place. I am sure you can remember as well as myself when silver wire was used as the conductor of electricity. Then that changed and we switched to copper wire for the conductor of electricity. Today we have shifted again to aluminum for the conductor of electricity.

I think that we must face facts that we must shift again to a new source of energy in America and in this world. In the next 25 years, the United States will build an almost new energy system. But if this system is to be effective, Congress must do its part. To date, though, they continue to drag their feet with an issue that needs decisive action.

There is no doubt that nuclear energy will play a major role in meeting future energy needs.

But development of nuclear energy is having its problems. Until recently, the Federal Government had hoped to increase the number of operating nuclear reactors from the present number of 56 which supplies less than 2 percent of the U.S. energy needs, to more than 200 by the year 1985.

Now this goal is under reevaluation in light of financing problems, a slowdown in energy growth, and general uncertainty over the future of nuclear energy. One source of energy that continues to get a second-class treatment by Congress and the administration is solar energy.

Solar energy by no means offers a complete answer to our energy problems. But it is a partial solution. It is neither dependent on scientific breakthroughs nor discovery of vast amounts of hidden resources.

We should all recognize that all sources of energy come from the sun. Whether it be wood, coal, oil, gas, uranium, or what-have-you. Maybe the good Lord is trying to tell us something and we ought to be smart enough to recognize it.

Currently estimates show that the solar energy is utilized effectively in areas such as the Southwest United States, the results would be a 40-percent reduction in the use of conventional energy resources or 10 percent on a national level.

To my knowledge, there has been no legislation proposed to date that would provide the same kind of incentives to the solar energy industry that were provided for decades to the fossil fuel industry. We must accept the fact that there is an energy crisis.

At the same time, we must make a national commitment to develop solar energy and to do so legislatively on a multiyear program. The commitment we need nationally is one that parallels that made by the President (Kennedy) to put a man on the Moon within a decade.

The only difference, however, is that we would achieve energy self-sufficiency before 1990. Some may argue that it is virtually impossible to achieve this in that short period of time. But if we can put a man on the Moon, develop an atomic bomb, the nuclear submarine and space crafts, we surely can put solar energy on line by 1986.

The Solar Energy Act of 1976, in my opinion, points us in that direction. The act recognizes that it is in the Nation's interest to initiate a national commitment toward achieving energy independence within 15 years.

It also recognizes that energy independence can be promoted through the use of solar and geothermal energy as a source for at least 10 percent of our energy needs by 1991. I would like to stress, though, the importance of funding two concepts within the bill that offer the most help for rapid development in the use of solar energy.

The two are photovoltaics and the solar thermal-electric programs. We must at least fund these two programs at the levels requested by the ERDA branch chiefs. Not only am I showing my support by testifying before this committee today, but I have also cosponsored legislation in the House asking for a commitment similar to what is outlined in the Senate bill.

I hope we can accept that challenge before the OPEC nations decide to do a repeat of the 1973 performance. Another oil embargo would bring America to its knees. So in order to achieve self-sufficiency in energy, Congress must provide the leadership and it is my sincere hope that we recognize this need and pursue solar energy through legislation such as S. 3227.

Senator Fannin. Thank you, Congressman Runnels. You have brought out some frightening statistical information that sets the stage for what we are doing in these hearings.

You have brought out the position we are in as far as the petroleum program is concerned. That is certainly very helpful, especially from a gentleman that is an expert in the field, who has had the years of experience in the petroleum development industry that you have had.

We are pleased that you have brought this information to us. I know Senator Humphrey appreciates it and I appreciate the support you are giving to the ERDA request. That is certainly shown by your own introduction of legislation in the House of Representatives.

We are very pleased to have you testify here this morning. It will be very helpful for the other members of the panel to read your testimony.

Representative Runnels. Thank you, Mr. Chairman. As you stated, I was trying to set the stage and prove a point that we do have a crisis. I think others will stress more of the details of the Senate bill which I do support.

Senator Fannin. As stated earlier it is our hope that you will be able to stay with us and participate in the hearings this morning.

Representative Runnels. Yes, sir.

Senator FANNIN. The next witnesses will be a panel for the photovoltaics. We are honored to have a learned group here with us this morning. These are leaders that are very well qualified to testify on this particular subject.

If they will come forward, we will introduce them as they are placed around the table.

We welcome all the witnesses here this morning. We are very honored to have you gentlemen with us. I know that the reporter can see the names but so the audience will know the gentlemen that are here with us, if they would just introduce themselves, I think—on my left, your right, Mr. Louis Rosenblum, Mr. A. I. Mlavsky, executive vice president of Mobile Tyco; Mr. Daniel Schneiderman, of the Jet Propulsion Laboratory; Mr. Charles Backus, of Arizona State University, professor of engineering; and Mr. Steven DiZio, president of SES, Inc.

Before we proceed with the testimony of the witnesses, the Senator from Illinois is with us this morning, Senator Percy.

Senator PERCY. Mr. Chairman, first of all I want to say that I always like to see a Republican in the chair. Second, it is particularly a great pleasure to have in the chair a fine friend with a deep interest in this subject and considerable knowledge of it. As the principal Republican sponsor of the bill that created ERDA and as the ranking Republican on the Government Operations Committee, I have a personal interest in ERDA's efforts to develop solar energy.

These hearings provide an opportunity to assess ERDA's solar energy efforts and to examine its funding and priority levels. Solar energy is again gaining attention within our cities. Nearly 200 private homes are now heated in America with solar energy.

More than 10 States have laws favorable to the development of this energy source. One indicator of this fact is the price of photovoltaic cells, which has plunged to $38.16 a watt from $300 2 years ago. Congress has a duty to see that taxpayers' money is spent wisely in such development efforts. Wasteful Government spending for capricious energy development should not be tolerated, particularly in a period when the Federal budget deficit has been setting peacetime records.

In order to bolster solar funding, we inevitably take fiscal demand away from nuclear and fossil fuel. Should the total R. & D. funding be enlarged? What is the correlation between the solar energy and nuclear energy? How will they be cost effective? These are only a few of the questions that I have not been able to solve. I certainly look forward to the testimony of today's very excellent witnesses to provide the counsel, guidance, and advice that the Congress needs in order to support a program that the Congress and the administration have worked together to implement.

Senator FANNIN. Thank you, Senator Percy. We are proud to have you supporting this legislation and the overall programs. I know of your expertise in the field of business and certainly the great knowledge you have on energy.

You have knowledge of how it ties in with the economy of our country. This morning, the panel as I understand it, has selected Mr. Daniel Schneiderman to testify first.

Mr. Schneiderman, please proceed, and you may handle the testimony in whatever manner you desire.

STATEMENT OF DANIEL SCHNEIDERMAN, MANAGER, CIVIL SYSTEMS PROGRAM, JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, AND MEMBER, PANEL ON PHOTOVOLTAICS

Mr. SCHNEIDERMAN. Good monring, Mr. Chairman. The Jet Propulsion Laboratory which I represent supports the Energy Research and Development Administration photovoltaics program and as the manager of the Civil Systems Program Office of the Jet Propulsion Laboratory I have a particular interest in this area.

The Civil Systems Program Office is responsible for the applications of NASA-derived technology to the problems of the civil sector at large. A primary interest in our broadly based program is the area of energy and a major part of this effort is in solar energy.

Because of our background in the use of solar energy for spacecraft electric power, we believe our capability at the laboratory can match the need to utilize solar energy to the maximum.

Our research and development activities in this area led to early collaboration with the National Science Foundation and initiation of programmatic concepts. The project of the overall ERDA photovoltaics program are low cost silicon solar rays, system definition, tests, and novel materials and devices.

We at JPL are sponsoring one element of that program and the approach of this particular project is to involve and collaborate with industry and achieve a goal to bring about by 1985 a production capability of 500 megawatts equivalent of solar rays per year at a price of better than 50 cents per watt in 1974 dollars, that is, to the consumer.

Photovoltaic conversion is the direct conversion of light into electricity. The essence of a solar cell is a sandwich of two types of materials. When light falls upon the cell, the light will be absorbed and the energy converted to free electrons.

The electrons will flow and supply the power as long as the light continues to illuminate the cell. The major challenge of increased utilization is to make the photovoltaic conversion systems economically competitive with other energy sources.

The project approach established is to achieve a program objective which includes the development of required technology and transfer it to industry for commercial practice and to stimulate the market growth by largely increasing annual solar procurement.

Achievement of price levels for silicon solar arrays that can be used for large-scale terrestrial power applications would require a substantial effort in a variety of technological areas related to the manufacture of these arrays. For example, materials, the price of the purity of the basic silicon used as a starting material in the production of solar cells must be reduced from the present price of around $65 per kilogram to less than $10 per kilogram.

This silicon material then requires conversion to thin sheets of material suitable for production into solar cells for an added price of less than $18 per square meter. This compares to the present price of about $240 per square meter. Then this array must be encapsulated for environmental reasons in order to achieve a practical array lifetime of greater than 20 years.

All of these elements must be combined in a low cost automated process and equipment must be developed to convert the sheet material into completely encapsulated arrays.

In late 1975 we contracted with industry for the delivery of 46 kilowatts of state of the technology encapsulated silicon photovoltaic array modules. These will be used in early ERDA test and demonstration projects.

The Lewis Research Center is responsible for the test and demonstration project. Mr. Rosenblum seated on my right will discuss this aspect later.

The current price ranges from about $30 to about $13 per peak watt which is an average price of about $22 per peak watt. A second procurement, for 130 kilowatts of improved silicon photovoltaic array is presently underway.

Mr. Chairman, it has been my privilege to have served as the project manager on several NASA JPL planetary missions and I believe there are certain necessary elements that must be part of a successful project.

There must be an objective that is perceived by the people involved as both desirable and feasible. There must be a long-term commitment on the part of the management that sets that objective. Then the resources must be provided in a manner that does not frustrate those who need room to accomplish the objective.

I and my associates believe in the objective of this program and we believe it can be achieved.

Senator FANNIN. Thank you very much, Mr. Schneiderman. We will hear all the panelists and then we will have the questions because some of the questioning goes to more than one panelist.

Mr. DiZio, will you proceed.

STATEMENT OF STEVEN F. DiZIO, PRESIDENT, SES, INC., AND MEMBER, PANEL ON PHOTOVOLTAICS

Mr. DIZIO. Thank you, sir. SES believes that solar conversion and photovoltaic devices in particular have the potential of providing a significant complementary addition to the world energy system. As evidence of our conviction, we have a very sizable production development effort underway to produce cadmium sulfide solar electric converters.

Our initial production line, which is planned to be operating by the end of 1976, is designed for an annual capacity to produce over 500 peak kilowatts of photovoltaic product. This compares with an estimated present world wide photovoltaic production capacity of 180 peak kilowatts.

I brought a single unit with me today. This is the smallest unit of our commercial product. These devices are produced on the production line in these modular designs. They are completely sealed behind tempered glass. They are designed to take hurricane force winds, inch-sized hailstones and all of the types of environmental degradation phenomena that we are aware of.

First, products have been carefully engineered to meet requirements for remote power systems. Our long-range objective, however, is for products which are cost effective as major energy producers. We are most interested in the concept of a distributed system, perhaps individual home rooftops, integrated with the conventional electric grid network and providing both thermal and electrical energy.

We are confident that we will achieve the necessary production cost improvements to meet this long-range objective.

The manufacturing that is used in producing this particular product is easily scaled up. There is no reason why these panels could not be produced in 2- by 4-foot sizes to be used on the roof of your house and distribute the thermal energy also collected by these particular panels.

This technology is such that production cost is very sensitive to volume. Basic materials are a small percentage of the cost, and automation and volume scale up can provide dramatic reductions. Ultimate achievable objectives are well within a competitive range as compared to other energy sources.

In introducing any new technology there are three phases we have to look at. First is the fundamental development or research phase where we prove the scientific concept. Second is the phase of production development and product development whereby we learn to produce the product in volume. And third is a market development or systems phase.

The first and third of these phases generally are carried out prior to the production development phase.

SES technology is based in part on concepts which grew out of scientific activity supported and developed by the Government. We would strongly suggest continued support for fundamental research to provide the basis on which future development and engineering, funded by private enterprise, can build.

At the other end of the spectrum, in the market development area, the rapidity with which solar energy will become utilized depends critically upon successful market development. Significant progress can be made only after satisfactory understanding of the complete system is attained, including local and State governmental inputs, regulatory agency impacts, and the total technological interactions. Industry is not well suited to attack such a complicated political, socioeconomic problem.

Thus, systems demonstrations and complete systems studies are considered a top priority for governmental support. It is our opinion that the most cost effective way to bring solar energy conversion to commercial reality would involve a joint effort between industry and government. The Government should provide support for the fundamental scientific work necessary for making valid business judgments. The Government should also support demonstration and systems projects which develop the market and identify product requirements.

Once the large scale power, solar conversion market is shown to exist, with product requirements and scientific knowledge available, production development can best be left to industry with no further encouragement or funds provided. Indeed if industry is unwilling to carry out such development it must be asked whether the market, product specifications, and scientific knowledge are truly sufficient for reasonable chance of success.

The size of Government funding which can be used effectively in photovoltaic systems development depends on the specific areas of allocation and the mission to be accomplished. We observe that in fundamental research additional meaningful work could be funded in fiscal year 1977 to further understanding of cadmium sulfide, and to show proof of concept for other theoretically promising photovoltaic material systems.

In addition, systems demonstrations and market development problems could very effectively be addressed by increased funding in fiscal year 1977. Indeed, a funding level of $60 million for this area alone may not be enough.

Significant data, proof of market, systems directions, and market stimulation can be accomplished without the need for large amounts of photovoltaic products. SES, speaking as a single segment of the industry, feels that megawatt quantities of material at attractive prices can be delivered starting late in fiscal year 1977. In the meantime, if a clear cut program has been defined which allows us to plan sufficiently for the needed capital expansion and cost objectives, then we can increase as rapidly as required after fiscal year 1977.

Gentlemen, entire markets can be created, hampered or even destroyed by the stroke of a legislative or regulatory pen. A concerted Government effort including legislation and funding can drastically change the requirements and improve the potential of solar conversion as a large scale energy source and most important, compares the timetable for commercial large scale utilization. This is certainly in the national interest.

If the Government carries out the task of setting the mission objectives and market requirements, leaving the choice of solution to be determined by free market competition, then as history has consistently demonstrated, the U.S. industrial community is ideally suited to developing the processes and products in the fastest way possible, and at the lowest possible cost.

Thank you, Mr. Chairman.

Senator Fannin. Thank you. The next witness will be Mr. Louis Rosenblum, of NASA.

STATEMENT OF LOUIS ROSENBLUM, CHIEF, ENERGY CONVERSION AND ENVIRONMENTAL SYSTEMS DIVISION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, AND MEMBER, PANEL ON PHOTOVOLTAICS

Mr. Rosenblum. The Lewis Research Center supports the ERDA energy conversion program. Our photovoltaic experience at Lewis dates from 1962. As mentioned by Mr. Dan Schneiderman, ERDA has assigned us the responsibility for their test and demonstration project.

This project consists of four specific areas: Applications, device performance and diagnostics; endurance testing; and project management. Although all these areas are important, I believe the application area may be of the most interest to you.

The objectives of the application area are two-fold. First, to stimulate early markets for solar cells through demonstrations of special applications. Second, to demonstrate technical feasibility of photovoltaic power systems having significant national energy impact.

The first objective directly supports the ERDA photovoltaic program goal which is to raise solar cell rate production from the present 100 kilowatts per year to 500 megawatts per year by 1985 and to reduce the cost from approximately $20 a watt to 50 cents a watt. Our approach recognizes that the market is latent and that many potential users are either unaware or unsure of the benefits which can be obtained from the use of solar cell power in their specific applications. As their awarenes increases, we fully expect that an ever increasing quantity of solar cell orders will be placed and that the market will be greatly expanded.

The second objective in the applications area supports the ERDA goal to increase the overall use of solar energy in the long term. We are determining through appropriate tests and demonstrations the operating characteristics as well as identifying the technical and institutional problems, associated with this potentially attractive energy option. Specific applications in this area range from special uses to residential power and may eventually include central station power generation.

At present in the early market development effort, we have finalized an implementation plan with the National Oceanographic and Atmospheric Administration for demonstration of six photovoltaic powered remote weather stations at diverse locations in the continental United States. Discussions and implementation of other government applications are in progress in areas such as navigational aids, water pumping, refrigeration, metal extraction, and communication.

In the residential and large load center application area, we have under construction a system test facility to evaluate sytem designs, operating characteristics and performance.

It is on schedule and 10 kilowatts of capacity purchased as part of the JPL project will be installed and ready for test in the June–July period. Also the first of several planned residential tests is now in the design stage.

Mr. Chairman, I believe the photovoltaic work we are doing for ERDA is important. We are committed to its successful completion. Assuming that the resources required over the next several years are available, I am confident that the ERDA program goals of 500 megawatts per year production capacity at a cost of 50 cents a watt, in 1974 dollars, will be achieved. I am confident that we will have both the ability to use the abundantly available solar energy for direct electric power applications and further that we will also have a good chance of developing new export markets.

Thank you.

Senator FANNIN. Thank you, Mr. Rosenblum. The next witness will be Mr. A. I. Mlavsky.

STATEMENT OF A. I. MLAVSKY, EXECUTIVE VICE PRESIDENT, MOBIL TYCO SOLAR ENERGY CORP., AND MEMBER, PANEL ON PHOTOVOLTAICS

Mr. MLAVSKY. Mr. Chairman, my name is A. I. Mlavsky, executive vice president of Mobil Tyco Solar Energy Corp., Waltham, Mass. I appreciate the opportunity to appear before this distinguished committee to inform the committee of our work on solar energy devices.

I have a brief opening statement, following which I will be happy to respond to any questions.

Mobil Tyco Solar Energy Corp., a joint venture company between Mobil Oil Corp. and Tyco Laboratories, Inc., was formed in August 1974 to carry out a program for development and commercialization of silicon ribbon and the photovoltaic conversion of solar energy through use of the solar cell.

In 1966, Tyco began development of a process for the growth of continuous shaped crystals directly from the melt. In 1970, the technique—"edge defined, film fed growth (EFG)"—was first applied at Tyco to silicon ribbon as a potentially low cost basis for the manufacture of silicon solar cells. By early 1974 the basic feasibility of the EFG approach had been demonstrated through the fabrication of small ribbon cells of efficiencies close to 10 percent. For comparison, conventional silicon solar cells of the same general type are 11 to 14 percent efficient.

From a detailed analysis of the cost factors implicit in the EFG technique for silicon ribbon and cell production, it was concluded that the solution of a set of relatively well defined technical problems would lead to a selling price for ribbon solar cells commensurate with their use in direct competition with conventional means for producing electricity. It was estimated that a period of some 7 years would be required to definitize the technology for such low cost solar cell production; accordingly Tyco decided to seek a joint venture with a company that was dedicated to the long range development of energy resources. Mobil, which also had proven ability in the management of scientific programs, was the company of choice, and the venture was launched.

