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Solar Irrigation Program Plan

REVISION

Robert L. Alvis, Sharla G. Vandevender

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SOLAR IRRIGATION PROGRAM PLAN
REVISION

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ABSTRACT

This report describes the ERDA solar irrigation program plan through fiscal year 1979. It is an update of the original program plan as outlined in Sandia Report SAND76-0594. The updated goals of the plan are listed, the participants named, and their responsibilities outlined. ERDA has the program responsibility, ERDA field offices the contractual responsibility, and Sandia Laboratories the technical direction responsibilities. Three solar irrigation experiments planned, system analyses to be conducted, and the participants of the program are described. This document is intended to be used as a program guide for accomplishing the program goals.

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To: Recipients of the Enclosed Program Plan

This Solar Irrigation Program Plan has been prepared by members of Sandia Laboratory technical staff. It has been written with the knowledge of ERDA/DSE, but has not been reviewed or approved by ERDA/DSE. It is intended as a planning document, an effort by Sandia Laboratories to describe the program objectives, participants, and specific responsibilities to fulfill those objectives.

This plan is subject to continuous review and periodic updating. Ideas and comments which will aid in meeting the overall program goals would be appreciated.

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FOREWORD

This Solar Irrigation Program Plan is an updated report of the initial Solar Irrigation Program Plan. This update, although prepared under the knowledge of ERDA-Department of Solar Energy, ERDA has neither reviewed nor approved of its contents. It is intended as a planning document -- subject to be updated periodically by the program participants.

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SOLAR IRRIGATION PROGRAM PLAN

I. PROGRAM OVERVIEW

INTRODUCTION

Background

At present, irrigated agriculture provides 15% (\$3.1 billion) of U.S. agricultural exports. Irrigated agriculture provides 20% of the value of the total national agricultural output. Approximately 30% of the U.S. cropland is dedicated to producing export foodstuffs, and 11% of U.S. cropland is irrigated. Energy consumption for irrigation purposes was 1.4×10^{14} BTU* in 1969 in the U.S.

The agricultural economics of the western states are heavily dependent on irrigation. In the western states, a wholly irrigated farm produces nearly seven times more crop value per acre than an unirrigated farm. The irrigated farms in the seventeen western states which represent over 80% of the irrigated land in the U.S. produced 20% (\$9 billion) of the total U.S. farm products in 1969. On the average, about half of the value of agricultural products sold in these states are derived from irrigated land [1]. The use of natural gas powered pumps is widespread in many of these states. Arizona, California, Texas, and New Mexico contain 35% of the irrigated land in the U.S. and use a combined total of more than 160,000 natural gas powered irrigation pumps. In 1973, agricultural products valued at more than \$50 million were produced from groundwater irrigated land in New Mexico alone. In 1974 the agricultural products exported were essentially equal to the petroleum products imported (~\$22 billion).

Lifting water for irrigation and other purposes by solar energy has been technically possible for 90 years [2, 3]. Early attempts at solar powered water pumping approached economic practicality around 1900. These pioneering attempts achieved efficiencies of 1 Bhp/272 ft² of collector (1 kWe/33.86m²), using focusing collectors and low pressure steam engines [4, 5]. However, the availability of inexpensive, plentiful supplies of fossil fuels doomed these early ventures to economic failure.

* Equivalent to 1.4×10^{11} cu. ft. of natural gas.

Price increases and potential shortages of natural gas have aroused renewed interest in alternate energy sources for irrigation. Presently, the farmer caught by the problems of supply and cost has little choice but to turn to even more expensive fossil fuels (diesel oil) or electrical power. In many areas of the U.S., supplies of fossil fuels and electrical transmission-generation facilities are inadequate. This lack of an affordable, guaranteed source of irrigation power results in a reluctance of financial institutions to make long term loans, further restricting the farmer's options. Under these circumstances, solar powered irrigation is becoming more attractive. Solar powered irrigation has the potential for being an alternate to fossil energy powered irrigation and in aiding in the production of more food in the future. It appears well suited for this application on areas needing irrigation are, in general, the arid regions that experience abundant insolation.

Approach

The overall objective of the ERDA/DSE Solar Irrigation Program (SIP) is the development of a practical power source for irrigation pumps. The effort involved in attaining this goal can be divided into two areas. The first is the development of the technology that will result in practical and economical designs required to accomplish the task. The second is to identify and assess the market requirements so the system can become a practical alternative to conventional power sources. There is a strong interplay of conflicting requirements between the above areas. Only by assessing these requirements will a technically and economically feasible solar irrigation system be defined—one that will be readily acceptable by the irrigation farmers.

The program is planned to be a joint effort between several interested and concerned groups: ERDA, farmers, financial institutions, industry, state governments and the U.S. Department of Agriculture. It is expected that each group will contribute its expertise to make the solar irrigation system development practical. To be practical it must be economically feasible; it must be accepted by farmers; and industry must be willing to incorporate it as a product line. Government incentives may be required, but these should be defined as part of the program.

