ERDA-116 (Vol. 8)

Balanced Program Plan

Volume 8
Solar Energy

Analysis For Biomedical & Environmental Research

Energy Research & Development Administration

Division Of Biomedical & Environmental Research

October 1976

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Available from:

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price: Printed Copy: $ 5.00
Microfiche: $ 3.00

ERDA-116 (Vol. 8)
UC-11, 59, 60, 61, 62, 63, 64

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Balanced Program Plan

Volume 8
Solar Energy

Analysis For Biomedical & Environmental Research

Energy Research & Development Administration

Division Of Biomedical & Environmental Research

Prepared By:
Lawrence Berkeley Laboratory
Berkeley, California 94720

Under Contract Number:
W-7405-ENG-48

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

This report constitutes the revised version of the Solar input to the Balanced Program Plan of the Division of Biomedical and Environmental Research of ERDA. The report was coordinated by Lawrence Berkeley Laboratory. The LBL personnel involved in this effort were:

Donald F. Grether, coordinator
Melvin K. Simmons
James C. Sandusky

The other general purpose ERDA laboratories were contacted and each provided material on one or more of the solar technologies. The contact people were:

Steven Danyluk, ANL
John M. Olson, BNL
John D. Balcomb, LASL
Ronald Wichner, LLL
William Dickinson, LLL
Royce Eckard, LLL
Robert M. Pearlstein, ORNL
Nels Laulainen, PNL
Bernard Zak, SLA
Alan Skinrood, SLL

The report was prepared at a workshop held at LBL during the week of May 19-23, 1975. The laboratories were invited to send representatives to this workshop. The people that attended, in addition to the above LBL personnel, were:

Erwin Fischer-Colbrie, LLL
Roy E. Thoma, ORNL
Richard McLean, ORNL
Bernard Zak, SLA
Thomas Brumleve, SLL

A number of others, at LBL and the other laboratories, contributed valuable comments or information.

This revised version reflects suggestions made by DBER staff at the Balanced Program Plan Workshop of June 23-27, 1975 held at ERDA headquarters. The laboratory representatives at the workshop for the Solar input were:

Donald F. Grether, LBL
Steven Danyluk, ANL
Nels Laulainen, PNL

The report's "Technology Timetables" were revised 31 October 1976 to reflect ERDA 76-1 and the FY76 Program Approval Document for Solar Energy Development.

TABLE OF CONTENTS

Introduction. 1

Solar Generic. 5

Solar Thermal Conversion. 8

Solar Heating and Cooling of Buildings. 14

Photovoltaic Conversion. 17

Wind Energy Conversion. 19

Ocean Thermal Conversion. 23

Bioconversion. 25

Tidal Energy Conversion. 28

Hydroelectric. 30

Program Units. 33

I. INTRODUCTION

The Balanced Program Planning (BPP) effort was initiated by the Division of Biomedical and Environmental Research (DBER) of ERDA to identify and develop a research plan for investigating the environmental impacts associated with energy technologies being developed by ERDA. "Environmental Impacts" is taken here to refer to pollutants, health effects, ecological effects, socioeconomic and long-term impacts. The responsibility for coordinating the BPP effort for solar energy was assigned to Lawrence Berkeley Laboratory, with assistance from the other ERDA laboratories.

As defined for the BPP effort, solar energy includes tidal and hydroelectric as well as the more usual categories of solar thermal conversion, photovoltaic conversion, wind energy conversion, ocean thermal conversion, bioconversion, and heating and cooling of buildings. The tides are, of course, more properly considered lunar energy. Hydroelectric power differs significantly from the other categories in that it is a developed technology and utilized to a significant fraction of its potential. But in a broader sense this grouping is appropriate since all of the above are techniques for diverting for man's use some fraction of the natural processes of energy transfer between the surface of the earth, its oceans and atmosphere, and the sun, moon and outer space. Bioconversion supplied most of man's energy needs until the industrial revolution and, as already mentioned, hydroelectric power has been developed for some time. But successful applications of the others have remained elusive; primarily because of technical and economic constraints. The recent increase in interest in solar energy results from its essentially perpetual supply and from the potential avoidance of the adverse environmental effects associated with conventional energy sources.

Most of the potential environmental effects of solar energy conversion are related to the dilute nature of the energy sources; the same factor that has limited the development of these technologies.*

---

*Hydroelectric power is the exception in that the energy could be readily concentrated by construction of dams.

That is, depending upon the particular conversion process, large amounts of land, substantial quantities of materials (metals, glass, etc.), and large flow rates of water or other fluids are needed if solar energy is to provide an appreciable fraction of the Nation's energy requirements. Large scale devices (e.g. for solar thermal conversion) will impact the local ecology and microclimate. Production of the necessary materials will have secondary environmental impacts such as air and water pollution. Massive diversion of land, water, or materials from alternate uses raises many socioeconomic questions. Finally, a successful conversion of some fraction of the earth's natural energy transfer processes may have global ramifications in the form of climate changes.

The environmental effects of solar energy conversion, although treated qualitatively in the literature, have not been investigated in detail and there is currently no national research effort to do so. There are several reasons for this. Some proponents of solar energy have ignored potentially adverse environment effects while proposing large-scale and occasionally bizarre* schemes. Sceptics, on the other hand, have argued mostly on economic grounds that large-scale use of solar energy will not occur in the foreseeable future. From this viewpoint, environmental research would be superfluous. In addition, much of the proposed technology has been largely speculative and the number of possible conversion schemes legion; this has rendered difficult the quantitative prediction of environmental impacts.

Several years ago NSF/RANN began a solar energy program to support systematic studies of solar energy conversion. This program is now continuing under the Division of Solar Energy of ERDA. The intent of the program is to develop the various conversion methods to the point of economic viability within, roughly, the next ten to fifteen years. In furtherance of this objective,

---

*For example, damming the Straits of Gilbraltor and, after a 200 year wait, running water from the Atlantic ocean thru turbines into a partially evaporated Mediterranean sea.

particular technological approaches will be selected and developed to the pilot plant and demonstration plant stage. For some of the conversion processes, initial selections have been made (e.g., the central receiver for solar thermal conversion). For others, plans call for decision points to be reached within the next few years. Pilot or demonstration facilities are generally scheduled to be in operation a few years after the selection of the favored technological approach.