As a result of the much increased effort deployed on the technical program through the participation of Mobil, progress since August 1974 has been quite rapid. The status of the program is exemplified by our ability to grow silicon ribbon 1 inch in width, 8/1000ths of an inch in thickness, in lengths up to 80 feet. One inch by 4 inches solar cells made from such ribbons exhibit efficiencies averaging 8 to 10 percent. By contrast, in August 1974 the maximum length of such ribbons was about 8 feet and the efficiencies of 1 by 4 inch cells was about 3 percent.

The total Mobil Tyco Solar Energy Corp. program now embraces projects to grow ribbon more cheaply through increasing its width and its rate of growth, decreasing its thickness toward the optimum value of 0.004 inch and simultaneously growing up to 20 ribbons from a single equipment. Processes for the conversion of ribbon into solar cells at low cost are also under development. The use of inexpensive solar concentrators to minimize the usage of solar cells per unit of

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electrical power output, and to provide heat as a useful byproduct is also being explored.

Although photovoltaics is only one of several possible approaches to the conversion of solar energy into electricity, and the so-called single crystal silicon solar cell is only one of several approaches to low cost photovoltaic conversion, we believe that the silicon cell has great merit in the direct production of electricity from the sun.

The materials of its construction are among the most plentiful in the Earth's crust; it is durable and reliable, as proven in many space applications; it is totally without harmful environmental impact; it is relatively efficient; and it can be deployed as assemblies of simple, replaceable modules. The only major obstacle to the widescale use of the silicon solar cell in alleviating our national dependence on nonrenewable fuels is its present cost. We believe that the ribbon technique under development will reduce this cost to the point where the silicon solar cell will be able to supply significant amounts of electricity by the end of the next decade.

I wish to thank you again for this opportunity to appear. I will be happy to respond to any questions you may wish to ask.

If I may, I will just show four or five slides which describe the process.

Senator FANNIN. Yes.

Mr. MLAVSKY. I have to thank National Geographic for this artist's representation of our process. [Slide.]

As has previously been stated, the silicon solar cell or any solar cell, is two layers of material which are activated by light. Starting on the lefthand side of this slide, we see a representation of a furnace in which the silicon material which Mr. Schneiderman referred to is melted. In a single operation it is converted into a ribbon or sheet of silicon.

This ribbon emerging from the furnace is converted through a second furnace into a double layer of silicon and at this point metal contacts are applied and the final product is the solar cell.

I have some of these with me for demonstration. They look very simple but are much smaller than those of my colleague, Mr. DiZio. The virtue of such a process as applied to silicon is that it converts raw silicon directly into the form required for solar cells. This obviates a great deal of waste in the cutting of silicon now necessary. [Slide.]

Here is a crystal actually growing from the furnace. This is no longer an artist's representation but a photographic shot of the ribbon. In order to make this process viable for low cost, it is obviously necessary to produce this material in continuous form and to process it in such form. [Slide.]

Here we see the example of the fact that even though silicon is a brittle material, in thin sections it can be taken straight out of furnace and put on to a spool. In my statement, I referred to the desirability of growing many such ribbons at once. Our program includes the equipment which would produce many of them simultaneously. [Slide.]

The product is very similar to what you see in front of you there. This is a solar cell panel made from ribbon solar cells. This is a very brief description of the process. I have a few artifacts with me which I will be happy to show you, if you wish.

In summary, silicon while by no means the only approach, is perhaps the most proven at this point. The only thing that stands between it and large-scale production is cost reduction. One method of achieving this cost reduction is to develop processes whereby the raw material can be converted by continuous processes into a final solar cell which can then be employed to produce electricity and heat simultaneously.

Senator FANNIN. You say you have some other material.

Mr. MLAVSKY. I just have a few demonstrations here which I will be happy to show. [Slide.]

This is a representation of a ribbon growing. Here is a ribbon, and these are simple solar cells. Since the weather is so fine, if one moves over to the window and moves the curtain, the little motor will start going. There are no moving parts except for the motor itself. The thing is extremely simple, very light and essentially indestructible if properly encapsulated.

Senator FANNIN. The next witness is Mr. Charles Backus. I am pleased to have the distinguished gentleman from my State, the State of Arizona.

STATEMENT OF CHARLES BACKUS, PROFESSOR OF ENGINEERING, ARIZONA STATE UNIVERSITY, AND MEMBER, PANEL ON PHOTOVOLTAICS

Mr. BACKUS. Last year I testified concerning the ERDA 1976 budget at about this time of year concerning solar energy. At that time I recommended that in particular the photovoltaic program could sensibly spend about $40 million in fiscal year 1976. The actual allocation was about half of that value but over the past year I have become even more encouraged that we need to and can spend very effectively many more times the amount of moneys we are spending now.

By that I mean that two and three times what is presently being spent.

I think it is very encouraging and exciting to work in a field in which there are a number of approaches, any one of which could lead to reaching the goals as specified by the ERDA programs plan. Incidentally that plan was arrived at by a consensus of experts in the photovoltaic field and was not set as an end goal to try to achieve, but a realistic goal which is expected to be achieved.

There are a number of approaches, which as I said, any one of which could reach those goals. But we have reached the stage now that we need to make some demonstrations of these.

We need development of material processing and manufacturing techniques, certainly, but we need basic research and understanding the material better. Even such materials as silicon and cadmium sulfide require additional basic studies. A third material is seriously being looked at for the first time. All sorts of new materials have not been investigated for their potential. There is an additional area of concentration which one can use reflecting surfaces which will reduce considerably the area required for photovoltaic cells and therefore the cost per watt. All of these and many subareas within those general categories could lead to the achievement of the specifications of the ERDA plan.

I would like to express some observations and concerns about the photovoltaic programs. The first of these is that I think the ERDA staff is grossly understaffed.

These people are very competent and have done a good job of conducting photovoltaic programs but they are just not big enough. If we are serious about the development of solar energy, we have to have the staff with which to conduct that program.

Another concern is about the universities. A university's organization and operation has a difficult time coping with the method of operation of ERDA in the request for proposal, the time requirements for proposing and performing on contracts make it very difficult to compete.

The RFP system of developing programs is a requirement. There is no question in my mind about that. That is a necessary way in which to develop an acceptable program. But as a result of this transition from NSF to ERDA in the solar development program I feel that university potential is not being realized by keeping them as involved as much in the last year or so. The university participation has decreased.

Another observation is that the uniqueness of photovoltaics. First of all, photovoltaics are not size limited. Therefore we can do a lot of experimental and demonstration programs of reasonably small size.

We do not have to build a 100-megawatt plant or spend $100 million per experiment. We can learn a great deal by fairly small, but a variety of different types of developments and demonstrations. Also it is not a go-no-go program in that photovaltaics is a proven conversion scheme. It is just a matter of how much contribution will we make, not will we make a contribution. That will depend upon how low a price is obtained. The lower the price, the greater the contribution.

Another point is that it is a good export product. The photovoltaic system is a very high technology, with a very receptive market around the world outside the United States. Besides releasing us from some of our requirements of importing energy from outside the United States, it may help the balance of payments by providing a good export product. In conclusion, we all realize that solar is not any type of panacea but indeed none of the other alternatives are either. We don't really have alternatives. We need all of the approaches that we can develop to survive. Certainly photovoltaics uniqueness is one of the most attractive areas in which the Government again can invest its money.

Thank you.

Senator FANNIN. Thank you, Mr. Backus. You gentlemen certainly have furnished some very capable information in the photovoltaic field. Our main objective today is to determine whether we are committing adequate support to meet our solar goal development.

Thus many of our questions will be aimed at the administration's budget request as opposed to levels others have proposed which are much higher. We will have Senator Percy start the questions.

Senator PERCY. Mr. Chairman, I should like to first ask why ERDA is placing so little emphasis on alternative solar cell material other than silicon? There are a number of other materials such as cadmium sulfide which are receiving considerable attention from the private sector.

Can anyone offer any comments on that?

I would rather you first decide whether the question is appropriate. If you have a conflict of interest, don't hesitate to say so.

Mr. DiZio. Since I am the only one here involved in the area of cadmium sulfide I think I can specifically talk to that. Of course ERDA has only recently come into the picture. The cadmium sulfide program previously supported by NASA and NSF developed much of the technology on which we are basing our production development. We are not looking for Government funds for support of the type of program we are involved in.

We would like very much to see the Government work with us on the next phase which is the ultimate market objective. I can only assume that the reason why ERDA is not investing in other technologies which look good relates to the amount of funds available.

From a technical viewpoint, we can look at cadmium sulfide and some of the other materials and it is not clear that you can write any of these technologies off. It must be a question of funding.

Mr. Mlaysky. I think it is fair to point out that ERDA has recently started to undertake activity in the field of other materials including gallium arsenide. I echo my colleague's remarks that they have not previously had the funds for such activities.

Even though these are in competition with silicon, I feel it is highly desirable that increased effort go into the development of these materials. The solar cell tends to be thought of as a single entity when in fact the spectrum of applications which it can address depends upon its efficiency and its cost, whether or not it can be used with optical concentrators, whether or not it is useful for some central applications rather than remote applications.

I think the total energy picture will be served by a variety of different cells which have their own characteristics. I think nationally we should give attention to any promising material or alternative.

Senator Percy. I would like to present to you the dilemma that Congress is in. We are living now under the restraints of a budget system into which I have helped introduce businesslike procedures.

For the first time we are really going to set our ceilings on expenditures and then try to live within them. It is going to be extraordinarily difficult to increase the total amount of funds available to ERDA, unless we are willing to expand our total financing.

As I recall some 55 percent of ERDA's budget now goes into nuclear energy. Rather than just increasing solar funding and then adding that on to the totals spent by ERDA, could funds be properly shifted from nuclear or fossil fuel? That way our total energy research and development and demonstration funding is not increased.

Can we justify shifting funds over from these other areas and increasing solar energy expenditure at this stage? Or do you think that the levels we have established are just about right? ERDA does get line item authorization so Congress is very deeply involved in this.

ERDA is able, through suggestions to Congress, to shift the funds, because their recommendations are based on a great deal of technical expertise as well as their own judgment.

Mr. DiZio. I cannot address myself to the question of the funds required for the nuclear development but I find it curious that if you look at the potential returns of the two technologies—in other words, the percentages of energies that might be achieved in the energy system from the two technologies and you look at the commitment of funds to the two technologies—you quickly see that there is a large discrepancy somewhere.

Whether that means one is too large and therefore should be reduced or whether it means that the total bundle is too small, I do not say.

Senator PERCY. Anyone else care to comment?

Mr. SCHNEIDERMAN. Well, I don't think I can speak for ERDA. I know I can't. I don't think I can address myself to the question of the total distribution between nuclear and solar. But I do believe that nuclear certainly has the promise of delivering massive quantities of energy a lot sooner than solar energy and perhaps we ought to consider that we have this energy available in order to do the conversion later on.

I am really suggesting that there is a rationale for the large commitment to nuclear now.

Senator PERCY. I asked the question in the light of the fact that ERDA estimates that solar contribution to total U.S. energy demand will be eight-tenths of 1 percent by 1985. ERDA also estimates that solar contribution will increase to 7 percent by 2000 and to 25 percent by the year 2020.

Project independence estimates that solar energy could contribute from 15 to 30 percent of the Nation's total energy requirements by the year 2000. Our question is whether or not we should increase that amount.

I think we ought to be spending as much as we can for such technology. We should absorb as much of the financial burden as seems feasible and cost-effective. But we can't just get development by pouring in money.

At what point are solar energy technologies expected to provide energy costs comparable to those of fossil and nuclear energy sources in the future? Do you have any judgments on statements made on this subject by ERDA?

Mr. ROSENBLUM. We have looked into that question. There are areas of application which exist today in which solar photovoltaics are cost competitive. These tend to be those areas where the system is to be mounted remotely. The cost of transporting fuel, the cost of maintenance and service and so on allows photovoltaics to be competitive. Such areas for example are the weather stations I mentioned earlier located on the top of a mountain and navigational aids used by the Coast Guard and which are difficult to service regularly. For applications such as these photovoltaics is here in terms of the economics.

Then, there are a number of applications which will develop as the price of the photovoltaics drops and ERDA approaches its goal of 50 cents a watt in 1985. There will be users who will buy in, let's say, at $2 a watt, $2 a watt and so on. Already we can see the outlines of such markets. In terms of volume, though, in terms of total power, will probably be relatively small—maybe a total of megawatts or tens of megawatts per year. The big payoff for photovoltaic comes when we can talk about hundreds of thousands of megawatts.

I think the question of whether or not the photovolts are cost competitive has to be viewed in terms of various markets and various types of applications.

Senator PERCY. My time is up.

Mr. MLAVSKY. I have two or three comments. It has been cited here that the photovoltaic systems are modular. By that we mean that the efficiency is independent of its size. This is in striking contrast to the nuclear central power station which I now believe has to be something like 1,000 megawatts to achieve economy of scale.

It is important to keep in mind that the possibility of decentralized use of photovoltaics is a change in the way we make and use electricity, but it is a fundamental feature and the option provided by photovoltaics.

In terms of the large picture, there is a number often quoted that each year in the United States, the total solar energy falling is over 500 times our total energy consumption. If one were to cover 2 percent of the United States with photovoltaic converters, this would provide all of our energy that we currently use, but as electricity.

A great deal of that area is already around in the form of roofs on houses and desert areas of the country. I think that the prospect for a very large fraction of our energy generation by photovoltaics is there for the taking, and that economy of scale applies to all of the processes. If the government is able, through its funding, to stimulate firstly proof of the viability of the systems, and then the stimulation of the markets for them, I think the technology will keep up and industry can supply these things and have an impact on energy needs.

Senator PERCY. Mr. Chairman, I have some questions I would like to submit for the record.

Senator FANNIN. The record will be left open 2 weeks and the questions that are asked can be answered by that time.

Senator PERCY. I would like to say that our witnesses this morning have been extremely helpful.

Like Senator Fannin, I am deeply interested in this field. Mr. Chris Palmer of my staff is the chairman of our energy task force in my own office. He may be contacting you for help.

The potential for solar energy is so great. The industry I am concerned with, photographics, was revolutionized when the Bell and Howell Co. developed the idea that you could take light energy and convert it to electricity for automatic focusing and automatic aperture setting. The latter innovation turned the photographic business upside down and gave Bell & Howell a monopoly for 2 years.

I have seen what potential solar energy can have in a number of fields.

Thank you.

Senator FANNIN. Thank you, Senator Percy. This morning we are privileged to have a very valuable member of the Joint Economic Committee. At this time we have questioning from Congresswoman Margaret Heckler.

Representative HECKLER. In Massachusetts, as Mr. Mlavsky knows, we have concerns. I am concerned about the fund with which the Institute would be able to operate. My question would be whether or not the laboratories are already utilizing all of the available funding so that the new Institute when it actually becomes operational and is formed will really have very little, unless we have a major new appropriation for that purpose which is not projected into the budget.

Now would you all comment on the funding problems that a new institute would involve and how much money might be available under the existing projections of the budget?

Does the spirit move anyone?

Mr. Backus. I might comment on the plan as asked by ERDA. I was one of perhaps a few people that was very encouraged by that RFP showing a rather modest start and building up and trying to assess whether it is really worthwhile or not before making a major commitment.

I think that is a very sound way in which to approach the problem and not have a large commitment right away and a long term commitment until one is sure that that is the right way to go. I think the funding required under that plan is reasonable and fits within the solar budget.

Representative Heckler. Do the other panelists feel that this modest experimental beginning is the right way to go or do you feel the state-of-the-art is sufficient to warrant a major investment?

Mr. Mlavsky. I think I agree with the comments of Professor Backus, to this extent. We are looking now to develop an industry. Hopefully one will be able to buy one's solar photo-voltaic panel from the local lumber yard. Under these conditions as a technologist I find it difficult to understand how a research institute will transfer its findings to the point where they can be used by industry.

I think this is much more of a challenge in the creation of a Solar Energy Research Institute than the question of its scientific and professional organization, which was beautifully presented by the National Academy. I think this is a very crucial problem, the technology transfer problem from an institute to an industry.

I feel that, in the early days, this Institute should address itself to this problem as much as to the question of its basic organization.

Representative Heckler. No further questions, Mr. Chairman.

Senator Fannin. Thank you. Congressman Runnels has a question.

Representative Runnels. Mr. Backus, I think you stated that in your opinion ERDA was understaffed at this point in time. I would ask all of the panel members if they care to comment. Mr. Rosenblum, I chaired a committee where NASA had originally asked in fiscal year 1976 for $12 million originally for outer space generation and beaming back to the Earth. Then by the time they got over to OMB they had cut the figure to $8 million. By the time it got to Congress, it was to zero. I am wondering—I go back to Mr. Backus' statement—have we studied solar energy long enough in most of you gentlemen's opinion and now it is time with a joint effort of the Federal Government and private enterprise to put some of these theories into actual demonstration plants and to junk those that will not work and to jump on those that will work?

If so, how much money should be included in the budget to put some of these pilot projects actually onstream? Does anybody have any ideas? In what time period are we talking about?

Mr. Rosenblum. Perhaps I can address your question. We are now involved with the matter of residential tests. I use the word test rather than demonstration deliberately because we are in that phase of our understanding—or I should say, lack of understanding—where we must run a good many tests of the power system as a whole. For a house, this means not only test the solar cells in the array but with power condition and other components. We use AC power in homes and have to convert from DC to AC. The matter of storage is involved. The matter of tying in with a utility is involved. All these interfaces have to be considered from a technical point of view and also from the institutional interfaces involved. There is safety and a whole array of related matters. All of these matters have to be attacked in a systematic and thorough fashion. I think the kind of program we are striving toward in the test and demonstration project addresses these in just that fashion.

Obtaining technical answers can only be rushed so far or so much. I do not believe that in the area of residential photovolts we are ready for a demonstration, if one thinks of a demonstration as the step preceding commercialization. We are somewhat back from that point.

We are approaching solutions to technical problems in the time proven manner. I would say that on that score, we are probably approaching things correctly, increasing the budget or a speedup would not really assist greatly to do a systematic job.

What can be done is to pump more money into *x* more options and perhaps in that way, minimize the risk of overlooking something important. There is that aspect to increased funding.

I have to finish my answer on this note. The job we are doing is a system test job as such it differs from a development job and responds differently to added funding.

Mr. DIZIO. I agree partially with what Mr. Rosenblum mentioned but there are some other things that have to be considered also. It is immaterial what type of a generator one has, whether it be solar or some other. If it is going to be a distributed one, there are many things we don't understand yet.

We are beginning to work with some selected power utilities to answer questions which you can't even imagine but sit down and try to do a system study on paper. The questions of having the large distributor generating system, how it interphases with the grid system of the United States.