The following subprogram objectives represent an approach to the attainment of the overall objective of the program:

1. A series of experimental projects to field the variety of design concepts required to satisfy the range of national applications.
2. Develop system designs based upon data obtained from the experimental projects and industry projections which will result in the highest maintenance free performance per unit cost.
3. Performance of analytical studies to identify and evaluate potential applications.

4. Analysis of the market potential and identification of the requirements of potential customers and supporting industries.
5. Development of those concepts and system characteristics identified in 3, that will enhance marketability of solar irrigation systems.
6. Development of a program plan with industry for the commercialization of solar irrigation.

SCHEDULE AND MILESTONES

To meet these subprogram objectives within the time allotted by ERDA/DSE for the solar irrigation program, the Program Schedule and Milestone Chart (Figure 1) has been developed. The major tasks required to meet each subprogram objective and the interactions of subprograms are shown on this chart. The program participant task responsibilities are also indicated. The participants are ERDA/DSE, Sandia Laboratories, Aerospace Corporation, various institutions and industrial users.

Design studies of solar powered irrigation systems will be conducted both by industry and Sandia Laboratories. ERDA, through Requests-for-Proposals, will direct industry activities. Sandia Laboratories will be the technical directors for the resulting contracts. Sandia has designed and is constructing a shallow well experiment in New Mexico. Acurex Corporation, Black & Veatch Consulting Engineers, and Honeywell are doing competitive design studies on a deep well experiment which will be located in Arizona. Peripheral system design studies will be conducted in order to optimally use the solar generated power. This appears necessary as irrigation isn't used continuously and once the solar system is obtained its costs nearly nothing to operate it. This added benefit will aid in making solar irrigation economically feasible at the earliest possible date.

System studies will be used to make preliminary assessments of the various design concepts that appear most promising performance wise. Following these preliminary assessments, experimental systems will be fielded to verify the analyses and to furnish performance data to support the final system studies. In conjunction with the preliminary system studies a market analysis will be performed with associated economic and environmental impact analyses.

The results of these analyses, with the supporting data on cost from the experiments and expected future improvements possible, will then be used to arrive at a configuration for a demonstration system. The results from more detailed and complete systems analyses will be available at this point to aid in this choice.

The market analysis study will be followed by a marketability enhancement study which will identify the technical, economic and social components of the system whose further development or implementation would result in improved economic feasibility for solar irrigation. A development plan outlining the goals and course of action for each of these areas will be assembled at this point.

As the final phase of the market analysis effort a commercialization plan will be developed. This plan developed with industry participation will outline the approaches and goals that must be pursued to develop an economically acceptable solar irrigation industry.

The final phase of the systems analysis and experimental portions of the program culminate in the fielding of a demonstration project. The demonstration solar irrigation system will encompass all the features deemed most likely to result in an economically and technically practical system and one acceptable to irrigation farmers.

Expected Results FY77

Sandia -- Sandia will continue as project director for the Estancia Valley experiment [6]. The early part of FY77 will be used to complete construction of the experiment, place the system in operation; collect data and complete performance calculations on the system. Planning and design work will be conducted with New Mexico State University on how off-season energy can best be utilized. Studies will also be conducted to upgrade the system to power a low energy center pivot system.

At the close of the 1977 growing season a series of experiments will be planned to fill in any data called for by review of the operating experience. The FY78 experimental effort for the Estancia Valley facility will be formulated at this time.

In conjunction with the Estancia Valley project, systems studies are being conducted and a broader series of studies will be initiated. These studies will address the regional and national application and configuration requirements for solar powered irrigation.

An ongoing effort will be initiated during this period to evaluate the results of the various related ERDA industrial and institutional projects with respect to possible applications within the irrigation program. The projects presented in Figure 2 represent a preliminary identification of related ERDA/industrial projects. The expertise developed by Sandia while participating in the Solar Total Energy Systems Program and the Central Receiver Test Project will be utilized during these assessments.

A Request for Proposal (RFP) for design study contracts for a solar powered irrigation experiment for the deep well case was issued through the ERDA/ALO office in early FY77. Twenty one proposals were received. Three awards for the competitive design study phase were awarded to the Acurex Corporation, Black & Veatch Consulting Engineers, and Honeywell. Sandia will coordinate and conduct a conceptual design review and contractor evaluation in cooperation with ERDA/ALO prior to the final approval of a contractor by ERDA/DSE for implementation, and will provide technical monitoring of contractor progress. To assure a sound evaluation Sandia will perform an in-house configuration and optimization study for the deep well system.