The ERDA solar energy development program will provide a heretofore unavailable opportunity for focusing environmental research. This research will be most effective if initiated prior to construction of the facilities. The preliminary research could then delineate areas of concern for more detailed investigation during the construction and operation of the facility. The support of environmental research during the early development stages of the various solar energy conversion techniques would serve the desirable (and oft-stated) goal of having environmental considerations interact with the technological development. Such interaction could influence choices between alternative approaches to a given conversion process; lead to modifications to mitigate the environmental impact; or contribute to the termination of the development of a technology that is judged to be environmentally unacceptable.

The possible solar energy conversion processes are so varied in concept and stage of development (e.g., wind energy vs. photovoltaics) that the environmental concerns can not be usefully classified under the single heading of "solar energy". Further, even for a given process the potential environmental effects depend upon the scale of utilization (e.g., industrial process heat vs. large arrays of solar thermal power plants tied to the power grid). We have thus established the following categories for the purposes of the BPP.

A. Solar Generic

B. Solar Thermal Conversion

(1) Large-scale Generation of Electricity

(2) Small-scale Applications

C. Solar Heating and Cooling of Buildings
D. Photovoltaic Conversion
E. Wind Energy Conversion
F. Ocean Thermal Conversion
G. Bioconversion
   (1) Bioproduction
   (2) Bioconversion to Fuels
H. Tidal Energy Conversion
I. Hydroelectric

Section II contains narrative descriptions of the above solar energy conversion categories. Included are discussions of the technological approaches, planned timescales for development, and potential environmental concerns. Section III contains the Program Units that are proposed as the basis of the DBER Balanced Program Plan. In the interests of brevity and credibility we have included, with the exception of tidal energy, only program units for those environmental effects that are related to technologies under active development, and that are judged to be appropriate for DBER supported research. We have not included Program Units for research on what are generally considered to be the positive environmental impacts of solar energy: the avoidance of the well-known deleterious impacts of existing non-solar sources of energy. Research on such positive (i.e., avoidance of negative) impacts of solar energy is not included because the assessment of the negative impacts to be avoided by the use of solar technologies must be researched individually for each of the non-solar energy technologies. Instead we provide here for the assessment of the impacts of the solar energy alternative, so that the benefits of energy scenarios including solar technologies can be correctly assessed in cross-technology studies.

Section IV contains a summary of the program units in the form of a matrix of the above solar energy categories vs. the King-Muir Categories.

II. A. SOLAR GENERIC

In this section we discuss those impacts of the utilization of solar energy for which a single methodology will suffice to study the effects of most or all of the various solar technologies. The research to be performed in the solar generic Program Units will largely be used to provide the solar component of input to studies and planning efforts that deal with choices among solar and non-solar technologies.

The most important of the generic impacts of solar energy technologies is expected to be the impact on the national economy of providing the high initial investment necessary for a solar energy facility relative to that required for other energy technologies. This investment involves diverting materials, energy, manpower, and capital from other uses in the economy. The more rapid is the implementation of solar energy, the more drastic will be impact of these requirements. We note in particular that the concept of net energy flow must be included in planning. Thus, in the short run, within a scenario that involves accelerated development of solar energy, solar might be a net consumer of energy.

In addition to the impacts on the national economy as a whole, there will be impacts that occur within those regions particularly suitable for solar energy applications. The diffuse nature of solar energy requires the dedication of significant amounts of land to certain types of solar energy facilities. This will compete with other uses for the land on which the facility is sited. In addition the prospect of less expensive energy may serve to attract industry to areas that had previously been undeveloped or used for other purposes such as recreation or agriculture. Thus regional land use planning will be significantly impacted. Strongly related to land use planning is water use. Since many of the favored sites for solar energy conversion already have serious water shortages, the demand for water for solar energy conversion, and any industry it might attract, must be carefully addressed within the context of

regional water planning.

Associated with the use of solar energy in previously sparsely populated areas will be an influx of population; first to construct the solar facilities, and then to maintain them. There may also be an influx of population associated with the movement of industry to the region. Thus demographic impacts of solar energy in sparsely populated areas must be considered.

Many of the solar energy technologies may have an impact on the aesthetic appeal of regions and their use for recreation. We note in particular the possible visual impact of large numbers of wind turbines scattered along the skyline, of receiving towers for solar thermal power plants, or of the electrical transmission lines or hydrogen pipelines that will connect solar facilities with urban regions. Public attitudes toward such alterations of the aesthetic appeal of potential sites for solar energy facilities must be carefully assessed.

The environmental impact of solar energy will also occur through the production of residuals from activity required in various existing sectors of the economy to supply the components of solar energy facilities. Thus the requirement of a solar thermal conversion facility for steel will require some fraction of the Nation's steel production, and in making that steel there will be a certain amount of pollution generated by the steel industry. That pollution must be accounted as part of the environmental cost of solar energy. Of course in a total assessment this cost would have to be compared with the corresponding costs of other (e.g., nuclear) facilities that also require steel for their construction. Data should be collected on the sectorial economic activity required for the various solar energy technologies and a methodology developed for assessing the production of residuals (air and water pollutants, solid waste, noise, etc.) resulting from that activity.

Considerable concern has been expressed about the possible long-term climatic alterations that might result from continued growth

of energy consumption. The possible impact of solar energy technologies on global and regional climate should be assessed, based on the local climatic effects estimated in program units associated with individual solar technologies. These impacts must then be compared with the impacts of other non-solar technologies as determined in other elements of the BPP. We note that in addition to the inadvertant climate alterations considered above, there are various suggestions for intentional alterations of climate, for example seeding clouds above a water basin to increase the resource for hydroelectric generation, or to prevent the formation of clouds in regions containing solar thermal conversion plants. The impacts of such intentional modifications must be carefully considered.

II. B. SOLAR THERMAL CONVERSION

Applications of solar thermal conversion include direct use of the thermal energy (e.g. for heating, cooling, industrial, or agricultural processes), conversion to electrical energy (e.g. by a conventional Rankine cycle), or a combination of both. As defined for the BPP, this category encompasses the Solar Thermal subprogram of the Division of Solar Energy's Solar Electric Applications (SEA) program, and the Agricultural and Process Heat Applications subprogram of the Division's Direct Solar Conversion program. The Solar Thermal subprogram includes the large-scale generation of electricity and Total Energy systems.