What this means in the sense of energies being fed in at different places at different times which suddenly come on line and go off line as clouds go by. What happens when a system's failure occurs and the lineman does not know from which direction the power is coming from?

All of these things have to be studied in a distributed sense. Those things have to look at the question of a distributed system in different parts of the country which are going to require different kinds of inputs.

Certainly the geological and meteorological conditions in Florida are not the same as in Massachusetts. There is no one that can give us the answer to the questions we have got to answer. We have got to get started now. Ten years is not too long. If we are going to have the economic problems involved in 10 years, we better start thinking now about what it is we want to create 10 years from today.

We can't do that on paper, as far as I am concerned.

Mr. SCHNEIDERMAN. I would like to comment that everybody is right. I am more concerned with an improper start in the utilization

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of solar energy so as to discredit it prematurely. There is a proper pace. I think both gentlemen are correct in terms of the difficulty of onsite or distributed systems.

I also think that something has to be done to find out what the real problems are by actually having experience.

But I suggest that there is a pace and we should not just jump in all arms and legs at once.

Mr. ROSENBLUM. May I clarify something for my friend Steve? We are as part of the program running actual tests with hardware. I did not want to leave Steve with the impression we are doing nothing but paper studies. Of course paper studies are needed as well as the system analyses and everything that goes along with it. But hardware tests are vital and so we are in total agreement.

That is the program we have underway now. That is the one I was referring to.

Senator FANNIN. Mr. DiZio, in your statement you say it is our opinion that the most cost-effective way to bring solar energy to realization would involve a joint effort between industry and Government. Are you satisfied with the program now projected?

Mr. DIZIO. I have not seen enough in the area of market development and systems study that gives us, as a business, a clear understanding of what type of time schedule we should gear our development to.

It is difficult to program a capital expansion to provide for a product if we don't know what that product is supposed to look like and we don't know what the needs of the market are. We are going to try to determine the answers to these questions ourselves as quickly as possible, but I really don't believe we can address the problem as effectively as the Government can. I don't believe what I have seen as the program that the Government is proposing is large enough to give us the answers in the length of time that we need them.

Senator FANNIN. Thank you very much. Mr. Mlavsky, you spoke in your statement on the first page about what is being done with the efforts going forward on the different programs that are involved.

We have heard a great deal about reduction in cost. What has taken place to date in the reduction of the cost as far as the manufacturing of these units is concerned?

Mr. MLAVSKY. It is very difficult to give you a point of time answer to that, Senator. We were able several years ago to define all of the technological hurdles to cost reduction. We are addressing them all. It is a bit like building a new house. Until the plumbers and the carpenters are out of it, you can't address the livability of the house.

We feel within a fairly short time these will come together to justify the approach. We are confident, for example, that the costs that have been talked about, 50 cents a watt, are achievable through this technology. We are moderately satisfied with the technical progress that has been made toward solving the problems which must be solved to achieve that price.

Senator FANNIN. Thank you very much. Mr. Backus, you gave some figures which reflect the amounts of money that should be expended or could be expended beneficially. I don't think we arrived at any definition. But you stated several. In the solar energy act that we have introduced, we proposed the sum of $78.9 million be allotted for the development of photovoltaics.

The President's budget allowed for $28.2 million in fiscal 1977. Do you feel there is sufficient R. & D. activity to absorb this increase in funding?

Mr. BACKUS. Yes, sir, I do. In my estimate, a $60 to $70 million program is well justified and could be well spent.

Senator FANNIN. I can recall when FAA Administrator Frank Zarb asked you the direct question would you be able to make work progress if you had more money? Could it be spent beneficially and advantageously and produce results? I think your answer to him was yes, you felt it could be. I appreciate your answer at this time. Are we yet at the stage where some of these funds could be expended to provide a market for solar cells in order to bring the cost of photovoltaics down to a competitive range with our alternatives?

Mr. BACKUS. We do have a program to do that to some modified extent. I think these programs are needed to economically justify applications for these special purpose power sources. More than that they are tests which are going to identify a lot of problems that you can't determine now in the laboratory.

What are the problems with large-scale power sources such as this? What is the degradation in the field and the type of environments you can't anticipate in the laboratory?

This will feed back to the development of cheaper cells which are coming out.

Senator FANNIN. We went through the same program with transistors. They said 9 out of 10 transistors manufactured were rejects. It was a tremendously costly program. I know it did turn out that in a few years' time, the cost went down fantastically. Although I don't anticipate that would happen in this case, I thought perhaps there could be some tie-in with the production.

Mr. BACKUS. I think that is true but there is more of a limit. It is not a parallel type of development in that you have a large material intensive product in this case. You have a limitation that way. I think that there will have to be a fairly major change in the technology from which cells are being made now, such as going to the ribbon cells or some other product, some other large-scale deposition before one can get well below 50 cents per watt.

If one uses the present technology of growing single crystal silicon, and making that into cells, even with increasing production rates, I don't think we can reach 50 cents per watt. We have to bring that along at the same time of developing processes.

Senator FANNIN. Thank you. I would ask the same question of the other witnesses. Do you feel there is sufficient R. & D. to absorb this increase in funding that I mentioned?

Mr. MLAVSKY. I think I agree with the comments of my colleague, Professor Backus. It does require a technology which is not current. It may be incipient, it may be in the development stage, but I think one can be beguiled a little with the analogy to the transistor. There their development came through getting more and more devices on a smaller and smaller piece of silicon.

I do believe we should continue to explore vigorously any potential new research which could lead to a solution. I think we should also very heavily undertake those programs which indicate the real, in-the-field problems which will arise.

I think it is worth emphasizing that the real successes or failures of these devices are going to be determined by using them under real conditions. Clouds come and go; freak weather in a region which has not had it occurs.

I really do believe this is receiving far too little emphasis since any solar device which produces electricity relies enormously heavily on electrical energy storage. This could be the Achilles' heel of photovoltaics and any other approach to solar electricity.

I do not feel we should cut off the basic research nor should we fail to take the developments that are now at some fairly advanced stage and subject them to real tests in the field.

Senator FANNIN. Are there any other comments on that? Are we at the stage where some of these funds could be expended to bring the cost of photovoltaics down to competitive range with our alternatives?

Mr. Mlavsky, you think this is something which is in the future?

Mr. MLAVSKY. Yes.

Senator FANNIN. Thank you, gentlemen, very much. I will have some questions Senator Humphrey has submitted to me. Senator Taft?

Senator TAFT. No, Mr. Chairman. I don't have any questions.

Senator PERCY. Very quickly, I want you to give me a yes or no answer, if you can. There have been some allegations that major oil companies who are funding solar energy R. & D. may have an incentive to slow down the commercial development of solar energy in order to maintain profits from other competing energy sources.

Do any of you have direct knowledge of whether or not this is taking place?

Mr. MLAVSKY. I can only speak from my own limited experience but the venture which I am concerned with is called Mobil Tyco. For a typical route 128 company in technology, these companies are in great shape until they actually invent something.

When we first determined that the silicon ribbon approach to solar cells looked promising, Tyco was faced with a large dilemma. It was obvious that a great deal of money would be required over a sustained period, no less than 7 years, in order to exploit this development. Tyco simply was not capable of funding such a development. When we sought a partner to help with this development——

Senator PERCY. Out of consideration for the next panel, I merely wanted to give you an opportunity to answer the question "yes" or "no." The record will be kept open for 2 weeks so you can supplement your reply.

Mr. MLAVSKY. I will simply state that without the participation of Mobil, this program would have died 3 years ago.

Senator PERCY. There is no slowdown whatsoever that you see?

Mr. MLAVSKY. No.

Mr. DIZIO. I can state the same thing. Our involvement is with Shell Oil Co., who is an 80-percent stockholder of SES. They are only impatient that we are not moving fast enough.

Senator PERCY. The second question is again a yes or no answer. Is there any duplication between FEA and ERDA in the effort made by the Government to commercialize solar energy?

The last question is whether ERDA has used international research efforts to solve common energy problems? Do you see any evidence that we are really reaching out among a community of nations now to see whether or not we can concentrate our energies and attention? If you think that we can profitably do so, we would like to hear from you on that.

Thank you.

Senator FANNIN. Thank you, Senator. The reason we are anxious to get some of these questions Senator Humphrey submitted answered today is that we are marking up the ERDA budget this week. We consequently need your help in determining just where the needs are. These questions will be asked so that you can respond accordingly.

Mr. SCHNEIDERMAN, the Jet Propulsion Laboratory presented a plan to ERDA for the development of low cost solar cells. This plan would bring solar electricity down to current cost of alternatives. What level of funding is necessary to get this plan underway?

Mr. SCHNEIDERMAN. Are you asking, Senator what is the present level of funding?

Senator FANNIN. What level of funding is necessary to get this program underway? What do you feel is necessary to get this program underway?

Mr. SCHNEIDERMAN. The initiation——

Senator FANNIN. I think you did make some recommendations in this regard.

Mr. SCHNEIDERMAN. We submitted a budget—as part of our share of the program to ERDA and of course we are not responsible for the distribution of funds within the program. I am not sure how to answer your question.

Senator FANNIN. Do you have sufficient funds to meet your goal? We are trying to determine whether or not more funds are needed to carry through the goals that you have set.

Mr. SCHNEIDERMAN. We believe that then at the present time funds are sufficient to get going.

Senator FANNIN. Would you ask for any increase at this time in that regard?

Mr. SCHNEIDERMAN. No. we are content.

Senator FANNIN. The photovoltaic conversion program background and rationale for the new 10-year plan is what I am referring to. We have some recommendations that have been made by JPL. What key technological breakthroughs effect the success of this program?

Mr. SCHNEIDERMAN. In my earlier statement I said reduction in the price of materials, developing processing which automate the assembly and so on. Of course, new inventions would not hurt.

Senator FANNIN. There may be some repetition in some of the testimony being given but we do want these questions answered if we could so that we will have specific answers to some of the questions that will arise during the mark up of the ERDA bill.

What other variables exist?

Mr. SCHNEIDERMAN. I would suggest that probably the largest barrier mentioned this morning and that is the market that might exist to take these things.

Senator FANNIN. What evidence do you have that these barriers can be overcome?

Mr. SCHNEIDERMAN. I think it is too early to answer that question. I think it requires 1 or 2 more years work to find that out.

Senator FANNIN. What has been ERDA's response to this plan for low cost solar cells?

Mr. SCHNEIDERMAN. I don't understand that question because we are only responsible for the array portion.

Senator FANNIN. We will have to give you a copy of this information that was furnished to the committee. Perhaps it will be of assistance in answering the questions.

Mr. SCHNEIDERMAN. I would like to introduce Mr. Bob Forney, the Project Manager for ERDA.

Senator FANNIN. Perhaps we could have the answers on a specific basis. I did not mean you were not giving them but perhaps you could be more concise.

Mr. SCHNEIDERMAN. Do you want the answers in writing?

Senator FANNIN. No. If you have the information there that you can give to us that can be a part of the record, it would be appreciated.

Mr. SCHNEIDERMAN. The program has laid out the approach to attack the high cost in the areas such as materials, the encapsulation process and the sheet processing. These have all been supported adequately in the way that the project plans were laid out originally. We now have underway some 25 contracts with industry to attack each of these areas which are called technology development areas that are needed to drive the costs down.

Senator FANNIN. So that we can have specific answers, perhaps you could give them to us later during the day.

Mr. SCHNEIDERMAN. Yes.

Senator FANNIN. If we continue our present pace, how long will it take to develop low cost solar cells? What would be the estimates? Mr. Rosenblum, do you have any idea?

Mr. ROSENBLUM. Is the question directed toward probing whether or not the ERDA goal——

Senator FANNIN. The ERDA goal and also the goal of industry. What is your estimate on how long it will take to develop low cost solar cells? I understand when you say low cost, it depends on the utilization. You feel there are low cost in certain utilizations we have today. If we are talking about the high generation of electricity, we would not say low cost.

Would you specify on what is your opinion as to how much it will go down in cost as the manufacturing increases.

Mr. ROSENBLUM. NASA as part of the space program has been looking into the matter of low cost. I can speak out of some experience on that subject.

We have had for the last 4 years a program for the development of low cost, space solar cells. Of course you recognize that for the space cell we look for a cell having higher quality and reliability than in terrestrial cells. But the thrust is essentially the same. We have a contract effort going at Spectrolab Corp. in the production of low cost solar cells for space which involve techniques that eliminate all vacuum processes and much hand labor; in other words, techniques aimed toward automation and eliminating costly processing. Based on the present results of the program, estimates made by Spectrolab predict that with a 2.5 megawatt production capacity and incorporation of the techniques now developed into automated production, a price of $1.60 a watt, can be expected.

That could be sometime perhaps in the period 1979 to 1980. This project is independent now of the ERDA program and as such provides an independent data point. This data point, incidentally fits very well with the ERDA projections.

I have been talking about technology that is in hand and is being exploited at present. In view of all this I would say the ERDA goals are very credible from a technology point of view and I expect they can be achieved.

Senator FANNIN. We will submit to each panelist the questions we are going to ask on this subject. If you have comments, it will be appreciated. Some of you may not have the information. If not, we would not expect you to submit any written answers. It was originally proposed that $60 million be spent this year on solar cell development. This figure was reduced by OMB and ERDA to $28 million.

Would each of you give me your evaluation of what impact this reduction could have on photovoltaic cells?

Mr. DIZIO. In my opinion the program which we see has been pretty much "one horse," you might say. I think the reason for that is because they don't have sufficient funds.

Of course you can't necessarily shorten the time constant by additional funds. But if you are interested in the probability of success, betting on more than one horse is the best way to come out a winner in a horse race.

Mr. BACKUS. I concur. It is just a matter of putting all your eggs in one basket. The increased funding would decrease the time scale somewhat but would certainly greatly increase the alternatives.

Senator FANNIN. I think you made that point before.

Mr. SCHNEIDERMAN. I have to concur that the confidence factor would increase but that is no guarantee of accelerated time.

Mr. MLAVSKY. I would concur with the proposal in the bill that we are discussing, that the funding be restored to $60 million.

Mr. ROSENBLUM. My comments would parallel the three panelists on the lefthand side of the table.

Senator FANNIN. Mr. DiZio, tell us how sensitive your research and development efforts are to decreases in ERDA solar funds?

Mr. DIZIO. I don't believe our research and development is particularly sensitive to ERDA funds because we are not using ERDA funds for this particular development work. On the other hand, the ERDA funds used in the market development could be very important because they might change drastically the direction of our program.

Senator FANNIN. Well, what are the major problems?

Mr. DIZIO. Our basic technology is such that we do not require new breakthroughs to achieve cost objectives.

Senator FANNIN. What about manufacturing larger quantities?

Mr. DIZIO. We will reduce the cost and expand production to meet the markets that are identified as existing.

Senator FANNIN. Would you want to answer the same question?

Mr. MLAVSKY. I think my answer is almost identical to that of the previous speaker.

A large proportion of our development work is supported inhouse. But the direction which it goes and our final ability to effect economies of scale and production depend upon the creation of a market. It is in that area that we feel that increased Government expenditures would be most useful to our technology.

Senator FANNIN. Are the major problems you faced in developing a long thin strip of solar material technical or economic?

Mr. MLAVSKY. Right now they are more technical. One of the advances of this technology is that it achieves a reasonably large scale at a reasonably small size plant. These are well defined advanced development problems, not research problems requiring breakthroughs but an ordinary and hopefully efficient conduct of an engineering type of development.

The problems of really achieving low cost, however, are economic rather than technical.

Senator FANNIN. How could the Government accelerate their efforts to get the cost down? Would your answer be similar to those previously made.

Mr. MLAVSKY. Yes.

Senator FANNIN. Mr. Backus and Mr. Schneiderman, you are both acknowledged experts on the solar energy technology of photovoltaics. This work is being achieved with modest Government help.

The photovoltaic branch of ERDA asked to spend $60 million on solar cell development. This was reduced finally to $28 million. In your opinion, first, can an outlay of $60 million in Government funds for solar cells be handled by the private sector? Will funds be used properly and beneficially?

Mr. BACKUS. Yes, sir. I think it can be used effectively and I think the plans were laid out to do that. As I understand it, their program plan was to achieve their objectives and that was the money required to achieve it.

Senator FANNIN. Is there sufficient research and development work that needs to be done on solar cells that requires $60 million?

Mr. BACKUS. I would say yes.

Senator FANNIN. Mr. Schneiderman?

Mr. SCHNEIDERMAN. I guess the system could absorb all the money you can give it. I am not so sure how productive it would be. Right now I think I would prefer a more gentle start in this arena and then a massive effort. Reserve the funds for a little later on when we know better what we should be doing.

Senator FANNIN. You gentlemen have been very patient and very cooperative. It has been very beneficial in establishing a good record. I think it will be very helpful to this committee and to the committees that are marking up the ERDA bill.

I very much appreciate your being here this morning. Thank you all for being with us. The next panel is on solar thermal electric systems. We have with us Floyd Blake of the Martin Marietta Corp., Donald Anderson of Sheldahl, and Yudi Gupta of E-Systems.

Thank you, gentlemen, for being with us here this morning. We very much appreciate your patience. We are very anxious to hear from you.

The ERDA personnel have testified several times. We do have their testimony and it will be utilized in the markup of the ERDA request. We are very pleased to have you gentlemen testify here today.
Please proceed.

STATEMENT OF FLOYD A. BLAKE, PROGRAM DIRECTOR, SOLAR ENERGY RESEARCH PROJECTS, MARTIN MARIETTA AEROSPACE, AND MEMBER, PANEL ON SOLAR THERMAL ELECTRIC SYSTEMS

Mr. BLAKE. Mr. Chairman, members of the committee, I thank you very much for the invitation to appear and discuss my favorite subject, electric power generation by solar energy.

Martin Marietta, in association with team partners, has been active in the central receiver—steam generator—solar thermal power program for the past 3 years under the sponsorship of both the National Science Foundation and the Energy Research and Development Administration. These have included one complete program and three ongoing programs.

The key approaches to the design of a high performance solar power system and a recommended development program for it were established in the now complete solar power system and component research program. Of most importance and benefit are the use of cavity configuration steam generators, concentrating heliostats, and a central receiver optical system featuring north side collector modules, of approximately 1,800 heliostats designed to be replicated relatively in small sizes.

Phase 1 of the central receiver solar thermal power system program is currently being performed in association with Bechtel Corp., Foster Wheeler Energy Corp., and Georgia Institute of Technology. The end objective of this phase is the preliminary design of the 10 megawatts electrical solar power pilot plant. Activities complete or underway to support this objective are the definition of a conceptual design, economic analysis and research experiments on the collector, receiver and solar thermal storage subsystems.

The first large quantity, solar powered steam generation will be accomplished in the 1 MWth bench model cavity receiver steam generator program, which has reached the checkout test stage. Solar testing will be performed under a French-United States cooperative agreement in the Centre National de la Recherche Solar Laboratory furnace at Odeillo, France. Major elements of the test installation are being provided under separate contract by Georgia Institute of Technology.