COMPONENT	FY76T QUARTER	77			
		1	2	3	4
COLLECTORS					
DISTRIBUTED					
PARABOLIC TROUGH	△	▽			△
FRESNEL	△				
STAT		△	△		
COMPOUND PARABOLIC		△			
PARABOLOID					
FIXED MIRROR					
CENTRAL					
HELIOSTAT			△	▽	
CAVITY			△		
RECEIVER SYSTEM				▽	
TOTAL SYSTEM					
WIND					
VERTICAL AXIS					
HORIZONTAL AXIS	▽				
PHOTOVOLTAICS			▽		
PRIME MOVER					
TURBINE			▽		△
STERLING/BRAYTON					
ENERGY STORAGE					
THERMAL		△			
COMPRESSED AIR	△				
BATTERY					
FLYWHEEL	△				
WATER PUMPS					
IRRIGATION/AGRICULTURE DATA BEING GATHERED					

△ COMPONENT TEST RESULTS
▽ SYSTEM TEST RESULTS

Figure 2. Component Development Projects Related To Small Solar Power Systems

A study will be initiated by Sandia early in FY77 to define the agricultural aspects of irrigation and to refine and expand the data base on irrigation system characteristics. An RFP will be prepared and issued in FY77 for a study to provide data on water utilization for irrigation and other farm uses of thermal energy along with studies of the tradeoffs between water and energy conservation. The results of these studies will be included in the preliminary applications analysis study which Sandia will provide in FY77.

Sandia will initiate studies to determine performance goals for solar powered irrigation systems which would improve their competitive position. These studies will include waste heat and off-season power use.

NMSU (ERDA/NM Project Only)-- Prior to starting the 1977 growing season NMSU will identify agricultural and irrigation techniques that appear most promising from a solar powered irrigation viewpoint. The 1977 growing season will be used to initiate the experimental evaluation of their techniques (agricultural experiments typically run 3-5 years). Toward the close of the 1977 growing season the Energy Research Institute at NMSU will begin the organization of an international workshop on Solar Powered Irrigation. This workshop will be used to disseminate the design and operating experience gained from the Estancia Valley experiment and to enhance the exchange of information between the various groups involved in irrigation.

Aerospace Corporation -- Early in FY77 a set of studies will be initiated to determine the potential market for solar powered irrigation and its requirements. Assessments will also be made by Aerospace on the societal, legal and environmental impacts of these types of systems.

During the middle of FY77 an economic analysis of solar power irrigation will be initiated. An outside agency or institution will be asked to define the role of state and local incentives in establishing a market place for solar powered irrigation.

To date ERDA has awarded design study contracts for the deep well experiment to Acurex Corporation, Black & Veatch Engineering Consultants, and Honeywell. These three studies include the study of distributive collectors, central receiver, and large dish systems. The systems must operate at 600°F temperature or higher and produce 150 kWe when the insolation intensity is 600 w/m². These design studies will be completed by Sept. 1, 1977 and a design will be selected for construction in Arizona.

The Arizona site has been selected by the Arizona participants. It is the Dalton Cole farm which is located approximately five miles southwest of Coolidge, Arizona. Mr. Jim Warnock, Jr. of the Arizona Solar Energy Commission is the experiment director for Arizona and Dr. Kenneth Barnes of the University of Arizona will be directing the Agricultural portion of the experiment.

An irrigation workshop is planned to be held at the Albuquerque Convention Center on July 7, 1977. On July 8, 1977, a dedication of the shallow well experiment will be conducted.

A consulting contract is being formulated to allow industry representatives to aid to formulating a solar irrigation system commercialization plan. This plan will also aid in determining the status of solar irrigation system economics. It is planned that this consultation occur near the time of the workshop.

Expected Results FY78

Sandia -- Early in FY78 the final design study for the deep well experimental facility will be completed. Sandia will conduct the review and evaluation of this effort for ERDA. Based on this evaluation, ERDA/DSE may approve a contract for implementation of the deep well experiment, expected to be placed through ERDA/ALO. Sandia will initiate design and construction for the upgrading of the shallow well experiment and have it in operation for the 78 crop season. Data from the 77 crop year operation will be analyzed and used in evaluating any design changes. Off-season energy usage will again be reviewed for usage in planning the next off-season usage. (The Regional/National Applications Analysis and Concept Design Studies will be completed during this period.) During the latter part of the year Sandia will identify, based on all earlier systems studies, cost/performance goals for system components which would improve the marketability of the system. These goals will allow formulation of a plan and schedule for a series of component design studies and experiments required to arrive at a set of hardware that will result in a practical, marketable solar powered irrigation system.

The conceptual design study will be refined following the completion of the Aerospace utilization studies to reflect their results.

Early in FY78 the marketability enhancement studies will be completed with recommendations for waste heat and off-season power utilization strategies; and evaluation of National and local incentives for use of Solar Irrigation Systems (SIS) will be completed.

Sandia will be technical director for two solar irrigation experiments during this time period. Sandia will be actively participating in the continued shallow well experiment to obtain more operational performance data on the hardware and more crop data. Both data are needed to make the systems analyses more accurate. Sandia will be technically monitoring the deep well experiment final design and the initial construction phase. It is in this area of the program that more detailed analyses will be required and economic tradeoffs finalized.

NMSU (ERDA/NM Project Only) -- An international workshop will be held early in FY78 to disseminate the results of the Estancia Valley experiment's first season of operation. The agricultural and irrigation experiments at the Estancia facility will continue under the direction of NMSU. Plans for next off-season energy usage will be formulated, and agricultural crops planned for the next seasons experiment. The agricultural experiments will be enlarged with the upgraded system being in operation.