The characteristics of devices for solar thermal conversion are summarized in Table I. A detailed discussion of the characteristics and relative merits of the various types is beyond the scope of this report. However, a few generalizations are perhaps in order. The complexity of the devices tends to increase with increasing concentration ratio and temperature. Thus Solar Ponds would be constructed from concrete, with a covering of plastic films, while the Central Receiver concept utilizes thousands of individually controlled mirrors to reflect solar radiation to a central receiver. In distributed systems incident solar radiation is absorbed by a large number of collector units; the energy is then conveyed to a centrally located power plant by an extensive piping network. For electrical generation, higher temperatures permit greater thermal-to-electrical conversion efficiency and hence less collector area is required for a given electrical output. For any given application, these as well as economic and other considerations must be evaluated to arrive at an optimum design.

(1) Large-Scale Generation of Electricity

This classification refers to solar power plants designed to generate electrical power for transmission to a distant point of use. Studies during the past few years have evaluated various collector configurations (e.g. central receiver, distributed parabolic troughs, etc.), site locations, types of load (base, intermediate, or

TABLE I

SOLAR THERMAL CONVERSION DEVICES

DEVICES	TYPICAL PARAMETERS Concentration Ratio	Operating Temp.	Unit Dimensions	Sun Tracking Motion
Distributed Collectors[1]				
Flat Plate	1	∿100°C	meters	none or seasonal
Non-tracking Concentrator (Winston Collector)	3-10	∿200°C	meters	none or seasonal
Line Focusing (Parabolic Trough)	10-20	∿300°C	meters	continuous - one axes
Point Focusing (Parabolodial Dish)	≥1000	>500°C	meters	continuous - two axes
Central Receivers[2] - Optical Transmission	≥1000	>500°C	meters	continuous - two axes
Solar Ponds[3]				
Deep (salinity Gradients)	1	∿ 75°C	tens of meters	none
Shallow - covered	1	∿ 75°C	tens of meters	none

1. Individual units collect and convert the incident radiation, and transfer the thermal energy to a fluid. A given system consists of many units, connected by plumbing to a central location (e.g. turbine).

2. Individual units are heliostats (sun tracking mirrors) that reflect the incident radiation to a central receiver-converter.

3. A given system consists of one or more ponds connected by plumbing to the point of use.

peak), thermal to electrical conversion methods, and energy storage requirements. Based on these studies, the configuration which appears closest to economic viability is the Central Receiver with conventional steam turbines, thermal storage, and operated in the intermediate load mode. A RFP was issued in March, 1975 for subsystems research and preliminary design of a 10 MW_e pilot plant. The plant is scheduled to begin operation in late 1979. Current plans are for a decision point to be reached in 1979 on whether to proceed with a 100 MW_e demonstration plant. Initial commercial plants are anticipated to be in operation in the late 1980's.

The selection of a particular configuration for development, together with the results of the various studies, permits a general picture of this type of solar power plant. The locations would be in generally flat, semi-desert areas of the southwestern U.S.. Commercial size plants will likely consist of modules (each with tower and mirror field) clustered about a power plant of 100 to 1000 MW_e capacity. The mirrors will cover roughly half of the land required. A 1000 MW_e intermediate load plant (providing power $\sim$16 hours a day) would require a land area of $\sim$15-25Km^2*. The method of cooling will very likely be wet or dry cooling towers, and some type of energy storage will be necessary. The potential environmental impacts of such plants can be divided into direct effects at or in the vicinity of a given plant; and indirect effects at the regional or national level resulting from the implementation of many such plants.

Direct Environmental Effects

The unique aspect of a solar power plant (as compared to a conventional plant of similar electrical capacity located in the same area) is that the collectors would partially cover large areas of land on an essentially permanent basis. The effects are mainly associated with the heat and water balance, and with the local ecology.

Concerning the heat and water balance, the surface albedo of the site would be reduced, but most of the solar energy incident

* The lower end of this range is taken from: A.C. Skinrood, T.D. Brumleve C.T. Schafer, C.T. Yokomizo and C.N. Leonard, Jr., Status Report on High Temperature Solar Energy Systems, SAND-74-8017. The upper end is from: Solar Thermal Conversion Mission Analyses, Aerospace Corp., Report No. A7R-74 (7417-16)-2, Vol. I, page 213.

on the mirrors or collectors would be conveyed to the power plant. The partial shading by the heliostats will reduce the surface temperature and the rate of loss of surface moisture, and possibly affect the ground water level. Surface wind velocity will be reduced by the impediment of the heliostats. At present there exists no analysis whereby the effects of these changes can be predicted. However, the type of terrain usually proposed for solar plants (a level and uniform plain of wide extent) can be successfully described by micrometerological modeling. The proposed research program would include such modeling, combined with meterological measurements at the pilot plant site both before (baseline measurements) and after construction.

Closely connected with the heat and water balance are the ecological impacts of the solar plant. The severity of the impacts will likely depend on the heliostat design. One type, in which the mirrors of a central receiver system are mounted on "turntables" close to ground level, would either cause or necessitate destruction of the local vegetation. Another type, in which each mirror is mounted on a tall pedestal, would permit vegetation and, presumably, some form of animal life. The shading provided by the heliostats and the possible increase in moisture retention may provide a more benign environment for flora and fauna than under natural conditions. Some have suggested that the area under elevated heliostats would be suitable for agriculture; perhaps as grazing land. The reduced surface winds and potential increase in vegetation could reduce wind-caused soil erosion and airborne dust. Increases in water-caused soil erosion could result from grading, access roads, and runoff from the heliostats. The proposed research program would investigate such possibilities, both thru field studies and by analyses done in conjunction with the micrometerological research discussed above.

Although the Central Receiver pilot plant will use a steam cycle for power generation, a variety of organic fluids, inorganic salts and other compounds are being considered as heat

transfer fluids (especially for the distributed collector system), or for change-of-phase, sensible heat or chemical energy storage. Large amounts of material will be required, some of which may be hazardous if mishandled or released in an accident. The proposed research would investigate the health and ecological effects of such release; with emphasis on materials that are new, not well characterized or known to be hazardous.

The above discussion has concentrated on the Central Receiver. However, the Solar Energy Division of ERDA currently plans to develop a Distributed Collector system as well; with pilot and demonstration plants scheduled for completion some two years after those of the Central Receiver. Since the environmental considerations for the two technological approaches are similar, a given program unit (for, say, Ecological Effects) will cover both.