Fabrication, installation, and checkout testing of the first field of heliostats for the 5 MWt central receiver solar thermal test facility being built at Sandia Laboratories in Albuquerque, N. Mex., are underway.

I have shown a layout of the heliostat field for that 5 megawatt facility, chart 1. The shaded zone is the zone that is presently under contract.

These three programs are dovetailing elements of the overall program to develop solar thermal electrical power generation technology which should reach the pilot plant stage in 1980 and demonstration plant stage in 1985.

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Senator FANNIN. Chart 1, is that the 10-megawatt there?

Mr. BLAKE. The pilot plant is the 10-megawatt, electric.

Senator FANNIN. Thank you.

Mr. BLAKE. The orderly program started 3 years ago to develop solar energy electric power generation is timely, important, and based on solid technical and economic foundations. The program, carried through the pilot and demonstration plant stages, will benefit the country by contributing a new element in the inventory of power producing systems. Obvious desirable features are the use of inexhaustible solar energy for fuel and the opening to useful production of arid land without excessive demands for water.

The technical foundation for the solar power system draws from a large body of effort in the field of solar concentrator energy conversion both in the United States and abroad, and four basic areas of the needed technology have been demonstrated separately, but not as a combined system. These include:

1. High performance solar concentrators.
2. High quality Solar Steam Generation. Steam at 150 atmosphere and 500 degrees Celsius has been generated by the central receiver configuration installation at Genoa, Italy.
3. High temperature Electrical Power Generation. Low levels of power suitable for spacecraft have been generated by solar thermionic generators at temperatures up to 3189° nearly three times the level needed for steam power cycles.
4. Large area Multi-Facet Solar Collector. The need to collect 2000 m^2 of sunlight with modest size equipment was met by use of 63 heliostats of 45 m^2 each, which work together as a collector subsystem to power the CNRS furnace.

Development of a solar power system centers around the problems of scaling existing technology rather than the need for any extension of the state of the art. With this in mind, the conceptual design of the pilot plant will demonstrate all of the solar unique equipment at the full scale required for the demonstration plant. The pilot plant is essentially a module of the demonstration plant. The complexity of the design problems, both optically and thermally, is substantial; but has received a strong assist from tools developed to solve similarly complex spacecraft problems.

In a very real sense, the solar powerplant's rapid development potential is a terrestrial application of space technology.

The item shown on chart 2 is the one megawatt boiler which is going to France and the two lower pictures show it as it was completed within the last month. The scaling that I addressed is illustrated by the three stages of the scale.

In 1976, where we are now, the unit is about 8 feet tall. In 1977, the 5-megawatt unit to be tested in Albuquerque is 30 feet tall, and the pilot boiler will be 60 feet tall. This is an orderly development process to solve our problems when they are small and to solve technical scaling problems in orderly steps.

Keys to economic competitive status with alternate power systems involve the absolute cost of the major working element of the system, the mirrors, and the ability to achieve high technical performance of the system. The basis for commercial plant costing analyses necessarily involves extrapolation from costs of currently available equipment which is generally low production and laboratory quality.

However, the breakthrough for realistic optimism is the current existence of a highly automated mirror industry which produces the high quality mirrors, chart 3, needed for modest costs, approximately $1 per square foot.

Technical efficiency of the system has direct leverage on the cost as it sets the collector subsystem sizes, such as those illustrated in this chart.

The current central receiver commercial plant is projected to deliver 183 watts per square meter of mirror when operating in 861 w/m² sunlight for an end to end efficiency of 21.2 percent.

In determining cost competitiveness with current power generating systems, the effect on cost of design maturity must be considered. The The thermal storage and electric power generation subsystem configurations are shown on chart 4. Thermal storage, on the left, is a picture of the experiment. It does have to be raised in scale for the pilot plant but only for the size and number of tanks. Control of sequences and materials and temperatures will be demonstrated in the experiment.

Costing summaries are shown on two pie charts of chart 5 and below them two field layouts. One is for 100-megawatt plant that could make 100 megawatts on sunlight but does not have within it storage. The second one is a plant which is of the intermediate size that would have 6 hours a day of storage.

Its operation would jump to 5,100 hours a year. There are many more collector fields. There are 8 collector fields in the conversion plant, 14 in the plant with storage. To illustrate that there is more than one part to this story, the solar plant alone would project at $894 a kilowatt. There are several small pieces of one and one very big piece, the largest piece here is the mirror.

The main working elements are not by themselves, as manufactured, the big item. The mechanisms to support them are. These lend themselves to mass production and cost reduction designs.

In the system with thermal storage, again, it is the mirror tracking units that are the big element and this is because there are many more mirrors. Essentially six of these fields pour their energy into storage so it can be withdrawn after dark.

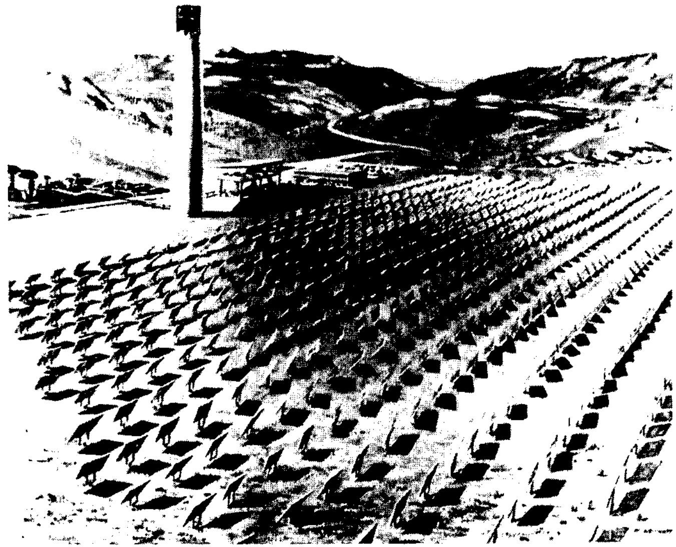
While the first demonstration plant will not be less expensive than nuclear or coal alternatives, we do project that a crossover with nuclear plant costs now being reported will occur with the fourth commercial size plant. The declining cost projection is based on the learning curve cost reductions and reductions resulting from high volume industrial tooling.

For the projected development to be accomplished in less time, that is the 10 years, than it would take to build a nuclear plant starting today—the substantial increase in authorized funding being considered for 1977 is critical.

Without it, I envision an unnecessary stretchout of the preliminary design phase or an interruption in the program between phase 1 and phase 2 impacting continuity and momentum of the development. I believe either of these events will increase the cost of development and delay the date when solar power is a realistic alternative.

[The charts referred to follow:]

10-MW$_e$ Pilot Plant Concept



Heliostat Layout for 5-MW$_t$ Test Facility

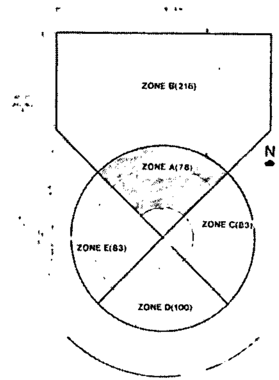
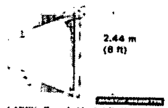
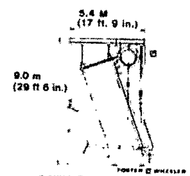


CHART 1

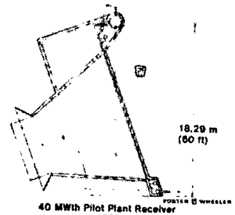
Central Receiver Steam Generator Development Perspective



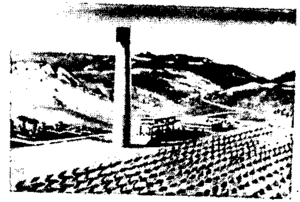
1 MWth Bench Model Boiler
1976



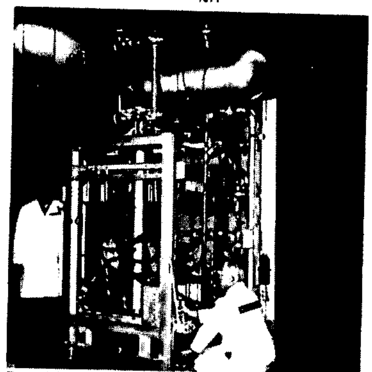
5 MWth Research Receiver
1977



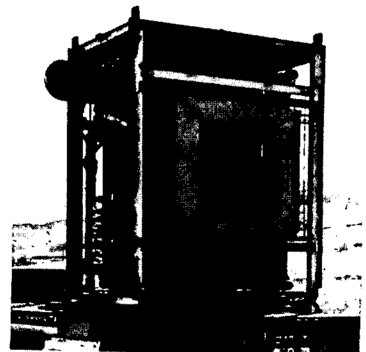
40 MWth Pilot Plant Receiver
1980



10 MW Electric Pilot Plant
1980



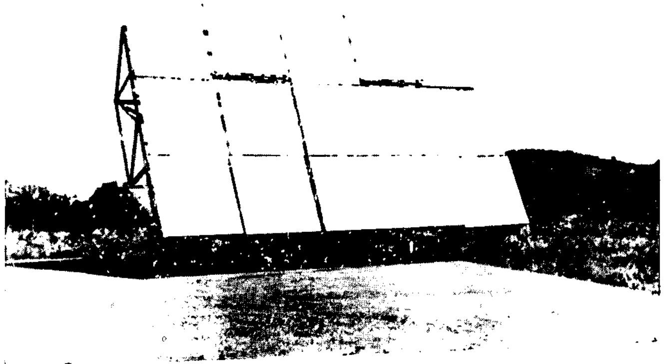
Rear View 1 MWth Receiver (Cavity Insulated)



Solar Side 1 MWth Receiver (Before Insulation)

CHART 2

Development Heliostat



5-MWt Test Facility Heliostat

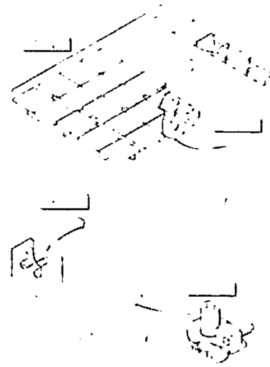


CHART 3

Thermal Storage & Electric Power Generation Subsystems

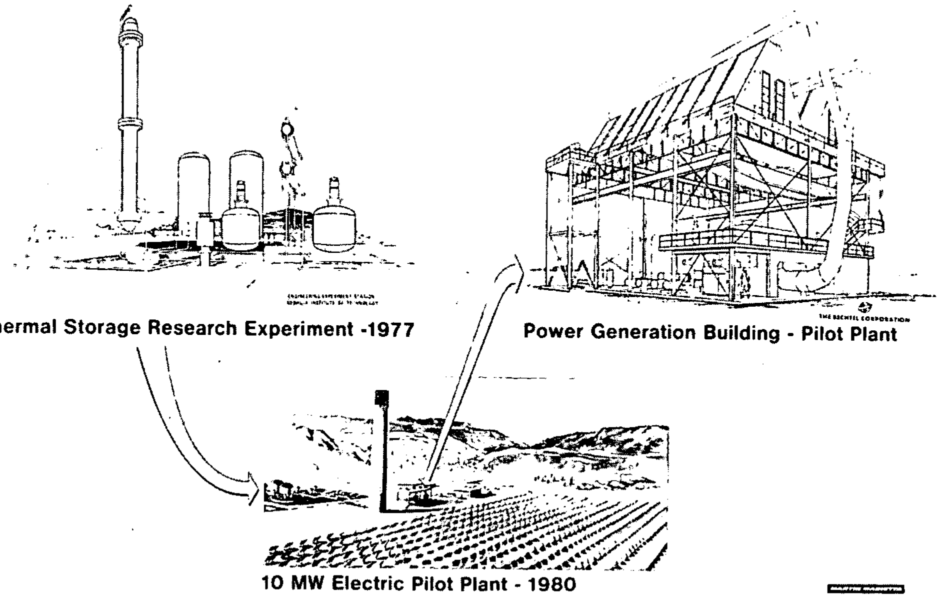
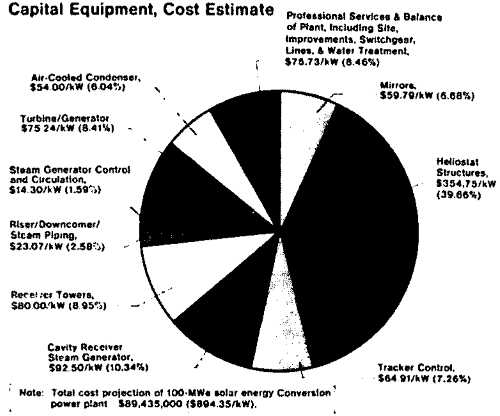


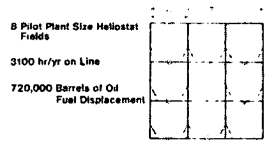
CHART 4

Commercial Demonstration Solar Power Plant Economic Perspective

Capital Equipment, Cost Estimate

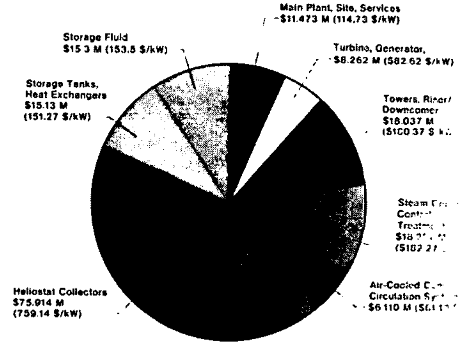


Note: Total cost projection of 100-MWe solar energy Conversion power plant $89,435,000 ($894.35/kW).

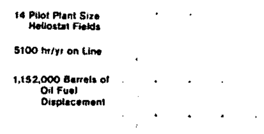


100 MWe Solar Energy Conversion Power Plant

Capital Equipment, Cost Estimate



Total Installed System Cost Projection = $168.5 M ($1685.0 $/kW)



100 MWe Solar Plant with 6 hr Storage

CHART 5

Senator Fannin. Thank you very much, Mr. Blake.
Mr. Anderson.

STATEMENT OF D. E. ANDERSON, VICE PRESIDENT AND DIRECTOR, SOLAR ENERGY GROUP, SHELDAHL, AND MEMBER, PANEL ON SOLAR THERMAL ELECTRIC SYSTEMS

Mr. Anderson. I would like to show some slides.

We have been involved in parallel programs to Floyd Blake's description for the last 3 years.

[Slide.]

This includes some work with central receiver designs. Rather than spend time on that, I will summarize that briefly by describing the fact that we first had a study contract through the National Science Foundation looking at the central receiver heliostat type plants. They definitely have economic potential.

We are proceding in concert with a team headed by McDonnell Douglas Astronautics on the development of reflective surfaces for a fairly similar heliostat concept. I would like to touch only here on the one statement of the feasibility of scale up to volume production.

We are interested primarily now in the development of first surface plastic phase materials for solar applications.

[Slide.]

In this area, we have adapted conventional glass and mirror lines to provide the materials on which a first surface mirror can be developed. A single line of this sort can produce there enough for one square mile of mirrors per month.

We have produced full size heliostat mirrors with reflectances in excess of 90 percent. Rather than spend more time on that, I would like to focus on the fact that there is a variety of concentration ratios, a variety of tasks being examined under the funding by many people for the application of solar thermal energy and different temperatures.

[Slide.]

Basically, the need for solar tracking is associated with the need to get higher temperatures. The operation for heating homes can operate at 180 degrees. In order to enhance this temeprature, we have to stuff more lighting into a smaller surface area. There are a variety of ways of doing this. Sheldahl is involved in two of them.

One of them is a light focusing system which can achieve concentrations ratios from 30 to 100 suns, providing temperatures of several hundred Fahrenheit. The higher temperature systems which tracks sunlight in two directions, can achieve concentration ratios above the limits of conventional boiler technology to convert the sunlight into thermal form.

In the intermediate temperature region, a number of applications exist which combine the production of electricity with the use of waste heat and solar total thermal energy systems.

The primary advantage of the intermediate temperature system is that the unit is modular which permits it to be installed adjacent to structures, on the roof of structures and the like.

Applications where the waste heat from this plant itself can be used. One of these systems is now operational down in Albuquerque.

[Slide.]

This has reached temperatures of 600 degrees Fahrenheit and has operated successfully. That system can collect in excess of 50 percent of all of the solar energy which impinges on the aperture.

[Slide.]

In the general sense, the line focus systems all require an appreciable amount of engineering attention to detail. Both in the optical and concentrators, the materials from which they are built, and the receivers which can convert that concentrated solar flux from high temperatures.

The concentrators can operate with high efficiency.

[Slide.]

The system wich Sheldahl has developed with its own funds is an adaptation of this simple line focus parabola, using then a number of long segments very much like venetian blinds which can be focused.

This lends itself directly to mass production because you have a very simple unit which can be fabricated and installed in a variety of applications with a modular size of 200 square feet to each unit.

The sole purpose here is sun tracking.

[Slide.]

The tracking system like this is well within the state of the art using very simple mechanisms and light sensors very much like the light detectors on cameras. A pair of sensors here mounted next to receivers are sufficient to provide complete automated tracking of such a system.

[Slide.]

The use of a system of this sort in commercial applications requires a complete automation of sensing of the sun, sensing of demand for heat and the detection of over temperatures. All of this is within the state of the art.

[Slide.]

The application of intermediate temperature units distributed fields to a solar total energy system has been studied in some detail under funding provided by ERDA to the American Technological University in concert with the Army, taking a specific existing dormitory complex at the Fort Hood installation in Texas.

[Slide.]

The building complex here consists of 19 buildings with 430,000 square feet of floor space. Over the past 2 years, careful measurements of the energy use of that complex and the available sunlight have been used in first phase engineering studies to study the impact, covering 214,000 square feet of surface area, about half the square footage of the building space being supplied with total energy. This included electrical, heating, air conditioning and hot water for the complex.

[Slide.]

The complex has had careful measurements of both the present use of energy and the availability of focusable sunlight. The studies to date would indicate that on the order of 61 percent of the total energy costs of that complex could be supplemented with this kind of a system with only short term storage.

[Slide.]

I attempted to address myself to the general question of the relative importance of solar energy in comparison to other forms. The general questions don't have to do with its ecological impact but rather has to do with the fact that the impact may be small, several percent for example by the end of the century. It obviously is unreliable on a given day in given weather. The cost of solar plants are around $10 per square foot or $1,000 per kilowatt.

[Slide.]

It cannot happen before the early part of the 21st century.

[Slide.]

It turns out if you look at the total use of energy in the United States, about 70 percent of all of our energy is supplied by burning fuels or nuclear energy in the stationary form and is used to produce temperatures below 1,000 degrees Fahrenheit.

Even without long-term storage, taking into account weather patterns, about 50 percent of that energy could be replaced by in a sense consuming sunlight when available, fossil fuels and nuclear when not available.