University of Arizona (Deep Well Project Only) --

1. Plan agricultural experiments for deep well project.
2. Aid in deep well site construction and planning.
3. Conduct information symposium on project.
4. Conduct off-season energy study.

Aerospace Corporation -- Early in FY78 the market potential study to identify size, acceptance requirements and industrial interest will be completed. The economic analysis portion of the program will be completed during the middle of FY78.

Late in FY78 the development of a commercialization plan for solar powered irrigation will be initiated.

Expected Results FY79

Sandia -- The final phase of the application analysis and design studies will be completed early in FY79. These will include the regional optimization studies and the assessment of sensitivity of components to cost/performance with goals identified for component development.

The Estancia Valley experiment for the 1979 growing season will be planned and executed. The deep well system experiment for the 1979 growing season will be planned and executed, and plans will be established for utilization of the waste heat and off-season power of the system. Sandia will initiate the effort on the demonstration system. This system has not been defined or site selected at this time.

Sandia will evaluate the performance of the deep well experiment from the performance data obtained. If this evaluation indicates areas of desired modification, a plan for experiment modification will be formulated for ERDA.

NMSU (ERDA/NM Project Only) -- The Estancia Valley agricultural and irrigation experiments for the 1979 growing season will be planned and executed in conjunction with the Sandia solar powered pumping experiments. The results of the experiments will be used as the basis for an international workshop organized and held during FY79 to disseminate design and operating experience information.

University of Arizona (Deep Well Project) --

1. Report on agricultural experiment results.
2. Plan next years experiments.
3. Conduct symposium on experimental results.
4. Re-evaluate off-season energy usage.

Aerospace Corporation -- The economic analysis will be updated to reflect the results of the component and systems cost/performance sensitivity analyses, the marketability enhancement study and the completed experiments.

The commercialization plan for solar irrigation systems will be finalized during FY79, indicating the most promising concepts for various applications, showing the required cost/performance characteristics, and identifying barriers and requirements for industrial development and consumer acceptance.

II. TECHNICAL PLAN

APPROACH

The activities within the Solar Irrigation Program begin with the broad identification of classes of potential solar irrigation applications, as well as any critical external issues and policies which influence such applications. Detailed systems analysis and design studies will be performed to synthesize conceptual systems and evaluate their performance. These will be conducted with industry participation. Any present or future technology not previously incorporated will be reviewed for program improvement. A wide range of technical and nontechnical considerations must be taken into account. These include knowledge of subsystem characteristics, performance, lifetime, and cost; detailed insolation characteristics and load data; fuel prices in various locations; and considerations associated with environmental, institutional, and societal impacts. A plan for guiding these activities is shown schematically in Figure 3. This chart divides the activities under the SIP into six major areas:

1. Applications Analysis
2. Analysis of Conceptual Systems
3. Market Analysis
4. Marketability Enhancement Studies
5. Commercialization Planning
6. Experimentation

Figure 3. Solar Irrigation Program Task and Responsibility Chart

TASK PROJECTS

Task 1. Applications Analysis

The objective of the applications analysis of SIS is to assess the deployment potential for each of the irrigated regions of the nation. The assessment will include the preliminary ranking of those regions and systems which appear most promising from the viewpoints of technical and economic feasibility and for maximum impact on national energy use patterns. This task will provide some of the data necessary to accomplish the market analysis. The attainment of this objective requires that the following subtasks be completed.

Compilation of Input Data -- The objective of this subtask is to establish a data base sufficient to allow performance of the work described in tasks 2 through 5. Detailed input data is needed on component characteristics, insolation characteristics, weather, and load characteristics. To reduce duplication of effort, and to provide a common basis for the evaluation of competing systems, the use of standardized data is suggested. In the initial phases of this project, a format for the collection of this data will be established. Input data will then be compiled from existing data for sites and applications of interest.

Analyses of various levels of sophistication may require data on an annual, seasonal, daily and possibly hourly basis. When sufficient data has been collected, an effort will be initiated to aggregate the information on a regional basis. The identification of the nation's primary irrigation characteristics on a regional basis will greatly expedite the determination of the regions where the various SIS concepts will be applicable.

Performance data on SIS components is also needed for systems simulation. The SIP will draw heavily from other program elements in the Federal Energy Programs for this data, where available. For example, data on the performance of organic working fluid turbines is being obtained under ERDA funding at Sandia Laboratories as part of the Solar Total Energy Program. A shallow well, medium temperature solar experiment is also being fielded by Sandia Laboratories. Both of these sources should be able to provide valuable data for use in applications analysis. Existing data will be utilized to the fullest extent. Where deficiencies exist, a determination will be made as to whether work should be initiated to obtain the data or whether "best guess" approximations should be utilized.

Agricultural Practices -- A subtask of major importance to the success of the SIP is the identification of current and possible agricultural practices within the regions of interest. This effort must ascertain not only current cropping patterns and irrigation practices but also those of the future. The potential effects of modification of conventional practice must be considered when evaluating SIS and comparing them with conventional alternatives. Care will be taken to monitor and be aware of possible impacts from other ERDA programs investigating applications of total energy systems.