Indirect Environmental Effects

Large-Scale solar thermal conversion requires large amounts of materials, and substantial amounts of land in a restricted geographical area. These requirements raise questions concerning competition for limited materials, land, water and energy resources; residuals from production of the solar devices; manpower, capitol and industrial dislocations; and regional or global climate modifications. Since these considerations are either common to or similar to those of the other solar energy technologies, they are treated in the Solar Generic section.

(2) Small-Scale Applications

This classification refers to solar thermal systems scaled to the requirements of, and located at or near, a particular energy use site. Agricultural, Process Heat, and Total Energy systems are currently being investigated by ERDA.

Agricultural uses include heating and cooling of animal shelters and greenhouses, and crop drying. ERDA's plans call for a series of pilot and demonstration facilities to be constructed in

the late 1970's and early 1980's, with commercial plants beginning in the late 1980's.

Process Heat applications would replace or supplement conventional sources of heat (usually fossil fuels) in industrial processes. ERDA distinguishes between low (<212°F), intermediate (212°F - 350°F) and high (>350°F) temperature applications. Plans call for construction of pilot and demonstration facilities in each of these temperature ranges during the period 1978-1987. Commercial applications are expected to begin in the late 1980's (or sooner) for low temperature applications, and in the mid 1990's for intermediate and high temperatures.

Total Energy systems would supply both electricity and heat for urban and rural communities, industrial/institutional load centers, and military bases. ERDA's plans call for construction of two pilot plants by 1981, and two demonstration plants by the mid 1980's.

These relatively small scale applications have many of the advantages of the large scale systems, such as reduced dependence on fossil fuels and low pollutant levels. Further, since the energy is used essentially at the point of conversion, the need for energy transmission is reduced. These systems can be expected to have direct impacts on the local environment similar to those of the buildings, parking lots, roads, etc. with which they will be integrated. Separation of the effects of these various components would be quite difficult, and the impact of any one system will be small. The proposed research unit would mainly serve to monitor developments in this field from an environmental point of view.

To the extent that small-scale solar thermal systems make a substantial contribution to the nation's energy supply, they will have <u>indirect</u> impacts similar to those described for large-scale systems. Again, these impacts are treated under Solar Generic.

II. C. SOLAR HEATING AND COOLING OF BUILDINGS

The goal of the ERDA program for solar heating and cooling of buildings is to stimulate the creation of a viable industrial and commercial capability for producing and distributing solar components and incorporating them in new construction of homes and commercial buildings. The technology for collecting solar energy to provide space heating and domestic water heating exists now. Manufacturers are beginning to make subsystems and systems available, but current prices are high. Practical systems for solar cooling are not generally available yet, and significant research and development are necessary to provide marketable units. The major effort in the ERDA program is on systems that combine the use of solar energy with a backup source of energy to provide the resident with the same thermostat-controlled comfort of conventional systems. Some attention is also being given to various passive systems that use solar energy to moderate, but not control exactly, the temperature and humidity of the building.

The ERDA program (as described in National Plan for Solar Heating and Cooling, ERDA-23, March 1975) includes three major elements:

- Demonstrations for both commercial and residential applications.
- Development in support of the demonstrations.
- Research and Development for advanced technology.

Present plans call for at least 2,000 residential and 400 commercial buildings demonstrations by 1979. In the first two years only solar heating will be demonstrated; in subsequent years combined heating and cooling systems will be demonstrated. The demonstrations will be dispersed throughout all regions of the U.S., and will be constructed by local contractors. The demonstration program will also include efforts to identify and remove economic, legal, and institutional constraints to widespread application of solar heating and cooling.

The research and development program will include research on components, materials, building design implications, systems analysis, and collection of insolation and climatic data. In particular, this will involve the development of new heat transport fluids, various salts and organic waxes for storage of heat by change of phase, and refrigerants for solar cooling units. There will also be some development of new materials of construction, though for economic reasons conventional materials will be primarily employed.

The potential market penetration of solar heating and cooling has been variously estimated as being from 100 thousand to 10 million buildings by 1985. With reasonable success in the research and development program, a significant industry will be active by 1985.

The direct environmental effects of solar heating and cooling will generally be subtle because the use of these systems will be widely dispersed in already developed urban and suburban areas. The solar systems will be installed as part of normal buildings and will generally employ standard construction practices and materials. Thus, the impacts will be minor alterations of the already drastic environmental impact of urbanization and building construction. Any new and unusual materials used in the construction of the systems may have some impact by release of materials in ordinary use (by erosion or corrosion) or in building fires.

A unique effect, through probably minor, will be an alteration of the urban heat island effect caused by the high density of energy consumption and the altered albedo of urban areas. This effect has been known to lead to a significantly altered climate in the city relative to the surrounding region. The use of solar units will alter this effect to some, probably small, degree.

A potentially more significant effect is the release from residential and commercial systems, either by accident or by normal maintenance that involves flushing the system, of fluids used for heat transfer, heat storage, or refrigeration. New fluids for these

purposes are being developed in the ERDA R&D program. Such fluids may be toxic to plants, animals, or humans, and they may become concentrated in the food chain if they are released into the environment. Research on the toxicity and the uptake by organisms of these substances should be conducted in parallel with their development and demonstration in systems.

A number of legal, institutional, and economic factors will be impacted by the widespread utilization of solar heating and cooling. Most of these factors are viewed as potential constraints on the introduction of the technology, and thus research on them is being planned as part of the program of the Division of Solar Energy. Appropriate for support by DBER is research on those indirect impacts that are the "externalities" of solar heating and cooling. These impacts include the effects on the economy of meeting requirements for materials, labor, and capital, and the effects of pollutants generated in the manufacture of solar devices. These are included in the section of this BPP on Solar Generic Impacts.

One indirect impact that is specific to heating and cooling rather than to generic solar technologies, is alteration of urban planning that would accompany the widespread use of solar heating and cooling in new communities (or redevelopment of old ones). An urban or suburban area planned for solar energy may be of low density, may have buildings sited in exposed positions, and may have limited numbers of trees in built-up areas. The social and economic consequences of such possible alterations in urban planning should be investigated.

II. D. PHOTOVOLTAIC CONVERSION

Among solar power conversion schemes photovoltaic conversion is unique in producing electricity directly from solar radiation without intermediate conversion steps and without moving parts.