[Slide.]

In terms of questions of unreliability, today we can replace 50 percent of fuel consumption with only overnight storage. There are advance concepts under study. Even seasonal storage is quite practical in the future with additional study. Our seasonal storage would make solar energy very much like hydroelectricity. The plant does have to follow the weather on an annual basis.

But at a given time we can load fuel and draw energy from it at a rate not directly correlated with the rate at which sunlight is arriving.

[Slide.]

In terms of expense, the thermal collection which can be used to displace other forms, break-even costs are on the order of $10 per square foot.

We are building the system at a cost of $19 per square foot. With a few breakthroughs we can get down to that range.

[Slide.]

Several systems will collect at least 200,000 Btu's per square foot per year. Taking those two numbers, we then have the capital cost of providing energy at something like $50 per million Btu per year.

I have a comparison shown on the last three lines of the slide to in a sense producing 1 million Btu's per year by buying 5 square feet of the system versus burning oil which cost $3.56 per million Btu. If one uses the capital investment of a long lifetime system, that $10 per square foot system would collect energy at $2 per million Btu.

If you view this as something where it must pay back over a normal commercial lifetime of say 20 years at 10 percent interest, that solar cost would be $5.88 a million Btu, within a factor of two of present cost of energy.

I find this encouraging.

[Slide.]

On the commercial system, it is available today. Speaking as a representative of a modest size company, $50 million per year, the prime concern has been to be associated with the systematic development of the market and of incentives for that market.

[Slide.]

As to whether it is too late, none of the technology required for solar development is beyond state of the art and once you produce the temperature at the same quality— steam at the same pressure as is used by fossil fuel plants—the rest of the system is conventional.

There are typical problems of making the systems cost effective and reliable and having a long lifetime. Thank you.

Senator FANNIN. Thank you, Mr. Anderson.

Mr. Gupta, please proceed.

STATEMENT OF Y. P. GUPTA, CORPORATE DIRECTOR OF ENERGY PROGRAMS, E-SYSTEMS, INC., AND MEMBER, PANEL ON SOLAR THERMAL ELECTRIC SYSTEMS

Mr. GUPTA. Mr. Chairman, I appreciate the opportunity to appear before this distinguished committee. I would like to speak to the thesis that there is a necessity and a need for research development and demonstration of a number of solar thermal concepts in parallel.

Citizens across the country are anxious to utilize solar electrical power to alleviate their energy problems. Solar power system requirements in small-to-moderate capacity include solar thermal power systems for small residential and urban communities, industrial parks, academic institutions, and defense establishments. In my testimony I would like to speak also of a system that meets the total spectrum of requirements from grouped modules comprising a central powerplant, to distributed modules close to the point of energy consumption.

Therefore I would like to submit that it will be highly prudent and in the best interest of the energy future of the United States to have a properly funded and accelerated program with emphasis on development and demonstration of several projects. To select one for development as is largely the case at the present and postpone the rest to low-level study is at best a very risky approach.

Here are 10 reasons why we believe so: (1) The scientific feasibility of solar to electric conversion is well established; (2) the technology base exists for construction of first-generation power modules; (3) industrial interests and capabilities are sufficiently strong to successfully complete development and demonstration programs on several basic system concepts in parallel; (4) examples exist in the recent history of technology that demonstrates the wisdom of pursuing several concepts in parallel. If the originally selected approach for the enrichment of uranium were to continue to be developed exclusively, we probably would not have nuclear energy today; (5) given a specific application mode, solar thermal systems differ from each other primarily due to the type of solar collector selected. There are over half a dozen different solar collector candidates proposed to date. Each has important differences with regard to the performance, technology, probable economics, and sensitivity to location including seismic activity. Thus it is highly unlikely that a single-system concept would be equally effective for a diversity of requirements; (6) the central receiver concept, the only one being developed with ERDA funds, is based on the philosophy of large solar electric powerplants; that is, 100 megawatts and over. Such a system cannot cost effectively meet the diversity of requirements, such as powerplants for agricultural and residential communities or as total energy systems; (7) large solar powerplants will be site restricted because of the enormous amount of cooling water required, particularly in the dry regions where solar powerplants are natural because of high insolation. Small modular powerplants in a given region are more naturally adapted to a distributed source of water supply. They can be located near dispersed reservoirs, or ground water; (8) centralized larger solar powerplants would of necessity have to be constructed in an area substantially removed from the load center. Thus power transmission losses will be higher compared to modular powerplants located close in to the load center; (9) at the anticipated rate of growth in the southwestern United States, a substantial fraction of the new powerplant starts over the next 2 decades can be solar power units, provided a small solar module with short construction time, 12 to 24 months, can be successfully demonstrated; and (10) to effectively utilize solar power units, transition from prototype demonstration to actual production is essential. This is time consuming since large amounts of funds will be required for production facilities essential to achieving the economiccs of mass production. These large investments cannot be prudently faced by the business community or the Government until prototypes have been built and tested.

A single concept approach, should it run into snags during the development and demonstration phases, could easily delay the utilization of solar power by a decade or more. The parallel multiconcept approach provides an inherent security in addition to making available a variety of solar power systems adapted at diverse requirements.

Earlier it was stated that to date several solar thermal power system concepts have been proposed. In general, the proposed concepts fall into two categories, one employing typically moving mirrors and the other fixed mirrors. In any case, large mirror areas supported on rigid structures capable of withstanding operational and environmental loads are required. Both types of systems are technically feasible and can be developed and demonstrated with speed. What needs to be determined is the cost performance relation for a variety of requirements solar thermal systems are anticipated to meet. This can be achieved by working, in parallel, several solar thermal options through the phases of research, development, demonstration, and evaluation. Moreover, such demonstrations and evaluations will be more effective if from the start they tie in with certain end applications and include an active interface and participation of the ultimate user.

Over 3 years ago, E-Systems, Inc., a diversified supplier of commercial and electronic systems made a significant commitment in the area of solar energy conversion. Since then we have been actively investigating a fixed mirror type solar thermal power system called the Fixed Mirror Distributed Focus (FMDF) system.

Let me describe the reasons behind the selection of this system, how it works and compares with some other concepts. As to the reasons for selecting the FMDF concept, one need not go beyond looking into the decades of technology and expertise E-Systems has developed for small-to-large size fully tracking as fixed-mirror and radiotelescope systems. E-Systems' current position as the world's largest supplier of large satellite communications antennas and radiotelescopes has been largely due to its unique innovative capabilities in engineering, construction, design, deployment logistics, and systems integration. E-Systems has designed and installed over 200 large antennas all around the world as shown in the first slide. [Slide.]

These installation have covered environments as diverse as Resolute Bay, Canada, 76 degrees north latitude, the deserts of Algeria and Oman, high seismic locations and heavily corrosive salt spray atmospheres as in Fiji and Guam. Significant advances have been made by E-Systems in operational reliability of large antenna systems. As an example, just 9 years ago, a maintenance crew of 30 technicians was considered necessary to insure successful 24-hour-per-day operation of large antenna systems. Today a crew of five technicians has been achieving a phenomenal operational ontime record of downtime of just 1 hour per year due to system failures.

Near Arecibo, Puerto Rico, E-Systems recently completed a significant modification and upgrading of the 1,000-foot diameter fixed hemispherical reflector which comprises the world's largest telescope. This program, funded by the National Science Foundation, included the redesign, fabrication, and installation of new panels and support structures which greatly increased the antennas scientific versatility and accuracy.

In October 1973, E-Systems received from NSF a contract to design and produce 28 fully tracking parabolic antennas for the Very Large Array (VLA) radiotelescope. The VLA program when completed in 1981 in New Mexico will provide an unsurpassed instrument for scientific research in the physics of radio sources beyond the Milky Way and greatly improve our understanding of these large energy sources.

The foregoing discussion of E-Systems' capability and programs in the field of antennas and radiotelescopes has been intended to illustrate the applicable technology and engineering experience that relates directly to the development problems associated with solar thermal energy systems.

An in-depth analysis of the extensive in-house data on real costs associated with the design, engineering, fabrication, construction, and operational maintenance of large electromechanical structures typical of solar thermal systems of both the fully tracking and the fixed mirror types provided E-Systems with a clear incentive to pursue development of a fixed mirror distributed focus type solar thermal energy system.

This view is partially adduced by a cursory observation despite the familiar technological relationship between antennas and solar thermal systems, industries and certain government laboratories with direct experiences in antenna design, construction, and utilization are not yet fully involved in solar thermal systems using large fully tracking mirrors or large numbers of smaller fully tracking mirrors.

How does E-Systems' Fixed Mirror Distributed Focus (FMDF) system operate? [Slide.]

This slide shows a schematic——

Senator FANNIN. Is that the same as the model unit that you have?

Mr. GUPTA. That is right. This slide shows a schematic of a solar thermal electric system. The FMDF solar collector employs a fixed section of a hemispherical mirror emplaced partly or mostly in or on the ground. The incident solar radiation is focused by the mirror on a small receiver that follows the motion of the Sun. The receiver here plays the role of a boiler in a conventional powerplant. The tracking of the Sun is accomplished simply by using an automatic drive to follow the Sun's orbit. The transfer of thermal energy from the receiver to the turbine/generator unit or another appropriate application unit is by means of a fluid such as water flowing through the unit. The spent fluid is reduced in temperature and reintroduced into the receiver.

Excess energy developed in periods of high solar insolation can be stored and withdrawn in low insolation periods for cycling through the turbo-generator. The electrical output of the generator is appropriately conditioned for interface compatibility with a utility distribution network. [Slide.]

The next slide shows a small model of the FMDF in operation. This is actually the picture of the model sitting here in actual operation.

Similarities between the FMDF system and the Arecibo radiotelescope with regard to operating principles, engineering design, and at least one method of construction are illustrated in the next few slides. [Slide.]

This is the Arecibo radiotelescope. Basically it is a 1,000 foot diameter dish lined with aluminum reflector panels. It is used as the radiotelescope antenna for astronomical studies. It operates on exactly the same principle as the FMDF solar power system. [Slide.]

This shows a close view of the surface that was installed. The surface is above the base of a depression in the ground. There is a plantation under the dish in order to stabilize the soil. It was a requirement placed on the contract for the particular soil conditions in that region. On the other hand, this reflector surface was built simultaneously while the remainder of the system was in constant operation.

Not a day or an hour of work was lost while the total installation was being carried on. This dish contains in excess of 38,000 panels that were built, assembled and installed in less than 3 months onsite. [Slide.]

This shows some of the preliminary civil work carried out. Basically there was a rim of concrete poured around the 1,000 foot diameter circle. The cables were suspended from the rim to achieve the configuration of the hemisphere. The surface could then be adjusted to the spherical configuration. [Slide.]

This is an artist's concept of a fixed mirror distributed focus solar thermal electric plant. This contains a distributed field of collectors connected together. The central powerplant would receive the steam and would convert it to electrical energy. Some of the strong points of this system I will discuss shortly.

In principle, it is possible to combine or design the central powerplant system such that you have dishes with different sizes and with different orientations. This has certain implications in regard to the performance matching with the requirements. [Slide.]

The next three slides provide production cost comparisons for 100-megawatt electric intermediate and hybrid FMDF solar powerplants in contrast to central receiver and other solar thermal plants of the same capacity.

The first chart is based on the analysis of Aerospace Corporation which has the responsibility to analyze a number of systems with regard to their cost, performance, and requirements. This information has recently been submitted to us. It is for an intermediate and a hybrid central receiver powerplant of 100-megawatts electric with 17.6 percent overall efficiency.

The cost of the completed central receiver plant in terms of 1975 dollars, 1383 per kW (electric). For the hybrid which works for about 8 hours per day, the cost is $837 per kW (electric). Only the lowest of cost estimates provided by ERDA contractors were used in the compilation of estimated costs for the central receiver system. [Slide.]

The 100-megawatt electric FMDF powerplant has an overall efficiency of 13 percent. The collector area is about 30 percent greater than for the central receiver system. The storage time is the same. Estimated costs shown range from a high value to a low value. The high estimated cost we know can be achieved now. The lower cost can be achieved with certain modifications. This is so because there are a number of concepts by which a hemispherical configuration of different sizes can be made.

The cost lies between $1,100 and $1,700 per kW (electric) for the intermediate FMDF solar powerplant. For the case of the hybrid plant it is in the range of $675 to $979 per kilowatt. Aerospace Corporation work has indicated that the parabolic troughs of various kinds, the east-west, the polar, the north-south as well as fully tracking parabolic distributed powerplants are more costly than the central receiver.

Although the FMDF powerplant system has not had the benefit of detailed baseline design studies and system optimization, these comparisons do indicate that the FMDF systems can be cost competitive or cheaper than the central receiver type systems at least in a certain plant capacity range.

Compared to other solar energy collectors, the FMDF system has certain special features that provide high system reliability, simplicity of maintenance and operation and potential cost advantages for such systems in production. These features include: (1) minimum structural material is required per unit area of the optical gathering surface. This is so because the mirror is fixed; (2) only one object, the receiver, tracks the Sun. The receiver is much smaller than a large movable mirror area of a large number of tracking mirrors. The required solar tracking is two-axis and is simple, more like a solar clock drive; (3) the receiver is fully stowable in severe weather and operable under winds of 50 knots and higher. Moreover, the receiver can be readily moved out of the focal region for repair in case of fluid flow failure; (4) the average flux concentration, depending on the designed considerations and the size of the individual dishes, can range from 100 to 600 resulting in high net system efficiency. The average concentration factor does not tell the story regarding the performance of a solar powerplant. The best indication is in the case of a system where the flux concentration is distributed along the receiver, that the boiler be designed to take advantage of what is known as coflux heating, that is, you generate fluids of progressively higher temperature as you progress into the higher and higher flux concentration region of the receiver. This provides high average daily efficiency, (5) the FMDF system is modularized. The modular approach to collector construction allows wide flexibility with regard to the system size, use of local materials, labor, and talents and choice of methods, materials, and logistics of construction and system integration; (6) multiple collectors can be clustered about a large central power generation system. The cluster output can be easily made to match this energy demand by coupling reflectors with differing tilt angles and sizes.

Simple maintenance methods are available for the optical gathering surface and easy replacement of parts. The entire reflector can be cleaned at once by a jet spray of water, steam, or detergent solutions issuing from the periphery; (7) the rainwater as well as the wash solutions can be drained by a pump placed at the bottom of the receiver. Thus, the system as a whole is adaptable to automatic cleaning as frequently as is required; and (8) the FMDF system makes maximum use of proven technology such as developed by E-systems such as in the construction of the 1,000-foot radiotelescope at Arecibo. These systems have a low visual impact on the land areas used since a fair portion of the hemispherical reflector is below the surface level.

In conclusion, E-systems has an extensive experience, expertise, and technology base that is directly applicable to the development of solar energy systems. We have completed decades of work in the field of antennas, radiotelescopes, and a host of other major efforts in electronic systems, controls, tracking, and guidance systems as well as complex aerospace systems. This experience establishes our credentials for participation in the development, demonstration, and production of solar energy systems; participation in ways that we believe would be meaningful, responsive to the needs, and productive in creating options for an early utilization of solar power.

We submit that the national interest demands that several alternate solar thermal concepts be actively and substantially pursued in parallel through the phases of research, development, demonstration, and evaluation. Serious consideration should be given to modular solar power systems for applications in the small- to moderate-size agricultural, residential, and urban communities.

We stay convinced that the fixed mirror solar energy systems of the FMDF type will play an important role in the national utilization and adoption of solar thermal systems. Investment in such concepts would appear to be amply rewarding. E-systems management has committed a significant investment in company funds and manpower to pursue solar energy conversion technology. However, a significant undertaking of the necessary magnitude can only succeed with flexible Federal support.

Thus, we fully support our earlier statement that funding and clear directives should be provided to encourage multiple demonstration or demonstrations of several alternate solar concepts in parallel.

Thank you.

[The prepared statement of Mr. Gupta follows:]

PREPARED STATEMENT OF Y. P. GUPTA

Dr. Y. P. Gupta is Corporate Director of Energy Programs of E-Systems, Inc. He previously was a Program Manager at Advanced Technology Center, Inc., then the Research Center of E-Systems and the LTV Aerospace Corporation; President of Centec Company; Director Materials Sciences Laboratory of Northrop Corporation; and a member of the faculty at the University of Minnesota. Dr. Gupta is well-known in the field of energy systems related research and development especially in the areas of materials, properties of liquid metals, electronic-optical devices, structural engineering and design.

I am pleased to have the opportunity to offer testimony in support of S-3027. I will confine my remarks to the Solar Thermal (Electric) area. Speaking simply, the concept of a solar thermal system includes a solar energy collector to collect incident solar energy as heat, and an appropriate machine to convert heat into mechanical and/or electrical energy as dictated by the specific application. In certain situations, a part of the heat energy can be directly used with the remainder converted to electrical and/or mechanical energy, thus resulting in higher overall efficiency. This latter situation is a simplistic view of what is called the Solar Total Energy System.

No one can argue a social acceptance problem with solar electrical power through community or regional power systems. In fact, citizens are anxious to utilize solar power systems to alleviate their own regional energy problems. There exists large requirements for a variety of solar power systems in small to moderate capacity range. These include solar power plants and total energy systems for agricultural and moderate-size residential communities, industrial parks, urban areas, academic institutions and certain defense establishments.

Therefore, gentlemen, I submit to you that it will be highly prudent and in the best interest of the energy future of the United States to have a properly funded and an accelerated solar thermal program with strong emphasis on research, development and demonstration of several alternate concepts in parallel. To select one for development, as is largely the case at present, and postpone the rest to low-level studies is at best a very risky approach. Here are the reasons why we think so.

1. The scientific feasibility of solar to electric conversion modes is well established.

2. Technology base exists for construction of reasonable first-generation power modules.

3. Industrial interest and capabilities are sufficiently strong to successfully complete development and demonstration programs on several basic system concepts in parallel.

4. Examples exist in the recent history of technology that demonstrate the wisdom of pursuing several concepts in parallel. If the originally selected approach for enrichment of Uranium were to continue to be developed exclusively, we probably would not have nuclear energy today.

5. Given a specific application mode, solar thermal systems differ from one another in respect of cost, performance, and operation primarily due to the type of solar collector selected. There are over half a dozen different solar collector candidates proposed to date. Each has important differences with regard

to performance, technology, probable economics and sensitivity to the environmental and site peculiar factors including seismic activity. Thus it is highly unlikly that a single system concept would be equally cost-effective for a diversity of requirements.

6. The central receiver concept, the only one being vigorously developed with ERDA funds, is based on the philosophy of large solar electric power plants—100MW and over. Such a system cannot cost-effectively meet the diversity of other requirements such as power plants for agricultural and residential communities, or as total energy systems.