Alternate Utilization Options -- The purpose of this subtask is the identification and preliminary assessment of alternate uses for the waste heat and off-season power available from a SIS. This will involve the study of current agricultural practices to ascertain potential applications and to identify possible modifications in current practices that would yield significant improvements. The effect of alternate use options on the design of the SIS will also be evaluated.

Task 2. Systems Conceptualization

The object of this task is to identify those conceptual designs that are best suited for application in the various irrigated regions of the nation. Based on the input data compiled in Task 1, conceptual SIS systems can be configured. Regional and national data on irrigation practices and requirements will be utilized to define the most promising locations for SIP. Subsystem requirements will be defined for matching insolation availability with load characteristics in those locations. Storage system requirements are of particular interest here because of their impact on system costs. End-use categories will be correlated with insolation availability data to determine strategies in the various regions.

Following identification of the various SIS applications, conceptual systems design studies will be initiated. Such studies entail identification and characterization of candidate systems, estimating cost and performance for each system. The conceptual designs will be optimized for each application and the performance/cost ratio sensitivities of the system and its related components evaluated. This information will be used in rank-ordering the systems. It will be necessary to develop a methodology for coherently evaluating the various system concepts. The methodology will involve computer simulation of the various systems. The simulation technique chosen will be sufficiently general so a detailed analysis of advanced systems will be possible when data becomes available on these systems. Also, it will be necessary to develop parametric descriptions of all subsystems for use in the simulation.

Once the methodology is established, each conceptual system will be evaluated technically. Insolation data from the various regions will be used as input to systems simulations. Storage requirements for the various applications will be determined. ERDA's Division of Energy Storage will be requested to provide information on candidate storage systems during this phase. For remote, or on-site applications, engine size and storage system requirements are the key parameters to be identified.

Task 3. Market Analysis

Since the acceptance of SIS will probably be determined by economic factors rather than technical factors, cost estimates for each conceptual system must be performed in order to establish the relative economic performance of each system. This information will, in turn, be utilized to define areas for cost effective improvements in system design. Iterations with Task 2

will then be necessary to determine the effect of postulated improvements on the design and performance of SIS.

The primary objectives of the market analysis task is the assessment of:

- a. The market capture potential for solar powered irrigation, i.e., the determination of that portion of the national energy market to which solar powered irrigation may be applicable.
- b. The market penetration, i.e., the projected installed capacity of solar powered irrigation systems as a function of time considering realistic constraints of budgets, schedules, and user and industrial acceptance.

An economic analysis will be performed in conjunction with the market analysis. The thrust of this effort will be the identification of system and component cost goals and potential national and regional economic incentives. This effort will culminate in an identification and assessment of the economic viability requirements of SIS vis-a-vis conventional systems. The effects of alternate utilization strategies for the waste heat and off-season power available from solar irrigation systems on economic viability will be evaluated.

An additional subtask of the market analysis portion of the program is the assessment of the societal impact of SIS. The purpose of this study is the identification of those attributes of SIS that must be modified or required when consideration is given to the following:

- a. Environmental impact
- b. Legal restraints
- c. Social and/or institutional constraints

Under some circumstances the interfacing of SIS with existing utilities may be of importance to the successful implementation of the system. An effort will be mounted as part of this subtask to identify interface requirements which must be met to facilitate the deployment of SIS.

Upon completion of the above tasks the most attractive sets of configurations/applications will be rank ordered for further consideration in Task 4. Those component characteristics which require further development or improvement in order to increase the viability of solar irrigation systems will be identified. Those utilization strategies and incentives that result in increased feasibility of solar powered irrigation will be identified and assessed for consideration in Task 4.

An additional objective of the market analysis task is to determine the potential impact of SIS on the energy requirements of the nation. To accomplish this, SIS will be compared with conventional sources of power, e.g., direct fossil and electrical. Various scenarios for the introduction of SIS into the different application regions will be postulated to allow investigation of the impact on utilization of conventional sources.

Using projected demand forecasts, estimates will be made of the percentage of the U.S. agricultural energy requirements which would be supplied by SIS. The impact of SIS on natural sources usage will be assessed for each region and for the nation as a whole.

Task 4. Marketability Enhancement

The objective of this task is to identify and plan those development efforts which will result in the increased marketability of SIS. The three areas most likely to require additional development are:

- a. Alternate utilization of energy/power available from SIS
- b. Component cost/performance
- c. Incentive strategies.

Each of these areas will have been studied prior to this point in time to identify and assess the technical-economic aspects of concepts or component performance that may result in increased marketability. At this point a set of goals which appear most likely to be achievable and to result in the attainment of the task objective will be identified. These goals will identify those elements that should be included in the demonstration phase of the SIP and those requiring further refinement and experimental evaluation.