Only thin layers (10-150 um for silicon) are needed to absorb a high percentage of the incident radiation. Hence, the volume of material needed is not excessive. Photovoltaic arrays may or may not track the sun and may or may not use optical systems to concentrate incident sunlight. A typical value of the incident solar power on a non-tracking surface is about 750 Watts/m^2 for about 5 hours a day. A photovoltaic array also delivers useful power from diffuse sunlight in cloud cover periods.

A conversion efficiency of 10% is presently considered as practical. Hence, as in all other solar conversion schemes, large surface areas are needed to produce practical amounts of electric power. This, in turn, also requires large production facilities for the photovoltaic components. An aggressive effort to utilize large-scale photovoltaic conversion will require the establishment of new industries, comparable in size with the existing steel industry. These factors are decisive for environmental, health and other effects.

Silicon, because of its abundance, its high theoretical conversion efficiency (26%) and its well advanced technology, is the material emphasized by the ERDA program for solar photovoltaic converters. It is assumed that with advances in fabrication technology, silicon will be the least expensive of photovoltaic materials. The ERDA program calls for extensive efforts in the cost reduction of silicon and the processes associated with its production, purification, crystallization and cell manufacturing. Plans call for the construction of a fabrication plant to be completed in 1985 that will produce each year photovoltaic cells with a capacity of 500 MW_e. A goal of 200 thousand MW_e of electric power by photovoltaic

conversion is set for the year 1995.

Processes for the purification of metallurgical grade silicon to the required "solar" grade and into the completed arrays require the use of toxic materials such as silane, silicon tetrachloride, boron halogens and phosphorus compounds. In the ERDA advanced research program, cadmium sulfide and other materials are also under consideration and they may replace silicon as the favored material if cost reductions for silicon are not achieved. Toxicity investigations should be conducted for silicon processes and for other material processes as they reach serious development.

No decision has been made as to which material will be used to cover cell arrays. Glass appears environmentally acceptable but has undesirable optical properties. Alternatives include plastics capable of resisting extremely long periods of solar radiation. There is need for an environmental and health research program dealing with the effects of materials released by the outer surface of large area installations, particularly if organic materials will be used. All materials in a photovoltaic cell, in addition to the cover material, may be released to the environment in fire or in disposal of cells. The hazard to health of released materials, especially cadmium, should be assessed in advance of a commitment to large scale production.

It has been proposed that large orbiting satellites might convert solar energy in space by photovoltaic arrays and then transmit the power to the earth's surface. The economics of this approach make it a very long term technology. In the event of serious development of this technique, microwave power transmitted towards the earth's surface will require careful study. A further area of concern is the large number of rockets required and their effect by fuel combustion in the stratosphere on ozone equilibrium. No research by DBER is recommended at this time because of the very long-range nature of this concept.

II. E. WIND ENERGY CONVERSION

In contrast to many of the other energy technologies now under development, wind power has a long history of successful application. Windmills appear to have been used in Persia before the time of Christ, and have been extensively used in Western Europe since the Middle Ages. In the United States prior to 1930, over six million small windmills were used to pump water and to satisfy other farm and household needs. In Denmark, where the first wind-electrical generator was operated in 1895, wind power supplied a portion of the country's electrical needs during both world wars. Interest in wind power slackened in the United States and Europe during the 1950's because of the ready availability of cheap fossil fuels. Changes in the economics of energy production have revitalized that interest.

In assessing the potential of wind power, it is useful to have an expression for the power contained in the wind. A given parcel of air of density ρ, moving with velocity v, contains kinetic energy $(1/2)\rho v^2$ per unit volume; the power associated with a stream of air passing through an area A is given by $(1/2)\rho A v^3$. Because of this dependence of wind power upon the cube of wind velocity, wind conversion systems favor sites where moderate to high winds are frequent. A large area of high wind-energy potential stretches across the great plains north from the Texas panhandle to the Canadian border and beyond. The total wind energy extractable from this area per year is large in comparison to U.S. power consumption in 1973.

To extract the energy from the wind, either horizontal propeller-type, or vertical axis wind turbines may be used. Both types offer about the same overall efficiency, but much more experience has been accumulated with the horizontal turbines and the primary emphasis in the ERDA program is on this type. The vertical turbine, which is omnidirectional and may offer savings in the cost of blade and tower construction, is also under development.

Because wind energy is diffuse, it will require large arrays of turbines to extract substantial amounts of power from the atmosphere. The number of turbines required to produce a given power output is strongly dependent upon the size of the turbines and the characteristics of the wind at a given site. At a favorable but not extraordinary site, approximately 2000 turbines each with a blade diameter of 60 meters would be required for a rated power of 1000 MW_e. Wind variability would probably limit the average power output to about 30% of the rated value. If the wind turbines were distributed in a square array, the square would have to be at least 6 km (perhaps as much as 30 km) on a side; the minimum area is dependent upon the required turbine spacing which is not yet well defined. There is no necessity, however, that the array be localized. The turbines could, for instance, be distributed along power transmission lines.

Because the wind fluctuates, so does the power output from a turbine array. Therefore, the power has to be conditioned in some way before it is used. The available power also varies with season and time of day. This may impose energy storage requirements for some use strategies.

The most serious potential environmental impact of large scale utilization regards weather modification. It is certain that large arrays of wind turbines will have some effect upon local, and perhaps regional, climate. The effect might be analogous to that which would be caused by an increase in surface roughness of the terrain. Conditions may exist for which the effects upon temperature, precipitation, or wind patterns would be significant. It has even been speculated that the addition of angular momentum to the atmosphere may have some relationship to tornado frequency.

The large-scale arrays of wind turbines will have an impact on the local ecosystem. The rotating blades may adversely affect the bird population, with a corresponding increase in the

insect or rodent population. The "scarecrow" effect may deter some types of wildlife from entering the area. The turbine noise, infrasonic pressure waves, and altered wind patterns could impact wildlife and domestic grazing animals. Since the arrays will leave most of the land available for other purposes, research is required to determine the compatible types of ecosystems. Conversely, the impacts may place constraints upon siting.

Concern has been expressed that the wind turbines could, in certain locations, interfere with electromagnetic waves such as television signals. The rotating, reflecting surfaces may provide multi-path interference similar to that caused by airplanes.* Since interference caused by the turbines would be essentially permanent, the seriousness of this potential impact should be evaluated prior to actual siting.