7. Large solar power plants will be site restricted because of the enormous amount of cooling water required, particularly in the dry regions where solar power plamts are natural because of high solar incidence. Small modular power plants in a given region are more naturally adapted to a distributed source of water supply, e.g., they can be located near water from distributed reservoirs or ground water in the area of the small plant can be used for cooling.

8. Centralized larger solar power plants would of necessity be constructed in an area substantially removed from the load center. Thus power transmission losses will be higher compared to an equivalent number of modular power plants located close-in to the load center.

9. At the anticipated growth rate in the Southwestern states, a substantial fraction of the new power plant starts over the next two decades can be solar power units, provided small solar power modules with short construction times (12–24 months) can be successfully demonstrated.

10. To effectively utilize solar power units, transition from prototype demonstration stage into actual volume production is essential. This is time consuming since large investment of funds will be required for production facilities essential to achieving the economics of mass production. These large investments cannot be prudently faced by the business community or the Government until prototypes have been built and tested. A single concept approach, should it run into snags during the development and demonstration phases, could easily delay the utilization of solar power units by a decade or more. Parallel multiconcept approach provides an inherent security in addition to making available a variety of solar power systems adapted at diverse requirements.

Earlier, it was stated that to date several solar thermal power concepts have been proposed. In general, the proposed concepts fall into two categories, one employing moving mirrors and the other fixed mirrors. In any case large mirror areas supported on rigid structure capable of withstanding operational and environmental loads are required. Both types of systems are technologically feasible and can be developed and demonstrated with speed. What needs to be determined is the cost-performance relations for a variety of requirements solar thermal systems are anticipated to meet. This can realistically be achieved by working in parallel several solar thermal options through the phases of research, development, demonstration and evaluations. Moreover, such demonstrations and evaluations will be more effective if from the start they tie-in with certain end applications and include an active interface and participation of the ultimate user.

Over two years ago E-Systems, Inc., a diversified supplier of commercial and military electronic systems made a significant commitment in the area of solar energy conversion. Since then we have been actively investigating a fixed mirror type solar thermal power system called the FMDF (Fixed Mirror Distributed Focus) System. Mr. Chairman, allow me to take a few minutes to describe the reasons behind the selection of the FMDF system, how it works and compares with some other concepts.

As to the reasons one needs not go farther than looking into the decades of technology and expertise E-Systems has developed for small to large size fully-tracking as well as fixed mirror antenna and radiotelescope systems. E-Systems' current position as the world's largest (approximately 30 percent of the World Market) supplier of large satellite communications antennas and radiotelescopes has been largely due to its unique innovative capabilities in engineering, design, manufacturing, construction, deployment logistics and system integration. E-Systems has designed and installed over 200 large antennas all around the world, as shown in Fig. 1. These installations have covered environments as diverse as Resolute Bay, Canada (76° N latitude), the deserts of Algeria and Oman, high seismic locations and heavily corrosive salt spray atmospheres as in Fiji and Guam. Significant advances have been made by E-Systems in operational reliability of large antenna systems. As an example, just nine years ago, a maintenance crew of 30 technicians was considered necessary to insure successful 24 hour per day operation of large antenna systems. Today, a crew of 5 technicians has been achieving, on the average, a phenomenal operational on-time record of down time of just one hour per year due to system failures.

Near Arecibo, Puerto Rico, E-Systems has recently completed a significant modification and upgrading of the 1,000 ft. diameter fixed hemispherical reflector which comprises the world's largest radio telescope. This program funded by NSF included the redesign, fabrication, and installation of new panels and support structure which greatly increased the antenna's scientific accuracy and versatility. In October 1973, E-Systems received from NSF a contract to design and produce 28 fully tracking parabolic antennas, each 82 ft. in diameter, for the Very Large Array Radio Telescope (VLA) now in construction in New Mexico. The VLA program, when completed in 1981, will provide an unsurpassed instrument for scientific research in the physics of radio sources beyond the Milky Way and greatly improve our understanding of these large energy sources and of the physical processes involved.

The foregoing discussion of E-Systems capabilities and programs in the field of antennas and radiotelescopes has been intended to illustrate applicable technology and engineering experience that directly relates to the development and technological problems associated with solar thermal energy conversion systems. An in-depth analysis of the extensive in-house data on real costs associated with the design, engineering, fabrication, construction and operational maintenance of large electromechanical structures (typical of solar thermal systems) of both the fully-tracking and fixed mirror types, provided a clear incentive to pursue development of the Fixed hemispherical mirror type solar thermal energy systems. This view is partially adduced by a cursory observation. Despite the familial technological relationship between antennas and solar thermal systems, industries and certain government laboratories with direct experience in antenna design, construction and utilization are not yet fully involved in solar thermal systems using large fully-tracking mirrors or large numbers of smaller fully-tracking mirrors.

How does E-Systems' fixed Mirror Distributed Focus (FMDF) solar thermal energy system operate? Fig. 2 shows a schematic of a FMDF solar thermal/electric system. The FMDF solar energy collector employs a fixed section of a hemispherical mirror emplaced partly or mostly in or on the ground. The incident solar radiation is focused by the mirror on a small receiver that follows the motion of the sun. The receiver here plays the role of a boiler in a conventional power plant. The tracking of the sun is accomplished simply by using an automatic drive to follow the sun's orbit. The transfer of thermal energy from the receiver to the turbine/generator unit or another appropirate application unit is by means of a fluid (such as water) flowing through the receiver. The spent fluid is discharged from the turbine, reduced in temperature and pressure, and recycled through the receiver. The excess energy developed in periods of high solar insolation can be stored and withdrawn in low insolation periods for cycling through the turbo-generator.

The electrical output of the generator is appropriately conditioned for interface compatibility with the utility distribution system. At the presentation, a small model of the FMDF solar thermal system in operation was shown. Similarities between FMDF solar thermal systems and the Arecibo radio telescope with regard to operating principles, engineering design, and one method of construction were illustrated by several slides. An artist's concept of a large power plant containing a field of FMDF collectors was presented and discussed.

Figures 3 and 4 provide production cost comparisons for 100MW intermediate and hybrid FMDF solar power plants vis-a-vis central receiver and other solar thermal plants of the same capacity. Figure 3's data are estimates obtained by Aerospace Corporation and recently upgraded by the Electric Power Research Institute to reflect cost in 1975 dollars. The basis of these estimates were studies performed by several ERDA contractors and only the lowest estimates provided by these contractors were used in the compilation of Fig. 3. Data for the FMDF system presented in Fig. 4, are based on E-systems' analysis and present both the high and low values. The estimated cost range in 1975 dollars for the FMDF system is predicated on the basis that (a) there are several methods that can be used to construct FMDF solar collectors, and (b) several FMDF collector designs are available.

Although the FMDF solar thermal systems have not had the benefit of detailed baseline design studies and system optimization, these comparisons do indicate that the FMDF solar thermal systems can be cost competitive or cheaper than central receiver type systems at least in a certain plant capacity range. Compared to other solar energy collectors, the FMDF System has certain features that provide high system reliability, simplicity of maintenance and operation, and potential cost advantages for such systems in production. These features include:

Minimum structural material is required per unit area of the optical gathering surface. This is effected by the use of a fixed mirror structure. As a result, the mirror cost is relatively low.

Only one lightweight object, the receiver, tracks the sun. The required solar tracking is simple.

The receiver is fully stowable in severe weather and operable under winds of fifty knots and higher. Moreover, the receiver can be readily moved out of the focal region for repair in case of fluid flow failure.

The average flux concentration, after allowing for practical optics and the sun's disc size, ranges from 100 to 600, resulting in high net system efficiency.

The FMDF System is modularized for manufacturing and field erection convenience. The modular approach to collector construction allows a wide flexibility with regard to the system size; use of local materials, labor and talents; and choice of methods, materials, and logistics of construction and system integration.

Multiple collectors can be clustered about a large central power generation subsystem. The cluster output can be easily made to match the energy demand profile by coupling reflectors with different tilt angles and sizes.

Simple maintenance modes are available for the optical gathering surfaces and easy replacement of parts. The entire reflector can be cleaned at once by a jet spray of water, steam, or detergent solutions issuing from the periphery and receiver support structure.

The FMDF System makes maximum use of proven technology such as developed by E-Systems in the construction of the 1000-foot diameter radiotelescope at Arecibo, Puerto Rico.

FMDF systems have low visual impact on the land areas used since a large portion of the hemispherical reflector is below the surface level.

In conclusion, E-Systems has an extensive experience, expertise and a technology base that is directly applicable to development of solar energy systems. The mainstream of this expertise has been decades of work completed by E-Systems in the fields of antenna systems, radiotelescopes and a host of other related major efforts in electronic systems, controls, tracking and guidance systems, and complex aerospace systems. This experience establishes the credentials of E-Systems for participation in the development, demonstration and production of solar energy systems; participation in ways that we believe would be meaningful, responsive to needs and productive in creating options for an early utilization of solar power. We submit that the national interest demands that several alternate solar thermal concepts be actively and substantially pursued in parallel through the phases of research, development, demonstration and evaluation. Serious consideration should be given to modular solar power systems for applications in small to moderate size agricultural, residential and urban communities.

We stay convinced that the fixed mirror solar energy systems of the FMDF type will play an important role in the national utilization and adoption of solar thermal systems. Investment in such concepts would appear to be amply rewarding. E-Systems management has committed a significant investment of company funds and manpower to pursue solar energy conversion technology; however, a significant undertaking of the necessary magnitude can only succeed with flexible Federal support. Thus we fully support the aims and purposes of S-3027 which would provide the level of funding and clear directives essential to insure that several alternate solar thermal concepts are thoroughly investigated in parallel prototype demonstration systems.

E-SYSTEMS, INC.

ANTENNA INSTALLATIONS

Earth station antennas have been installed us in scattered locations and varied climates around the world. Stations completed or in progress include:

LARGE DIAMETER (25 to 32 Meters)

Arkansas	Belgium
Panama	Greece II
Brazil I, II	Peking I, II
Peru	Shanghai
Lebanon	Portugal
Iran	Angola
U.S. Military I, II, III	Mozambique
Spain II, III	Sudan
Guam	Dominican Republic
Alaska, U.S.A.	Hanley
Venezuela	Three Peaks
Nigeria I, II	Italy III
Canary Islands	Andover II
Zaire	Etam II
Philippines II	Fiji
Israel	Dubai
	Oman

SMALL DIAMETER (10 to 13 Meters)

Canadian Domestic 8
U.S. Locations 9 (4 ASC, 3 RCA Domsat)
China 1
Alaska 1
Kwajalein 1
Osage 1
Brazil 3
Algeria 14
U.S. Satcom 5

MID-SIZE (15 Meters)

Western Union Domestic 10
Hawaii 1
Brazil SSM

ARECIBO OBSERVATORY (300 Meters)

Arecibo Resurfacing, Puerto Rico

RADIO TELESCOPE (25 METERS)

VLA for NRAO 28
Jodrell Bank 1

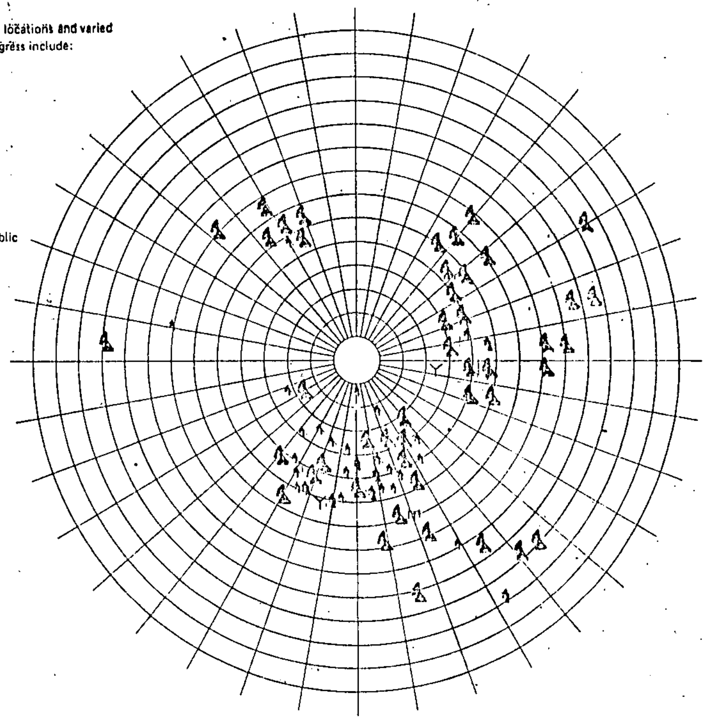
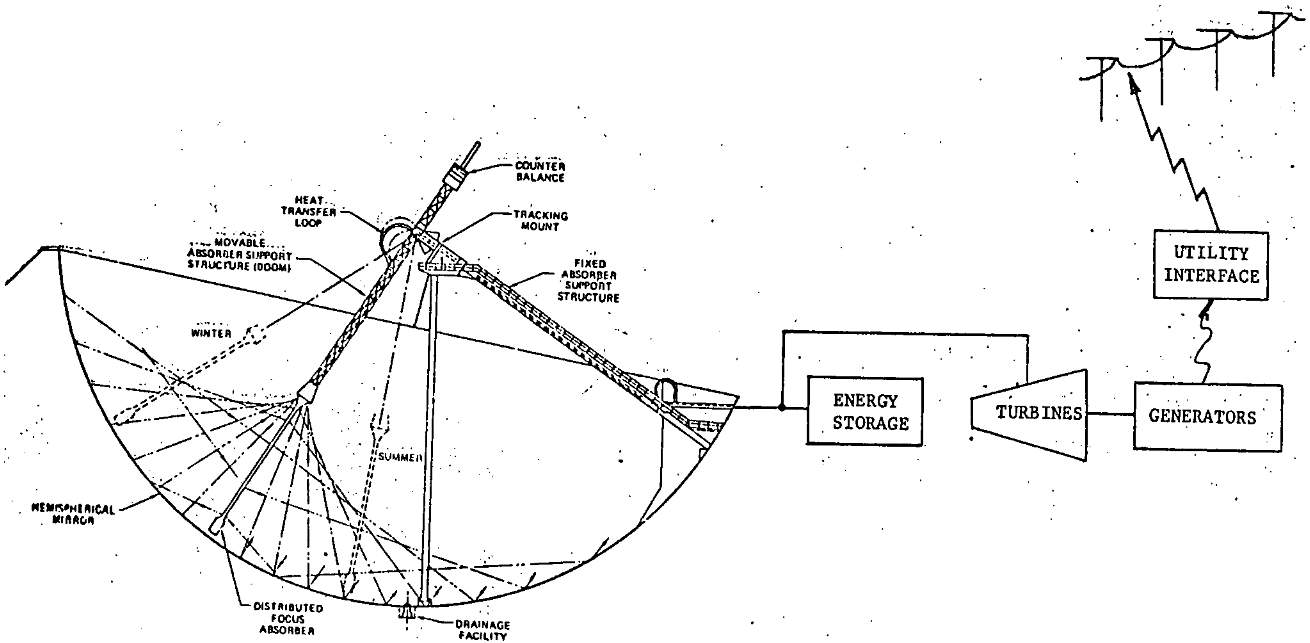


FIGURE 1

E-SYSTEMS INC.



FMDF COLLECTOR

FIGURE 2.—Schematic of FMDF solar thermal/electric plant.

FIGURE 3

100 MWe CENTRAL RECEIVER POWER PLANT COST

[17.6 percent overall efficiency]

Plant type	Intermediate	Hybrid
Collector area (km²)	1.0	0.5
Storage time (hr)	6	.5
Account (dollars per kilowatt electrical):		
Land	2	1
Structures and facilities	44	51
Heliostats ($60 per square meter)	600	300
Central receiver/tower (260m)/heat exchanger	95	68
Storage/tanks (830 per kilowatt-hour electrical)	180	15
Boiler plant		73
Turbine plant equipment	80	80
Electric plant equipment	21	21
Miscellaneous plant equipment	4	4
Allowance for cooling towers	20	20
Total direct cost	1,046	633
Contingency (5 percent)	52	32
Indirect costs (10 percent)	105	63
Total capital investment (1975)	1,203	728
Interest during construction (15 percent)	180	109
Total cost at completion	1,383	837

FIGURE 4

100 MWe FMDF POWER PLANT COST

[13 percent overall efficiency]

Plant type	Intermediate	Hybrid
Collector area (km²)	1.3	0.65
Storage time (hr)	6	.5
Account (dollars per kilowatt electrical):		
Land	3	1
Structures and facilities	44	51
Concentrator ($30 to $50 per M²)	390–650	195–325
Absorber	50–150	25–75
Piping	50–150	25–75
Storage/tanks	180	15
Boiler plant	0	73
Turbine plant	80	80
Electric plant	21	21
Miscellaneous plant	4	4
Allowance for cooling towers	20	20
Total direct cost	842–1,302	510–740
Contingency (5 percent)	42– 65	26– 37
Indirect (10 percent)	84– 130	51– 74
Total capital investment (1975)	968–1,497	587–851
Interest (15 percent)	145– 225	88–128
Total cost at completion	1,113–1,722	675–979

Senator FANNIN. You gentlemen have made very impressive presentations and I am thankful to you. I am sorry all the Senators could not be here to hear you. I know they missed a very excellent presentation by each of you. Their staffs are here and the staff members will carry the message back to their Senators and Congressmen.

So it is of great value to us for you to present the testimony that you have given. Are you all in agreement that the alternates in parallel multiconcept approach should be taken?

Mr. BLAKE. To the degree there is a considerable body of data already in existence which does give grounds for realistic choosing of optimums to pursue then and there is more than one good answer. But there are some things that should be played down.

Senator FANNIN. If something has not proven to be a success, we don't want to repeat our struggles to try to make it successful. I know that we have had over the years some favorites that have been very disappointing. In fact my entry into solar energy was that I was in the heating business and we sent out to replace some solar energy equipment. That was my introduction over 20 years ago to solar energy, although not in the generation of electricity.

The problem we have is to have a budget as adequate as possible and still within the limits of what we feel can be spent on solar energy development. Personally, I feel that the budget that we have now is not sufficient. That is why I have gone to Senator Humphrey in an attempt to see what we would do to revise the original budget of ERDA.

If more money is needed, I think we should ask for it. We will be marking up the bill. You gentlemen have been very helpful in your testimony in determining what should be done. Many of the members are not familiar with solar potential and have not seen fit to push for the increased amounts although we were able to get a very adequate budget through the Senate last year.

It did not hold when it went to reconsideration in the House of Representatives. I think that you have stated that you feel that parallels are beneficial and should be followed. At the same time you have certain desires to see programs developed that you feel have the greatest potential. That is where you would like to have the concentration made.

Compared to the fiscal year 1976 figure of $14,300,000 for solar thermal development, does this amount seem like an unjustifiable jump?

Mr. BLAKE. We are very thankful for the funding and the support we have had. But the programs are still very, very tightly funded. I am sure everyone can absorb from 30 to 50 percent more in things that are actually being deferred for lack of funding at this moment.