Task 5. Commercialization Plan

A program plan for the commercialization of solar irrigation will be developed during the final phase of the SIP. This plan will address the development and wide scale deployment of solar irrigation systems. In particular, it will address or identify:

- The introduction of SIS by application region.
- Those applications which can result in an economically viable system.
- Those geographic areas having the highest potential for utilization.
- The market capture potential and size for SIS.
- The conditions under which SIS can become competitive with conventional irrigation systems.
- The effect of energy conservation and changes in agricultural practice on current energy and irrigation usage patterns.
- The impact on resources and environment resulting from commercial production of SIS.
- The effects and sensitivities of major system design parameters on overall system economics.

Task 6. Experiments and Demonstrations

The Solar Irrigation Program as described in this document includes three experiments or demonstrations. The three are briefly described below.

ERDA/New Mexico (Shallow Well) -- A shallow well solar irrigation experiment will be constructed in the Estancia Valley of New Mexico. This experiment will utilize 6,720 sq ft of parabolic tracking collectors which heats Caloria HT43 fluid to 420°F. This fluid will be stored in a thermocline type thermal storage reservoir and will be used as needed to power a 25 hp (19kWe) Rankine cycle heat engine. The engine drives a turbine-type deep-well irrigation pump. The water pumped (700 gpm for approximately 23 hr/day) will be used to cool the condensor and is temporarily stored in a pond.

The water is taken from the pond by a conventional engine and pump to irrigate 100 acres. Different crops will be grown and different types of irrigation equipment will be used to apply the water. The equipment is scheduled to be operational May 1, 1977. Data obtained from these experiments will be utilized in determining the economic feasibility of the different experimental approaches and the performance of the system design.

ERDA/Arizona (Deep Well) -- A deep well solar irrigation system study is being initiated. It will be located in Southern Arizona and it shall be capable of generating 150 kWe of energy from a solar heated fluid above 600°F. It is expected that the higher operating temperature will result in higher thermal efficiencies and will have the potential for powering several irrigation pumps which are driven by electric motors.

The best one of three design studies to be completed by the end of FY77 may be accepted for the construction and use of one design. This experiment will be used to obtain the same type of information as the ERDA/New Mexico experiment. Data obtained will again be used to determine the economic feasibility of the design and to compare its performance with the shallow well design. The University of Arizona will conduct agricultural experiments to determine the optimum use of the pumped water.

Demonstration -- This system has not been defined. Its design will be strongly dependent upon the results of the previous two experiments and the component developments accomplished to date. Initial work on it is expected to start in FY79.

Technology Dissemination

In order to provide timely technical information to interested scientific and industrial communities at large, Sandia personnel involved in the technical work will participate in and present technical papers at scientific meetings and workshops. Contractor, institution and other agency representatives will also be encouraged to do so. Significant technical accomplishments will be written in the form of special reports, or will be submitted to appropriate scientific and

technical journals. Publication of research results by contractors will be encouraged, but will be in accordance with the terms of the contract and conditions regarding release of information. Seminars and workshops will be organized. The first workshop is scheduled for July 7, 1977.

Sandia public releases will be coordinated with ERDA. Sandia is a no-fee, nonprofit ERDA laboratory and energy R&D information is made available to all interested parties. All patents developed by Sandia's staff are assigned to the U.S. government and are handled in accordance with ERDA policies to protect the public interest.

A continuing literature survey will be initiated at Sandia so project participants can be kept abreast of developments in the field during the course of the study. Care will be taken as the project progresses to assure that information is disseminated as rapidly as possible. For example, as the design evolves, design information will be made available to the manufacturing and engineering communities. Two quarterly status reports have been published by Sandia in addition to monthly progress letters. These are available to all interested parties.

III. MANAGEMENT PLAN

APPROACH

The Solar Irrigation Program (SIP) management group consists of ERDA, ERDA field offices, Sandia Laboratories, and the Aerospace Corporation. This group will plan, direct, and conduct solar-powered irrigation projects and studies in an effort to achieve ERDA's goal of developing solar energy as a power source for irrigation. The group will interact with each other, other governmental agencies, industry, and private individuals to accomplish specific tasks. This interaction between the participants is schematically shown in Figure 4. The solid lines indicate lines of authority and the dashed ones indicate Sandia's review and consultation role. Because the exchange of information is vital to the management of SIP, those connections are shown even though they represent no authority function.

Program Direction: ERDA/DSE will retain the overall programmatic responsibility for conduct and direction of SIP. This is being done in a newly created Solar Irrigation Branch with Mr. Joe Weisiger being the Program Manager. With assistance from other participants, ERDA/DSE will set program objectives, make major program decisions, establish major milestones, and provide the resources required to execute the program. Specifically, ERDA will provide:

1. Agreements, formal and informal as needed, with other participants for the effective execution of SIP
2. Final approval of program plans, budgets and schedules, and delegation of responsibility for execution of SIP

3. Procurement (through ERDA field offices) of major contracts for large-scale experiments and demonstrations

Figure 4. SIP Management Organization

It is the responsibility of each participant to see that the activities assigned to his or her organization, by contractual agreement and/or by action of the ERDA/DSE, are within budget and on schedule. In response to problems, ERDA/DSE will take corrective measures, including the assignment of specific action items to members, within the constraints of existing agreements. Suggested modifications to the governing contracts or project redirections which might have implications for the overall Solar Irrigation Program are to be treated by the participating organizations and established procedures.