Visual and aural aethetic effects are likely to impose some restrictions upon wind conversion system siting. The nature of these constraints can be explored immediately, but opportunity should be taken of the operation of the first multiunit demonstration system to perform a case study.

The remaining potentially significant effects are common to other energy technologies as well. Wind conversion systems will utilize large quantities of materials for construction. Comparisons of energy strategies require knowledge of the environmental burdens associated with the production of those materials. Also, as with all large construction projects in less developed areas, wind energy systems will impose some socioeconomic dislocations, and some secondary environmental burdens. These concerns are treated under Solar Generic.

The present ERDA Wind Energy Conversion implementation schedule calls for a $10MW_e$ facility to come on line in 1981. Large scale production of wind turbines is slated to begin in 1983. Under optimum conditions, a rated wind energy conversion capacity of

* This effect may be avoided if non-conductive surfaces are used for blades.

15,000 MW_e is predicted for 1985.

In addition to the large-scale electric-generating application, there are small-scale applications to a variety of remote (non-grid) power needs. Heating and cooling of buildings, fertilizer production and crop drying are among the uses that will be investigated by ERDA. Plans call for a major demonstration or incentives program to be initiated in 1978. The direct environmental effects of any given small-scale application were considered to be of such small impact that no specific research program is recommended. The potential indirect effects (materials, land, etc.) of widespread small-scale applications are covered under Solar Generic.

II. F. OCEAN THERMAL CONVERSION

Vertical thermal gradients of the seas present an almost unlimited energy source. Radiation from the sun is collected by the surface of the water as sensible heat which may be utilized to drive power generating equipment. Heat engines for conversion of this thermal energy appear feasible, such as Rankine-cycle engines using ammonia, propane or a flourocarbon as the working fluid. A power plant based on the Rankine-cycle requires a boiler and a condensor, heated and cooled respectively, by the warm surface water and cold water from the ocean depths.

The conversion efficiency of ocean thermal plants is expected to be low: only about 3%. As a consequence, the volume throughput of heating and cooling water must be quite large. Approximately 9×10^6 gallons/minute of cooling water is required for operation of a 100 MW_e unit; with a volume of surface water drawn into the plant of about the same magnitude. However, such flow rates are not significantly greater than those in large hydroelectric power plants.

The minimum temperature differential for operation is approximately 20°C (40°F), thus restricting suitable sites to tropical or semitropical waters (including, however, the Gulf Stream).

ERDA's plans call for a 100 MW_e sized prototype hull with a 25 MW_e power module to be completed by 1983. A demonstration plant consisting of the same hull but refitted with four advanced power modules is scheduled for completion in 1985.

The type and severity of the environmental impacts of ocean thermal conversion are particularly difficult to estimate since the technology is not yet well defined and there are essentially no precedents for comparison. However, a number of potential impacts have been identified that merit attention during the early technological development.

The large volume of cold water required for the condenser will be pumped from depths of 600 meters or so. This water is rich in nutrients but sparse in living organisms. These organisms will, however, be entrained in the cold water pipe and killed by the pressure drop as the water is pumped to the surface. The severity of this impact is expected to be site dependent.

The transport of the nutrient-rich cold water to or near the surface is expected to support a highly productive ecosystem much as do natural upwellings of nutrients. This "pasture" could be an important food source if ocean thermal conversion is widespread. However, depending upon factors such as the distribution of nutrients in the cooling water, there might be produced mainly undesirable species.

The relatively warm heat exchange surfaces (for transfer of heat to the working fluid) and, to a lessor extent, the relatively cold condenser, may be subject to biofouling. If so, normal operation of the conversion plants will likely involve the release of biocides. Accidents, such as ship collisions, could release the working fluid. Finally, surface films may be used to increase the surface temperature of the water. These various chemicals, depending on their toxicity and extent, may adversely impact the pasture and other, more natural, ecosystems.

The ocean thermal plant will alter the local surface temperature and the temperature gradient to depth. Local turbulence and currents may be increased. These effects, together with the pasture or artificial surface film, will affect the local albedo and the overall energy balance in the vicinity of the plant. These changes may have global climatic implications (treated under Solar Generic) if ocean thermal plants become widespread.

Preliminary assessment and baseline measurements of the above local environmental effects should be made prior to construction of the pilot facility. Research at the pilot and demonstration plants would then quantify the severity of the impacts.

II. G. BIOCONVERSION

Bioconversion energy systems utilize the solar energy stored in chemical form in plant materials, animal wastes, and urban refuse. Bioconversion systems may be considered in two categories: bioproduction; and bioconversion to fuels such as methane gas, methanol, or oil. Although not enough urban waste products currently exist to produce a major fraction of U.S. energy needs, more than enough exists to make waste disposal an energy independent process. Enough additional raw fuel could be obtained by collecting agriculture and wood industry plant wastes and feedlot animal wastes to produce 5-10% of the Nation's current natural gas requirements.

(1) Bioproduction:

Energy production by bioconversion could be substantially increased by crops grown specifically to provide raw fuel for a bioconversion plant. At a 1% photosynthetic efficiency, 5% of the U.S. total land area would be needed to produce 55% of the current electrical and natural gas requirements. Favored plant species are presented in the table on page 27. These species require little care or fertilizer. In some cases, algae and water hyacinth can be grown in the effluents of a waste conversion plant to further increase operating efficiency and reduce disposal problems.

A long-range alternative to energy farms is the direct use of solar energy to produce hydrogen from water by biophotolysis. Research is underway but no practical devices now exist.

Environmental problems associated with these "energy farms" may be serious. Competition with food production and paper pulp industries for land, water and fertilizer use might occur since the areas which produce crops with the greatest photosynthetic efficiencies might be used to produce food. With today's critical world food situation, this could lead to severe conflicts. In addition, there are the usual problems associated with agriculture such as pest control, pesticide contamination of the food chain and ecosystem disruption and simplification. The extensive areas involved

may result in increased erosion, local wind and temperature changes. Cultivating extensive marine areas could drastically alter ocean ecology and adversely affect fishing industries.

(2) Bioconversion:

Bioconversion techniques can be classified into three major categories: combustion, fermentation and pyrolysis. Limited combustion of urban wastes and plant materials in conventional fossil fuel plants is already underway. The energy content of waste fuels is about half that of coal but the process is favored because of waste disposal benefits and lower level of sulphur pollutants from plant combustion.