Senator FANNIN. Timing is essential. We do face an energy crisis. We need significant developments as far as our solar performance is concerned. So considering the great need for the programs to go forward as rapidly as possible, I do feel that what you gentlemen have stated is very important in defending our position.

Mr. ANDERSON. I think it is the general experience that there are two classes of programs. One is where ERDA has indicated intent to move through deliberate phases. In those, the funding limitations show up two ways. One is a stretch out in programs. Instead of block funding, a fairly intensive effort, it is all too frequently where the request for proposal for the next phase are tied in with the next fiscal year's allocation which is not agreeable with anything like a crisis atmosphere. The other thing is quite early in the game, we are making fairly critical choices in selecting one or two alternatives.

Mr. GUPTA. I think ERDA's funds obviously have been restricted and much of it has been utilized on a single concept based on an early decision. The early decision was made when only certain concepts did exist and was limited to that point in time and to what the state of knowledge was at that time.

Since this knowledge is expanding, there is room for additional concepts and there should be a directive for establishing a detailed analysis and design base through development phases, of other concepts because cost analyses, until something has been built and tested are just that, really.

Senator FANNIN. Thank you. We have had several proposals that have been submitted over a period of time. One has been a pump—I know that you are talking about that heat storage and in the picture, you utilized, in the hills in the background, would it be practical to have a pump back water program?

Mr. BLAKE. The unit on the left was originally conceived to be associated with an existing storage system such as the hydroelectric. The Horse Mesa Dam was used to work out that analysis.

The thermal storage is one where the storage is keyed tightly to the program. But very definitely, the conversion, site, the one on the left, is that which we associated with the pump back.

Senator FANNIN. I was just thinking of the general utilization around the country. There are so many places in the southwest where there are hills and places where the pump back might be quite feasible.

I was thinking about the feasibility of generally utilizing something of that nature. Would it be cheaper than the heat storage system?

Mr. BLAKE. Pump storage exists now and does not require any further development. The thermal storage, whether it is for the 6 hours or a very short period like a cloud interruption has not been developed and even for that short time needs the development work.

Senator FANNIN. Your heat source is very essential for continued generation of power?

Mr. BLAKE. Yes, sir.

Senator FANNIN. Senator Humphrey did have some questions that I would like to present. Do you think the technology of solar, thermal and electric systems has progressed to the point where a large number of demonstration projects, more than three now underway, are justified?

Mr. BLAKE. I believe it is desirable to have more projects than the reduced budgets certainly would permit.

Experience or fly off between concepts is desirable. There is enough divergence between competitive programs that they may well indicate there are two very strong ways to go and it would be tragic not to have one of those good ways demonstrated.

Senator FANNIN. Do you all agree with the answer?

Mr. GUPTA. Senator, that is the basis of my testimony. I agree without question that in most of these cases, the difference between paper studies and getting real full scale operational systems in the field is significant. Many of the real issues of adaptability to a given task can only be faced by trying things. Otherwise we have a problem anlaogous to attempting to have a committee make a decision on the one vehicle which for example can transport all objects and all peoples.

There is not one best answer. The best answer is to look at all the concepts.

Senator FANNIN. Is there sufficient private interest in solar thermal powerplants that cost sharing arrangements can be developed for any new demonstration facilities?

Mr. BLAKE. We at least have heard that there is substantial expected response to the program opportunity announcement that is about to go forth requesting that to the utilities. At least two consortiums of utilities that I know about have indicated that they intend to respond positively to that.

Mr. GUPTA. There is a substantial interest provided there may be matching funds. We have been approached by a number of utilities located in New Mexico, Texas, and Nevada. In fact we have discouraged them at this point to really participate until we have 1 or 2 demonstrations firmly in operation. But if that is any indication of the utility companies' interest or the interest on the part of the municipality owned powerplant in these cities, there is substantial interest.

You have heard of names like Bridgeport, Tex. The citizens there are looking for, even on a matching basis, some assistance in installing or demonstrating solar powerplants. A city in west Texas, has been talking to ERDA for over 2 years now.

Then there is a utility company that currently operates a plant of 120 megawatts (electricity) using natural gas as a fuel.

This is located in Lea County, N. Mex. They have been very anxious to support jointly and participate in a solar powerplant that would essentially be hybrid in character and at the same time would accelerate not only the participation of the ultimate user, the utility company, but also the development and the utilization of solar energy.

Senator FANNIN. Thank you.

One major problem with solar power stations is the storage problem we have all discussed. A solution suggested is to combine solar with fossil fuel and run the solar energy during the daylight and the coal at night.

I think you said you are aware of that. Are you aware of any research in this concept of the hybrid solar power station?

Mr. BLAKE. The National Science Foundation programs that preceded the current ones addressed several aspects of this. Each of us was given one to look at. Ours was hydroelectric but Don's was as a hybrid for coal.

Senator FANNIN. I wanted to get this information into the record. Although we may have some duplication, we would like to have the questions answered so that when we are in session, considering the markup of the ERDA legislation, that we will have the answers at hand.

Gentlemen, we greatly appreciate your being here. You have been very, very patient. You have been certainly very responsive. We are extremely appreciative of your great interest and efforts. You certainly have done a tremendous amount of work.

We appreciate the extra work you have done in preparing for these presentations. You have been very, very helpful to us.

Thank you, gentlemen.

The record will be kept open for 2 weeks in case you have further entries. The committe now stands adjourned.

[Whereupon, at 1:07 p.m., the committee adjourned, subject to the call of the Chair.]

[The following information was subsequently supplied for the record:]

DOWNERS GROVE, ILL., *April 3, 1976.*

Hon. HUBERT HUMPHREY and PAUL FANNIN,
Joint Economic Committee,
U.S. Senate, Washington, D.C.

DEAR SENATORS HUMPHREY AND FANNIN: We regret so much not being able to testify before the Joint Economic Committee which you will chair on Monday on the economics of solar energy. (Notice appeared in the Phoenix Gazette on Friday, April 2). It would cost too much for us to attend.

Instead we are submitting this statement which we feel responds to the purpose of the Hearing. We are impressed by the comments by Senator Fannin to the Joint Engineering Legislative Forum, emphasizing the need to broaden the development of solar systems. While we have not seen your proposed legislation to speed-up solar energy research and development, we are very much aware of the need for helping individuals who pioneer in this field.

We are about to start construction on a house using the Skytherm System for heating and cooling. I am omitting a detailed description of Skytherm to reduce the length of this statement, also because Skytherm has received so much recognition nationally, by the Bi-Centennial Commission and the U.S. Government.

It seems to me that a brief description of our experience will help our presentation. My husband has been involved in conservation programs in Illinois since his retirement, and I have made a special study of solar energy. I was particularly interested in reports of a prototype Skytherm building which had been constructed in Sunnyslope, Phoenix, Arizona, 1967–68. In 1974 we learned of the construction of a house using Skytherm in Atascadero, California under the auspices of HUD, and we visited the house in January 1975. We were favorably impressed, decided to build a Skytherm house in Phoenix, and purchased a lot in February 1975. Our intentions were communicated to Harold Hay the inventor, and to John Yellott, a nationally known engineer, who had been involved with Skytherm from its inception. Upon Mr. Yellott's recommendation we engaged two graduate students of architecture at Arizona State University to prepare the design. They are part of a group which specializes in energy-saving systems, and are working closely with Mr. Hay on plans for Skytherm.

We returned to Arizona from Illinois in January 1976 expecting to get under way. We had been working on the plans during the year, so working drawings were soon completed, and negotiations began with a contractor who is himself interested in solar energy. Next we needed a mortgage to help financing.

At first we were turned away from all but one of the banks and savings and loans we contacted in Phoenix. The reason, too new, too risky. The bank that accepted us added to the interest rate for construction and for the mortgage, and for "points". There were other restrictions. We held on to this offer expecting to be forced to accept the added cost and conditions. We pleaded with the lender, pointing out that we did not want to set a precedent for future energy saving construction by accepting conditions other than those terms given to applicants for residential loans.

We realized that we had to obtain better financing or face the beginning of a loss. It took someone to speak to the president of an institution to simply obtain a mortgage under normal conditions. Thus, there is no reason to conclude that other individuals can readily get financing for solar systems. Here are the figures in our project:

1. We paid for the lot; $5,500.
2. Architectural design, working drawings; $2,839.
3. Construction estimate; $42,500.

4. Bank to provide; $25,000.
5. We provide; $17,500.

Both ERDA and HUD grant programs do not provide for individuals, only for developers, builders, and contractors. Most of these people are unfamiliar with the technology and have to be encouraged to enter the field, and they are reluctant to use their business enterprise to pioneer. There are many individuals like us who are pioneers dedicated to achieving conservation of our resources, but can not obtain grant assistance.

It is possible that we will continue to construct other projects, but we do not now have a basis for declaring ourselves to be developers, builders or contractors. We would have prepared a proposal to HUD for this project but could not because of the special provision that excludes individuals. We would have requested only $5,000, the approximate difference between Skytherm and a conventional house at this time. Volume purchasing will soon reduce this difference considerably. Our Skytherm house, in addition to adjusting to the hot weather in Phoenix, as against the cooler weather in Atascadero will include a number of newer features over the house in Atascadero. Also, we are trying to bring the manufacture of the system to firms in Arizona for construction in Arizona. As of now most of this material comes from Los Angeles and San Diego thereby adding to our costs.

Here is an excerpt from an article in the Los Angeles Times, Sunday, 3/28/76, which speaks to your concern:

"Down at ground level, a tremendous amount of research and development is being done by entrepreneurs, individuals and small manufacturing or construction firms.

"There is an opinion prevalent among many of them that the massive government spending may hurt the total endeavor.

" 'They're using the NASA approach,' one declared.

" 'Pour in tons of money and just overwhelm everything.'

"The general feeling was that such huge programs are inefficient in terms of money-in, results-out and that the more efficient small operations could be forced out of the field. Also, they feel that the government and big business programs tend to pick a small number of areas and ignore everything else while a crowd of private entrepreneurs will try everything and let the market weed out what is unproductive."

1. Your legislation should provide for grant assistance to individuals who are constructing new and innovative systems in a given area. For example: the first 100 residences in a city, the first 100 commercial buildings. This is simple direct incentive to the private enterprise system. The assistance could be in the form of grants, income tax deduction, or lower interest rate (government to subsidize partial interest cost).

2. Financial institutions should be given assurance to encourage loans to construct solar projects. FHA would not insure a loan for us without a complete forced air heating system with ducts, in addition to the Skytherm System. This would have required a change in ceiling construction adversely effecting Skytherm, and put our construction cost out of sight. In response we pointed to the fireplace in the living room, heat lamps in the bathrooms, and the fact that space heaters could be used, but FHA said, "No."

3. For the first 5 years of occupancy the real estate tax set by the local government should be reduced, possibly by permitting a higher deduction from the U.S. Income Tax. This too is a direct old fashioned type of incentive.

I respectfully request that this statement be made part of the record of the hearing which you are conducting. Thank you for your consideraton.

Sincerely,

CHRISTINE O. BRUDER.

RESPONSE OF DANIEL SCHNEIDERMAN TO ADDITIONAL WRITTEN QUESTIONS POSED BY SENATOR PERCY

1. At what time are solar energy technologies expected to provide energy costs comparable to those of fossil and nuclear energy sources in the future?

How will your estimates of this date vary with the different levels of government expenditure on solar energy?

If some of the solar electric technologies will be commercially competitive with nuclear energy well before breeders and fusion, why is ERDA spending 10 to 12 times more on those nuclear technologies than on solar electric?

Is there not a conflict looming in the massive proposed spending on nuclear power plants while at the same time solar energy will be coming on line at competitive prices? In other words, might there not be some point before the year 2000 when scores of nuclear power plants that have 20 years or more life left in them are suddenly no longer needed because people have switched to photovoltaics?

2. Is federal spending by ERDA the best mechanism for pushing solar energy into the marketplace?

Should other approaches be explored, such as injecting federal monies directly into the private sector through R and D tax refunds?

3. Is there any truth to the allegation that major oil companies (like Shell and Mobil) who are funding solar energy R and D, may have an incentive to slow down the commercial development of solar energy in order to maintain profits from other competing energy sources?

4. Is there any duplication between FEA and ERDA in the effort made by the government to commercialize solar energy?

5. What attention has ERDA given to the use of international research efforts to solve common energy problems?

RESPONSE OF DANIEL SCHNEIDERMAN TO ADDITIONAL WRITTEN QUESTIONS POSED BY SENATOR FANNIN

JET PROPULSION LABORATORY,
CALIFORNIA INSTITUTE OF TECHNOLOGY,
Pasadena, Calif., April 22, 1976.

To: Code C, Office of Legislative Affairs, NASA.
Through: Code NE, Kurt Strass, Office of Energy Programs.
For: Paul J. Fannin, Joint Economic Committee Congress of the United States.

DEAR MR. FANNIN: The following is my personal response to the questions posed in your letter of 8 April and does not necessarily reflect the opinions of JPL and/or NASA:

1a. There are a number of different techniques that fall within the definition of "solar energy." Each has a uniqueness that requires a different investment and will yield on a different time scale. This investment/time scale ratio is not constant, but will also vary.

The time in the future where solar energy concepts may supplant fossil and nuclear energy sources is not readily defined. Fossil fuels include coal, which at the present time is simply not produced at a rate that can substitute for the present use of gas and oil. The present rate of expansion of coal production cannot head off the near term fossil fuel dilemma. Thus even coal production requires serious investment in order to be a competitor in the next couple of decades.

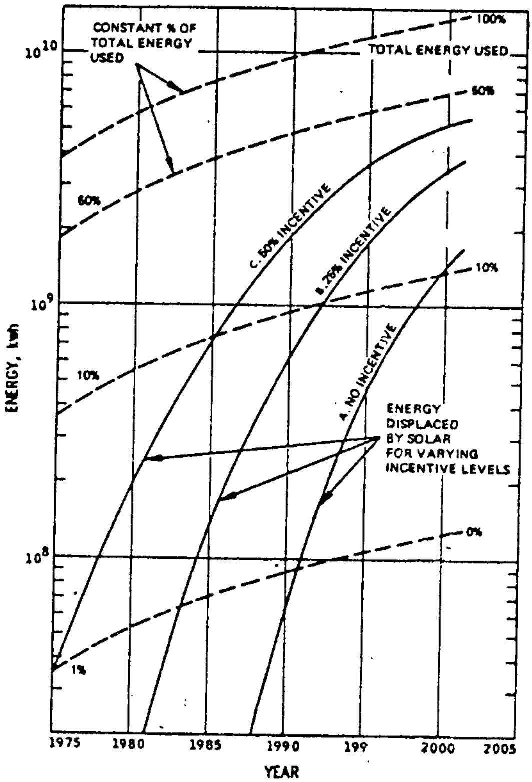
Nuclear energy costs are escalating and so are its fuel costs. In order to keep the price of nuclear power down, the breeder reactor must eventually be employed. This development also requires an investment/time scale decision. I will avoid the political and social implications of the waste products and their costs.

Thus the question cannot be definitely answered, since all of the many factors are unknowns at this time. If the government should decide not to pursue fission and dedicate itself to fusion, then the time scale of nuclear may be many decades.

I tend to concur with those who believe that solar energy will not have a large impact until the end of this century. However, there are applications of solar energy that today are reaching a competitive state, and if properly supported can have an impact on our dependence on oil and natural gas.

For example, the use of solar energy to provide hot water heating and space heating are well known and could, with the proper commercial incentives, start to be installed on new homes and apartments.

The figure below is extracted from a report by Alan Hirshberg at JPL on "policy issues for the rapid implementation of solar energy." From these curves one can get an insight on the impact of an incentive program. As an example, reduction by 10% of the amount of natural gas in the private single home through the use of solar energy can take place as early as 1985 with a 50% incentive program or as late as 1998 with zero incentive.



Energy displaced by solar systems

The chart assumes that natural gas prices are fixed at 1974 dollars and that electrical prices will rise by 4 percent per year from 3.5 cents per Kw hour in 1975. I present the chart in order to demonstrate the large uncertainty attached to any answer at this time. In order to estimate when various solar technologies become economically competitive with fossil and nuclear energy sources will require, I believe, legislative action. Previous scenarios such as developed by Project Independence do not provide a complete base for decision making. I suggest that there is a need for an appropriate federal agency to establish on an annual basis the target price for electricity ten years from the date of the study. This would be a moving target and set anew each year. I have selected electricity because of its ubiquitous nature and the fact that it is one of the sources of energy presently heavily influenced by regulation. This could provide the framework for a larger study of the cost/benefit of alternate sources and help ERDA in its allocation of R&D funds.

1b. This question can only be answered by ERDA. I do not know the reason for ERDA's decision.

1c. I am not concerned about a possible excess of nuclear power plants in the year 2000. I do not believe that any non-fossil source of energy should be neglected. What will power our conversion to solar energy? What a tragedy it would be to find that we have the knowledge and not the tools to do the job of conversion if we are power limited. The gamble and the consequences to our society of an energy deficiency for the next several decades are unacceptable.

2. In my personal opinion, government investment is the only way to keep solar energy research and development as a viable contender. When solar energy becomes a contender, with societal values comparable to its competitors, exponential growth can be expected. This exponential growth implies large payoffs later for relatively small investments now.

If the opponents of solar energy investment can demonstrate that it will never be a part of our future then I would suggest that we cease our effort and relegate it to the confines of the laboratory. However, it is not sensible to ignore this source of energy and not expect it to be exploitable in the future. Thus the delay in its exploitation will cost dearly in the long run.

However, federal R&D funding is not sufficient. The interest of industry must be aroused and the sustaining investment must come from that sector. This will happen if the market incentives for private commercial effort can be formulated. The use of solar heating in energy systems can be spurred greatly by federal incentives such as low interest loans, tax credits, and accelerated depreciation allowances. In addition, the value of encouraging utilities to commercialize solar heating systems should not be ignored. Given the proper regulatory initiatives, utilities could own solar equipment, rent it to building owners, and charge them on their normal monthly bill. This type of utility action could substantially spur the early use of solar energy.

Our present energy infrastructure is the result of fifty years of evolution. The attraction of the massive amounts of capital is necessary to replace it. This will not occur unless government has paved the way. Loan guarantees are probably necessary. But upon what is the government basing its support of the loan? In other words, the technical concept and its costs to the consumer must be understood before committing to a massive construction program. This, in my view, is an ERDA responsibility.

2b. Funds injected through R&D tax refunds may dilute the investment. Demononstration will require concentrations of large quantities of money. Here again, ERDA can act as the focus for effort by controlling the funds for the demonstration.

3. I have seen no evidence to support such an allegation.

4. There does not seem to be duplication of effort between ERDA and the FEA. In fact, some evidence of coordination would be welcome. Duplication, in my opinion, is not evil. It is valuable to have questions of import examined from different viewpoints. The uncertainty of who has the responsibility for decision is a much greater evil.