Contractual Management: ERDA field offices will be responsible for initiating and maintaining all ERDA/DSE SIP contracts. The field offices will assure that the legal requirements are met, that financial arrangements are within the program goals, and that required solicitations are fulfilled. Sandia will assist the field offices as to technical content, financial amounts available, and desired schedules of each contract. When bids are received on a proposed contract, Sandia will be responsible for evaluating the technical portion and, in cooperation with the field office, making recommendations to ERDA/DSE.

Technical Program Direction: Sandia shall be responsible for the overall technical direction of SIP. In performing its duties Sandia shall pay particular attention to the following activities:

1. Prepare, with other participants, procurement (RFP) and Statement of Work (SOW) contracts for ERDA solicitations.
2. Assist ERDA/DSE in major program decisions.
3. Provide comparative evaluations of systems designs as they develop throughout the program.
4. Assist ERDA/DSE in evaluating and placing major contracts for large scale experiments and demonstration plants, by participating in the choice of contractors and applications.
5. Soliciting, evaluating, awarding, and administering the other smaller contracted activities for component, subsystems, materials support and systems engineering.
6. Establish a program of technical reviews and reports which adequately documents the progress of the program.
7. Provide day-to-day technical direction to all contracted effort.
8. Provide an annual financial operating plan for ERDA/DSE approval.

Program Management Support: The Aerospace Corporation provides mission analyses, planning input, and advice to ERDA/DSE for the Solar Thermal Program, of which the SIP is an important element. Aerospace has the responsibility to assure that the SIP is consistent with the goals of the Solar Thermal Program.

RESPONSIBILITIES

ERDA/DSE: Overall conduct of the program is the responsibility of the ERDA/DSE. With assistance from the participants, ERDA/DSE sets program objectives, makes major program decisions, establishes major milestones, and provides the resources required to execute the program.

ERDA/Field Offices: At the direction of ERDA/DSE, and with the technical assistance of other participants prepare, execute, and maintain all large scale program contracts. This does not include small contracts, i. e., purchases, required by the participants to complete their effort and that are within their budget authorization.

Sandia: The following tasks, unique to the solar irrigation program, are to be pursued by Sandia. These tasks may be accomplished by either inhouse or external contracts.

1. Participate in the operation of the ongoing Estancia Valley shallow well irrigation experiment.
2. Conduct design studies which exercise any new component or system concept to determine its worth to the SIP.
3. Establish an insolation-weather data base suitable for the analysis of solar powered irrigation system concepts for the various regions of the nation.
4. Establish an irrigation requirements (load) data base. This effort will yield information to support economic and market analyses and systems optimization studies.
5. Investigate optimum cropping patterns or agricultural practices for the reduction of conventional and solar powered system costs.
6. Identify alternative methods of utilizing the waste heat and off-season power of a solar powered irrigation system.
7. Initiate a conceptual systems design effort to identify those concepts most likely to succeed from a technical viewpoint. Designs will be evolved on a regional application basis.
8. Optimize the results of (7) for the various regions of the nation.
9. Identify the performance/cost sensitivities of the various systems and their associated components.
10. Rank the design concepts identified in Task 7 in order of technical feasibility.
11. Perform design analyses independent of industry to determine correctness of deep well proposals.
12. Evaluate component performance and explore production costs to compare with proposals.
13. Call meetings to disseminate information and evaluate technical progress of participants.
14. Provide technical monitoring and evaluation of industrial contractors to give technical guidance, discuss progress being made, and determine areas where more effort should or should not be applied.

15. Report on the direction and progress being made by industry on the proposals and recommend to ERDA/DSE any areas of technology which may require redirection.

The results of the above efforts will be utilized by Aerospace in performing market, economic, and environmental analysis of solar powered irrigation. The results of these market studies will then be used to identify and rank those irrigation concepts that are most promising from a marketing as well as a technical viewpoint. Aerospace will also furnish Sandia with an assessment of the utilization strategies that appear most promising and the system/component cost/performance goals that would be required for solar powered irrigation to be competitive with alternative power sources.

Sandia will make use of these results to refine the most promising conceptual designs. A program plan for the definition and experimental verification of the most promising utilization strategies will be formulated by Sandia.

Aerospace: Responsibility for the identification and assessment of the potential market and its requirements will lie with the Aerospace Corporation. In meeting this responsibility Aerospace will:

1. Perform a market analysis to assess.
 - a. the market capture potential for solar powered irrigation, i.e., the determination of that portion of the national energy market to which solar powered irrigation may be applicable, and
 - b. the market penetration, i.e., the projected installed capacity of solar powered irrigation systems as a function of time considering realistic constraints of budgets, schedules, and user and industrial acceptance.
2. Perform economic analyses for the selected configurations/applications with consideration being given to
 - a. Transmission line costs
 - b. Capital investment costs
 - c. Busbar energy costs
 - d. Cost effectiveness versus conventional alternatives
 - e. Possible incentives for solar irrigation system deployment
 - Tax incentives
 - Favorable financial rates
 - Off-peak power rates

3. Assess the societal impact of solar powered irrigation with consideration being given to:
 - a. Environmental impact
 - b. Identification of legal restraints.