Anaerobic fermentation of sewage wastes is a well developed process. Extension of this process to fermentation of organic biomass for commercial production of methane is technologically feasible. Enzymatic fermentation of plant sugars to methanol or ethanol can be achieved. Alcohol can also be produced by using acid hydroysis or enzymatic action coupled with fermentation to degrade cellulosic wastes.

Another possibility is the conversion of urban refuse and organic plant materials to liquid fuels or gases by pyrolysis. In this process, organic material is pyrolized in a high temperature reactor operating at 600 to 900°C to yield oil in amounts of approximately two barrels/ton of dry materials. This process has been adapted from laboratory to pilot plant scale but has not been commercially demonstrated. Reduction of organic biomass to oils can be achieved by heating the material to 300 to 400°C in the presence of H_2O, CO and an appropriate catalyst. This process, called catalytic gasification, bears a similarity to one of the approaches proposed for coal liquifaction but thus far has only been tested on a lab scale.

Although classified under solar energy, bioconversion more nearly resembles fossil fuel conversion in terms of severity and nature of environmental impacts. Combustion, pyrolysis and

gasification all generate atmospheric pollutants. Pretreatment of organic biomass may produce significant amounts of aromatic hydrocarbons, phenols and trace metals. Liquid and solid waste disposal may pollute surrounding areas and cause additional water pollution from rain leaching and create a health hazard. Storage of large amounts of unprocessed or preprocessed wastes may also cause health problems.

Type	Harvest* ($\frac{tons}{acre \cdot yr}$)	Cropping interral	Date (pilot/ demo.)	Photo-synthetic efficiency
Eucalyptus (Cal.)	13-24	1 year (slash) 5-10 years (mature harvest)	79/86	1 %
Sudan Grass (Cal.)	15-16	1 year	79/86	
Giant Sea Kelp		1 mo.	82/90	0.5%
Water Hyacinth - freshwater algae	8-39	1 day	80/--	$\lesssim 3$ %

*J.A. Alich, R.E. Inman, 'Effective Utilization of Solar Energy to Produce Clean Fuel,' Stanford Research Institute, June, 1974.

II. H. TIDAL ENERGY CONVERSION

Energy can be extracted from the tides in a manner similar to that for hydroelectric power. Dams would be constructed across the entrances to bays and estuaries and, typically, reversible turbines used to generate electricity during both the filling and emptying of the basins. Relatively few locations in the world have sufficiently high tides to have merited consideration in the past, and the energy potential of these locations is estimated to be only ∿1% of that of hydroelectric power.[1] Of these locations, the only one of direct interest to the U.S. is Passamaquoddy Bay, which is on the Maine - Canada border and is a part of the much larger Bay of Fundy. Plans for a tidal power project were drafted during the 1930's and construction begun, but the project died for lack of congressional interest. A revival around 1960 met a similar fate. This latter project would have had an installed capacity of 300 MW_e and is thus of no particular significance from a national perspective.

The ERDA Solar Energy Division, as a part of the Ocean Thermal Energy Conversion program, plans to support a review of the potential of tides, as well as other oceanic energy sources such as waves, currents, and salinity gradients. Since the potential for tides can be estimated from reasonably well understood parameters (namely the tidal height and surface area of the basin) it is difficult to believe that this review will differ substantially from previous studies that have essentially excluded the use of tidal power except for very special locations. Nevertheless, the environmental impact of tidal power development is of such potential severity that some discussion of these impacts is in order.

Bays and estuaries support a wide variety and relatively high density of aquatic life and land-based predators. Many ocean dwelling species spend part of their life cycle either in or passing thru the estuaries. Disruption of the ocean-bay-estuary ecology by

construction and operation of a dam could result from: changes in the tidal levels, timing and velocities within the estuary; changes in the salinity variations; entrapment of silt from fresh water drainage; contamination by lubricants or chemicals used to control biofouling; blocking of passage between ocean and estuary or bay; killing of biota entrained in turbines. Such dams would also impact the shipping and fishing industry, and the use of the bays and estuaries for recreation.

For completeness, a Program unit on tidal energy conversion is included in section III. However, DBER support of a research program for tides is not recommended unless serious efforts to develop tidal power are initiated elsewhere in ERDA or other government agencies.

---

[1] M. King Hubbert, "Energy Resources", from Resources and Man, W.H. Freeman and Co., 1969.

II. I HYDROELECTRIC

Hydroelectric power has been extensively developed in the U.S. for some time. Additional development is possible but will not make a substantial contribution to the nation's future energy supply, since only a limited number of suitable sites remain. The environmental impacts of hydroelectric power are generally associated with the impoundment and subsequent controlled release of water that would have otherwise flowed to the ocean in some natural manner. The impoundment is devastating to the pre-existing ecosystem, but the lake often supports a new system that may be considered more desirable. Forced large fluctuations in the lake water level have effects on these new aquatic organisms that are not completely understood. The lake may alter the local climate, and inundation of land raises questions of alternative land use.

The dam provides a hinderance to migratory and spawning species such as salmon. Dissolved nitrogen gas supersaturation, fluctuating flow rates, water temperature changes, and pollutants released by activities associated with the hydroelectric plant affect the downstream riverine, estuarine, and marine ecosystems. These effects are not generally well understood.

The environmental impacts related to impoundment and controlled release of water apply not only to hydroelectric installations, but to daming for flood control, irrigation, recreation, and combinations thereof. Two possible future developments would also have similar impacts. The first of these is pumped hydroelectric. This energy storage method is currently used to some extent as a load leveler for conventional electrical power sources and is a candidate for storage for naturally intermittent solar energy sources. The second possible development is impoundment for use in shale oil or coal conversion processes, or as cooling water for various thermal-to-electrical conversion systems.

Many Federal and State government agencies are involved with one or more of the multiple uses for impounded water. All of these agencies are likely to be concerned with, and some have

supported research on, the various environmental concerns. The role of ERDA in these matters is not yet clearly defined.

Given this complex situation, and the usual time and manpower limitations, the major effort of the Solar portion of the BPP was concentrated on the new technologies currently being developed by the Solar Energy Division of ERDA. A further rational for this concentration was that no source of comprehensive and detailed information on hydroelectric power could be identified within ERDA. The program unit for hydroelectric power is thus intended to develop within ERDA the expertise necessary to identify the areas of research suitable for DBER support.