5. It is my understanding the ERDA is heavily involved with IEA, the International Energy Agency, which is formed by the non-OPEC western countries. I believe this should be encouraged. The question of energy is intimately related to life style. There are civilized countries that have faced the question of limited energy generations ago and have adapted. They have sought technologies that minimize the need for energy. The European transportation system is a case in point. I believe we could learn a great deal and contribute a great deal to the solution of our mutual problem, energy. It would be quite useful for an organization such as JPL, that supports many federal agencies through NASA, to have available to it a consistent federal policy on international relationships, especially where there is a possibility of commercialization of high technology.

I trust this provides the answers you were seeking. It has been a pleasure to cooperate with the Committee. Please let me know if I can provide further aid.

Sincerely,

DANIEL SCHNEIDERMAN,
Manager, Civil Systems Program.

RESPONSE OF STEVEN F. DIZIO TO ADDITIONAL WRITTEN QUESTIONS POSED BY SENATOR PERCY

Question 1. At what time are solar energy technologies expected to provide energy costs comparable to those of fossil and nuclear energy sources in the future?

Answer. SES calculations indicate that electricity derived from solar energy technologies can reasonably be expected to be competitive within a period of 7-10 years. It is not our opinion that greatly increased levels of government expenditure on research and process development will change the time required to reduce the present technologies to practice. It is clear, however, that the government can initiate work in different technologies and therefore increase the probability of succeeding in commercialization within the next 10-year period.

It appears to us that nuclear energy is going to remain an important part of our entire energy system in conjunction with other energy sources such as solar and hydroelectric power. I cannot comment on why ERDA is presently spending 10-12 times more on nuclear energy. I can only assume that the problems are 10-12 times greater than the solar technologies. I do not visualize any conflict appearing as a direct competition between nuclear power plants and solar energy. I think both of these technologies will be complementary and indeed both will be required. If we had all the technical answers today and began a crash program in manufacturing capacity, it does not seem reasonable that we could expand our solar electric production plants at a rate which would obsolete any of the nuclear power plants between now and the year 2000. Conversely, it does not seem reasonable to expect that sufficient nuclear power plants can be built in that time period either. As a result, it appears that both solar energy and nuclear energy systems must be expanded at the maximum possible rate within our available resources.

Question 2. Is federal spending by ERDA the best mechanism for pushing solar energy into the marketplace?

Answer. It is SES's firm opinion that the federal government must have a program involving many sectors in order to maximize the rate at which we introduce solar technologies into the marketplace. Much must be done to delineate and solve the problems of political and regulatory bodies that exist at local, state and federal levels. Tax incentives in the short-range can make solar energy technologies competitive before the reduction of production costs would make them otherwise viable and, of course, the overall definition of the market requirements in light of the resulting tax advantages and regulations must be defined before industry can be expected to invest large sums of capital.

Question 3. Is there any truth to the allegation that major oil companies (like Shell and Mobil) who are funding solar energy R&D, may have an incentive to slow down the commercial development of solar energy in order to maintain profits from other competing energy sources?

Answer. Shell Oil Company is a majority stockholder of SES. While I have never been an employee of Shell, I can comment on direct experience between SES and Shell. In initial attempts at financing, SES approached many companies and other equity funding groups in the United States. These results were largely unsuccessful until a relationship was established with Shell Oil Company. Shell, being an energy company, was extremely interested in the long-range potential of solar technology as a major producer of energy. In addition, their corporate philosophy made them comfortable in investing large sums of money in a high-risk area with potential of return existing only after many years of work.

I am aware of absolutely no case where an oil company has done anything but accelerate the development of solar energy. Indeed, it is difficult for me to conceive of any large, well-managed company restraining development in a potential market as large and potentially lucrative as solar energy.

Question 4. Is there any duplication between FEA and ERDA in the effort made by the government to commercialize solar energy?

Answer. SES has had little or no contact with the FEA and as such cannot comment on whether this agency and ERDA exhibit any duplication of effort.

Quesiton 5. What attention has ERDA given to the use of international research efforts to solve common energy problems?

Answer. While I am unaware of any efforts of ERDA to use international research to solve our common energy problems, I personally feel that work being produced in the U.S. is in the forefront of technology throughout the world and feel that we will be exporting the results of our research.

Response of Louis Rosenblum to Additional Written Questions Posed by Senator Percy

Question 1. At what time are solar energy technologies expected to provide energy costs comparable to those of fossil and nuclear energy sources in the future?

How will your estimates of this date vary with the different levels of government expenditure on solar energy?

If some of the solar electric technologies will be commercially competitive with nuclear energy well before breeders and fusion, why is ERDA spending 10 to 12 times more on those technologies than on solar electric?

Is there not a conflict looming in the massive proposed spending on nuclear power plants while at the same time solar energy will be coming on line at competitive prices? In other words, might there not be some point before the year 2000 when scores of nuclear power plants that have 20 years or more life left in them are suddenly no longer needed because people have switched to photovoltaics?

Answer. The ERDA Photovoltaic Program has its goal to develop by 1985 the technology for making solar cell systems at a low enough price to be competitive with alternate energy systems. We believe that an array price in the range $500/kilowatt, the ERDA goal, will make the systems competitive and that this goal is attainable. Arrays alone, however, do not make a working system. Therefore attention must also be given to other components in the photovoltaic power system (structure, inverters, controls, concentrators, etc.), and to related institutional and nontechnical factors. The intent of the ERDA program, as I understand it, is to provide by 1985 all the information needed to make a definitive assessment of the total impact and merits of wide-scale photovoltaic power generation. How much of an impact photovoltaics will make on our future energy supply, and when, will depend on decisions made in 1985.

An important question before the nation is how do we provide energy options to meet our future far-term needs? The next ten years will be critically important in amassing the knowledge and information needed to make an assessment of the viability of the photovoltaic option.

I do not believe it is possible to significantly speed the present ten year schedule with massive infusion of money. Some of the problems that need answers must be addressed sequentially and, further, new technology needs to be developed. What additional funding (above the level needed to sustain the present program) does affect, however, is the chance of obtaining adequate solutions to the technical problems on schedule. More support allows the examination of parallel potential solutions, thereby increasing the probability of achieving the goals set.

Question 2. Is federal spending by ERDA the best mechanism for pushing solar energy into the marketplace?

Should other approaches be explored, such as injecting federal monies directly into the private sector through R and D tax refunds?

Answer. Yes, definitely, other approaches should be developed.

Question 3. Is there any truth to the allegation that major oil companies (like Shell and Mobil) who are funding solar energy R and D, may have an incentive to slow down the commercial development of solar energy in order to maintain profits from other competing energy sources?

Answer. None that I am aware of.

Question 4. Is there any duplication between FEA and ERDA in the effort made by the government to commercialize solar energy?

Answer. None that I am aware of.

Question 5. What attention has ERDA given to the use of international research efforts to solve common energy problems?

Answer. None that I am aware of.

Response of A. I. Mlavsky to an Additional Written Question Posed by Senator Percy

Mobil Tyco Solar Energy Corp.,
April 8, 1976.

Hon. Charles H. Percy,
U.S. Senate, Dirksen Senate Office Building,
Washington, D.C.

Dear Senator Percy: I appreciate this opportunity to provide a written answer for the record to your question concerning the impact of the involvement of Mobil Oil Corporation in a joint venture with Tyco Laboratories, Inc. to develop and commercialize the silicon ribbon solar cell.

As described in brief in my prepared statement presented to the Joint Economic Committee, I, as senior vice president for research and technology, and my colleagues at Tyco had developed a crystal growth process and demonstrated its initial feasibility in the growth of silicon ribbon for solar cells by early 1974. However, the nature and the amount of investment which would be required to develop this technology for commercial practice were far beyond the financial and perhaps even the organizational capabilities of Tyco. It became clear, therefore, that a partner for a joint venture would be needed. In analyzing and indeed approaching various major U.S. corporations for a suitable partner, Tyco rapidly recognized that the partner should be a very large corporation which was willing to undertake risk ventures, and possessed scientific, financial and management resources for such an undertaking. Thus, although we believed the technology to be very promising, there was and still is a fair possibility that the approach might not meet all of the necessary criteria of economic feasibility. Very few companies in America have expressed the willingness to make major investments in such speculative technology. The oil industry traditionally has accepted the possibility that, despite the best of preparation and analysis, a "dry hole" can result.

Through our familiarity with Mobil's background in major scientific programs and our recognition that the company makes major investments with the foreknowledge of the possibility of failure, we approached Mobil Oil Corporation as a possible joint venture partner.

Since they had already been involved in the field of new energy alternatives, they were in a position to evaluate our technology. Very shortly an agreement in principle was reached to form the joint venture. This entity thus became known as Mobil Tyco Solar Energy Corporation and its present status is described briefly in the formal statement referred to above.

In the ensuing 18 months, Mobil has provided all of the support necessary to formulate, staff and implement a technical program directed towards the development of low-cost silicon solar cells for general application. Had Mobil not elected to support this program, the entire technology might, by now, be abandoned and the nation deprived of a leading candidate technology for the production of electricity directly from the sun.

To address your question directly, the involvement of Mobil in our program—far from being an impediment—has been of quite vital importance in accelerating the development.

Very truly yours,

A. I. Mlavsky,
Executive Vice President.

Response of A. I. Mlavsky to Additional Written Questions Posed by Senator Fannin

Question 1. At what time are solar energy technologies expected to provide energy costs comparable to those of fossil and nuclear energy sources in the future?

Answer. I estimate that by the year 1990, technology for the direct conversion of solar energy into electricity will be reduced to a practical form so that mass production of photovoltaics can begin. By that time we should be able to manufacture photovoltaic devices which produce power at costs comparable with present costs of power from fossil and nuclear energy sources. This does not mean that the nation will have much photovoltaic capacity—but rather that it will have a technology base for the future growth of this energy source.

Question 1a. How will your estimates of this date vary with the different levels of government expenditure on solar energy?

Answer. There is obviously some dependence of the outlook for photovoltaic development on government expenditures. If there were no government spending, the only programs which would be explored would be those which private industry now considers commercially viable. To make manageable the large investments required, private industry would seek out the limited intermediate markets for photovoltaic devices to provide the cash flow needed to finance the long-term development of a truly low-cost system. The risk of no government spending is that good new technology prospects might languish or indeed never be explored.

At the other extreme, if there were enormous increases in government spending, we would not necessarily be able to shorten arbitrarily the time it takes to commercialize photovoltaics. The technological development cycle has its own built-in scale; only to a limited degree can it be hastened by increased funding.

Where the government can help most is in assisting very new technologies, and in providing support for large-scale demonstration of existing technologies.

On balance, I think that the specific recommendation of the Solar Energy Bill of $59.2 million for expenditures on photovoltaics in 1977 is commensurate with the target of developing a commercial technology by 1990. I would assume that these expenditures would increase in subsequent years to further those technologies which begin to show promise.

However, we can only contemplate a massive displacement of current power sources by a device which depends on the sun if we have very efficient, very low-cost, reliable electrical energy storage. Development of economic means of storage for power is a critical facet of the long-term outlook for photovoltaics, and one which receives insufficient attention. This may be a more important limit to the viability of the photovoltaic system than the photovoltaic device itself. Any increased efforts on solar electricity should be matched by corresponding increases in development of better electrical storage.

Question 1b. If some of the solar electric technologies will be commercially competitive with nuclear energy well before breeders and fusion, why is ERDA spending 10 to 12 times more on those nuclear technologies than on solar electric?

Answer. While it is hoped that solar electrical systems will some day be commercially competitive with nuclear energy for electric power production, it is too early to evaluate the relative competitive merits of solar electric technology versus breeder reactors and fusion devices, especially for base load power. Accordingly all alternative forms of generating electricity should be explored simultaneously.

To respond to the second point raised in your question, in comparing nuclear technology with photovoltaics, one enormous difference must be recognized: There is no simple experiment to test a concept in fusion or the breeder reactor. Such tests need very large installations. A single experiment is extremely expensive.

In contrast, one of the most appealing features of photovoltaics is the relatively low cost of experimentation. Large arrays of solar cells consist of assemblages of smaller arrays. We can easily test a concept on a bench scale model whereas a nuclear experiment, by its very nature, requires a single central device which must be large to ascertain its potential efficiency.

Since I am not a nuclear expert, I cannot say whether it is true that nuclear development costs ten to twelve times more than photovoltaics. But the difference between the two technologies implies a significant difference in the scale of development costs.

Question 1c. Is there not a conflict looming in the massive proposed spending on nuclear power plants while at the same time solar energy will be coming on line at competitive prices? In other words, might there not be some point before the year 2000 when scores of nuclear power plants that have 20 years or more life left in them are suddenly no longer needed because people have switched to photovoltaics?

Answer. I find it extremely unlikely that any method of producing power we will have in the year 2000—unless grossly unsafe or uneconomic—will not be used to its capacity.

For photovoltaics to provide for just the incremental power that we are going to require by the year 2000 would be a major achievement. Clearly, solar electricity will not be in a position, by that time, to obsolete existing plants.

Question 2. Is federal spending by ERDA the best mechanism for pushing solar energy into the marketplace? Should other approaches be explored, such as injecting federal monies directly into the private sector through R & D tax refunds?

Answer. The approach of injecting federal monies directly into the private sector through research and development tax refunds is an extremely intriguing alternative which has recevied far too little study.

Generally, the total efficiency of R & D spending is much greater in private industry than via government grants or contracts. The alternative R & D tax refunds would enhance the private sector's incentive to create a viable technology and to move quickly into the marketplace to get its return on investment. At the same time, it would simplify the government organizational structure needed to dispense funds. I think the private sector would be very receptive to this approach. I highly recommend that such an approach be explored.

Question 3. Is there any truth to the allegation that major oil companies (like Shell and Mobil), who are funding solar energy R & D, may have an incentive to slow down the commercial development of solar energy in order to maintain profits from other competing energy sources?

Answer. I have attached a letter to Senator Percy dated April 8, 1976, in partial answer to this question. As my letter states, Mobil has provided essential support in the program to develop our photovoltaic technology. Without Mobil's backing, this promising technology might have been abandoned by now.

My involvement with Mobil Oil Corporation dates back only 18 months when the joint venture, Mobil Tyco Solar Energy Corporation, was formed. My previous background was with Tyco Laboratories, Inc. Because my work durng the 18 months has focused solely on managing the development of photovoltaics technology, it would be presumptuous of me to speak for Mobil.

Nonetheless, as a citizen and a photovoltaics practitioner, I find it difficult to see how Mobil could have an incentive to slow the deevlopment of solar energy, for two pragmatic reasons:

The first reason is timing. It will take 20 or perhaps 30 years before photovoltaics or any other solar technology can have a major impact on total energy supply. This will be at about the time when oil itself will become a scarce material. Moreover, electrical energy from photovoltaics cannot easily replace several critical uses of oil—namely, gasoline and petrochemicals.

So, both on the basis of the time frame for photovoltaics development, and on the specific uses of crude oil and natural gas, I see solar energy and the oil business as complementary, not competitive. From my experience with Mobil, I think that oil companies have a positive incentive to accelerate the development of solar energy.

Question 4. Is there any duplication between FEA and ERDA in the effort made by the government to commercialize solar energy?

Answer. The progress of FEA and ERDA to commercialize solar energy have received too little exposure for us to properly evaluate them. Because FEA and ERDA appear to be still in the planning stage, it is difficult to comment on potential duplication.

However, from my limited experience working with both agencies in the field of photovoltaics, I believe that they are cooperating well and that the likelihood of duplication is minimal.

Question 5. What attention has ERDA given to the use of international research efforts to solve common energy problems?

Answer. I am aware of ERDA's interest in international efforts in the field of solar energy. We have cooperated by suggesting companies and institutions abroad which have programs the agency might wish to explore, such as Project Sunshine in Japan. In fact, I participated in a group consisting of representatives of ERDA and Japanese government and industry, specifically to address the need for coordinating efforts, disseminating results, and minimizing international duplication.

I feel fairly confident that ERDA is tracking international developments and using this information appropriately in planning its own program.

RESPONSE OF FLOYD A. BLAKE TO ADDITIONAL WRITTEN QUESTIONS POSED BY SENATOR PERCY

Question 1. At what time are solar energy technologies expected to provide energy costs comparable to those of fossil and nuclear energy soucres in the future?

Answer. For the Central Receiver Power System, the cost analysis performed in the NSF/RANN (January 1975) sponsored phase projected a cross-over point with nuclear plant costs after the fourth solar plant. This would be in the 1990's. The cross-over with fossil fuel would be after 30–40 solar plants, which should occur in the first decade of the 21st century.

Question 1a. How will your estimates of this date vary with the different levels of government expenditure on solar energy?

Answer. These dates are based on orderly and vigorous development supported by the Government through the demonstration plant phase.

Question 1b. If some of the solar electric technologies will be commercially competitive with nuclear energy well before breeders and fusion, why is ERDA spending 10 to 12 times more on those nuclear technologies than on solar electric?

Answer. I cannot presume to speak for ERDA; however, it must be appreciated that understanding our solar resource and its potential is a recent and growing phenomenon compared with nuclear technology's 30 year history.

Question 1c. Is there not a conflict looming in the massive proposed spending on nuclear power plants while at the same time solar energy will be coming on line at competitive prices? In other words, might there not be some point before the year 2000 when scores of nuclear power plants that have 20 years or more life left in them are suddenly no longer needed because people have switched to photovoltaics?

Answer. I believe that our energy problem needs all of the contributions available from the renewable energy sources, and that solar energy will be additive in its contribution to our capacity rather than replacement in nature.

Question 2. Is federal spending by ERDA the best mechanism for pushing solar energy into the marketplace? Should other approaches be explored, such as injecting federal monies directly into the private sector through R and D tax refunds?

Answer. I believe the ERDA programs will effectively push solar energy into the marketplace and should be strongly supported. I do not feel competent to comment on alternative approaches.

Question 3. Is there any truth to the allegation that major oil companies (like Shell and Mobil) who are funding solar energy R and D, may have an incentive to slow down the commercial development of solar energy in order to maintain profits from other competing energy sources?

Answer. I have had no oil company contact on solar energy and cannot presume to comment.

Question 4. Is there any duplication between FEA and ERDA in the effort made by the government to commercialize solar energy?

Answer. Our primary relationship has been with ERDA; but the FEA contacts, while indicating interest, have not indicated duplication.

Question 5. What attention has ERDA given to the use of international research efforts to solve common energy problems?

Answer. From the earliest proposal, we have planned the cooperative program between C.N.R.S. of France and the United States to most efficiently accomplish the development of large scale solar energy conversion equipment. Representatives of France, Italy, and Japan met with U.S. program participants in an NSF sponsored seminar on large scale solar energy test facilities in November 1974. Technical interchange delegations have visited Russia and hosted Russian visitors.

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