Upon completion of the above tasks, Aerospace in conjunction with Sandia will then rank order the most attractive sets of configurations/applications. Those component characteristics which require further development or improvement in order to increase the viability of solar irrigation systems will be identified by Aerospace. Aerospace will also determine those utilization strategies and incentives that result in increased feasibility of solar powered irrigation. A program plan will be prepared by Aerospace for the assessment of the impact of the most promising incentives on the marketability of solar irrigation systems.

Sandia will utilize the results of the Aerospace studies to decide whether the most promising conceptual designs need to be modified. A program plan to experimentally evaluate and refine the most promising utilization strategies will be prepared by Sandia.

Upon the completion of the above program plans Aerospace will prepare a program plan for the commercialization of solar irrigation. This plan shall address the development and wide scale deployment of solar irrigation systems.

TECHNICAL REVIEW AND REPORTS

Documentation of the program is essential for managing, evaluating, and planning future activity required to reach the desired program goals. The reviews and reports discussed in this section, with the exception of the contractor reports, (1) refer to the overall Solar Irrigation Program, (2) are the responsibility of the Technical Program Director, and (3) are presented to ERDA/DSE.

Program Reviews: Formal program reviews are conducted semiannually for evaluation by ERDA/DSE. These reviews, coordinated and conducted by Sandia, are in the form of detailed oral presentations by the personnel involved on the status of various program elements. Accomplishments, problem areas affecting objectives, schedules, costs, and recommendations for programmatic responses to difficulties are emphasized. It is the responsibility of each participant at the time of his presentation to provide Sandia with a written summary of his presentation and duplicates of his visual aids suitable for copying. Sandia will collect the written summaries, add a brief of the review meeting, which includes documentation of any conclusions and assigned action items, and distribute copies according to a list maintained for that purpose.

Informal program reviews are conducted each quarter. These reviews will also be coordinated by Sandia and may be held more frequently as required. The reviews will be oral presentations by the participants responsible on the status of various program elements.

Monthly Reports: A letter program status report is provided to ERDA/DSE on a monthly basis showing:

- Any deviations from program schedules,
- Summaries of significant accomplishments since the previous report,
- Brief descriptions of problem areas,
- Recommendations for any program plan modifications,
- Budget updates,
- Summaries of any other activities which influence SIP.

Topical Reports: Attached to the monthly letters are technical reports which contain complete documentation of technical activities done by Sandia, Aerospace, other agencies or institutions, and contractors, which have been completed during the month. Also attached to each monthly letter is the documentation (perhaps in the form of letters and memoranda) of the justification for any major program management redirection. The intent is to make the file of monthly status reports with their attachments a complete record of the history of the program. The maintenance of this file is Sandia's responsibility. It is the responsibility of each program participant to see that his/her activities are properly documented and that copies of all program documentation are submitted to Sandia.

Semiannual Reports: Semiannual reports are issued at the middle and end of each fiscal year and cover all aspects of SIP. These reports are to be brief, referring to the documentation in file for technical and managerial detail. They emphasize the achievements of the report period and their implications relative to overall program objectives and milestones. The semiannual report provides a measure of the progress in comparison to the program's established objectives and schedules.

Contractor Reports: Each solar irrigation contract will include a schedule of technical reviews and reports to document adequately the performance of the contract effort. Such schedules will be influenced by the nature of the activity and the contractor but include at least periodic reviews and a final report. Technical findings from contracts are to be addressed to a technical audience with executive and management summaries as appropriate.

Special Reports and Reviews: From time to time it may be necessary to prepare special reports or to call special review meetings to be responsive to some programmatic demand. For

example, information in the form of visual aids, models, and prototype hardware as well as written reports may be needed by the ERDA/DSE staff in presenting program overviews for planning and budget exercises. Significant technical accomplishments may be written in the form of special reports and submitted to appropriate scientific and technical journals.

Workshops: Upon completion of each experimental project and at significant milestones, workshops and seminars will be held to acquaint the various interested parties with the results of the project. These international workshop/seminars will have two-fold purposes:

1. To disseminate the information gained from the experiment to the agriculture industry including farmers, manufacturers, financial institutions, researchers, and legislative and regulatory agencies, and
2. to obtain information on new developments in the field from outside researchers.

Project Reports: Upon completion of each task project within the SIP including each experimental project and workshop/seminar, a Project Report will be published by Sandia summarizing the project and detailing the results. The participation in and response to each workshop/seminar will be documented in a Project Report. The Project Reports will be used as the bases for articles to be submitted to agricultural publications in order to ensure a wide dissemination of information to the interested parties.

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