III. PROGRAM UNITS

Program Unit

Technology: Solar - Solar Generic

King-Muir Category: Integrated Assessment

Program Unit Title: National Economic Impacts

Scope: The manufacture, installation, and maintenance of solar energy devices will make demands on the national economy for materials (including energy), manpower, and capital. The provision of these will have certain ramifications for other sectors of the American economy. Of particular importance is the high initial investment necessary for solar energy relative to other energy technologies. This necessitates a consideration of the net energy balance of solar technologies, and of possible shortages in materials or manpower that may result from rapid implementation of solar energy. This program will involve collecting data on the materials, energy, manpower, and capital requrements of various solar technologies, and assessing the impact on the national economy of meeting those requirements. This information will be used in studying mixes of solar and non-solar energy technologies that make best use of limited resources.

Milestones: Develop methodology for and conduct initial studies prior to demonstration phase. Detailed studies will be performed during demonstration phase.

Technology Timetable:		
	Heating and Cooling Demonstration	1979
	Solar Thermal Demonstration	1982
	Photovoltaic Demonstration	1985
	Bioconversion Demonstration	1980
	Wind Energy Demonstration	1979
	Ocean Thermal Demonstration	1985

Priority: A

Severity: B - The economic requirements of the energy sector is a fraction of the national economy, but solar will have relatively greater requirements than present technologies.

Extent: A - Many types of materials and categories of labor will be impacted.

Need: A - The requirements of solar technologies are not yet known in sufficient detail to make such assessments.

Urgency: B - These impacts will only be felt as the technologies reach widespread implementation. However, policy decisions requiring this information may precede such implementation.

Estimated Cost:

$350,000 per year for solar component. This will be one part of the overall program involving comparative studies of solar and non-solar technologies.

Program Unit

Technology: Solar - Solar Generic

King-Muir Category: Integrated Assessment

Program Unit Title: Residuals from Production of Solar Devices

Scope: The manufacture of solar energy devices will require the extraction and processing of materials, the operation of various industries, and various construction activities. All of these activities will involve the production of residuals: air and water pollutants, solid wastes, noise, etc. The production of these residuals should be included in the environmental impact of the technology, even though the impact will generally occur elsewhere than at the site of the solar energy collection. This program will include collecting data and making estimates of residuals production for solar technologies and providing that information for comparative studies with other technologies.

Milestones: This program should be conducted in parallel with the construction of demonstration plants of the various solar technologies, and the data updated as the technologies evolve.

Technology Timetable:		
	Heating and Cooling Demonstration	1979
	Solar Thermal Demonstration	1982
	Photovoltaic Demonstration	1985
	Bioconversion Demonstration	1980
	Wind Energy Demonstration	1979
	Ocean Thermal Demonstration	1985

Priority: B

Severity: C - Residuals production is expected to be significantly less than by existing energy technologies. In most cases the additional residuals production is not expected to be large.

Extent: A - Production of solar devices will probably involve some activity in nearly all economic sectors.

Need: B - This data is needed for comparative studies of future energy scenarios and is not now available.

Urgency: B - This information is needed for some policy studies, but the impacts will not be significant in the near future.

Estimated Cost:

$100,000 per year for about ten years.

Program Unit

Technology: Solar - Solar Generic

King-Muir Category: Integrated Assessment

Program Unit Title: Regional Land, Water, Demographic, and Aesthetic Impacts

Scope: Successful widespread commercial application of solar conversion processes will impact those regions of the country suitable for, or near to, conversion sites (e.g., southwest for solar thermal conversion, coast for ocean thermal, midwest for wind, etc.). Water and land use, demographic shifts (of industry and population) and the aesthetic acceptance or rejection of the solar conversion facilities are interrelated factors that will be the focus of this research. Constraints imposed by competing requirements for limited resources (e.g. water) will be investigated. Results will provide a basis for including solar energy facilities in regional planning.

Milestones: Develop methodology for and conduct initial studies prior to demonstration phase. Detailed studies will be performed during demonstration phase.

Technology Timetable:		
	Heating and Cooling Demonstration	1979
	Solar Thermal Demonstation	1982
	Photovoltaic Demonstration	1985
	Bioconversion Demonstration	1980
	Wind Energy Demonstration	1979
	Ocean Thermal Demonstration	1985

Priority: A

Severity: B - Potentially severe for some technologies (e.g., water use for solar thermal), less so for others.

Extent: A - Many regions will be affected by one or more of the solar technologies.

Need: A - Qualitative analyses are now possible, but quantitative studies will require additional data and methodologies.

Urgency: B - These impacts will be felt only as the technologies reach widespread implementation. However, policy decisions requiring this information may precede implementation.

Estimated Cost:

$250,000 per year through demonstration phase.

Program Unit

Technology: Solar - Solar Generic

King-Muir Category: Transport

Program Unit Title: Global and Regional Climate Alterations

Scope: To the extent that man's activities influence regional and global climate changes, widespread use of solar energy conversion may impact the climate or may avoid such impact by other energy technologies. Such impacts may occur with greatest severity in a few regions. This research will incorporate information developed in program units for each of the solar technologies into climatic models. Comparisons will be made with the effects of non-solar technologies. The impact of deliberate weather modification on behalf of solar energy conversion will also be investigated. Such modifications might include seeding of clouds to increase hydroelectric production or to prevent clouds over solar thermal installations.

Milestones: Develop methodology prior to demonstration of the various solar technologies. Detailed studies will be made as data become available from the program units on specific technologies.

Technology Timetable:		
	Heating and Cooling Demonstration	1979
	Solar Thermal Demonstration	1984
	Photovoltaic Demonstration	1984
	Bioconversion Demonstration	1980
	Wind Energy Demonstration	1980
	Ocean Thermal Demonstration	1984

Priority: B

Severity B - Expected to be less severe than conventional energy sources. But solar presents some unique and unknown effects.

Extent: A - How wide is the ocean, how deep the sea?

Need: B - Climatic models are under active development. But solar effects are not yet included.

Urgency: B - Impacts will not be significant in near future, but the information is needed for policy studies.

Estimated Cost:

$150,000 per year through demonstration phase for solar component. This will be incorporated into existing climate models.

Program Unit

Technology: Solar - Solar Generic

King-Muir Category: Integrated Assessment

Program Unit Title: Decentralized Energy Sources and Social Movements

Scope: There exists a still small, but growing, movement in the United States toward the development of alternative life styles that depart from the mainstream of American economic life. A critical component of these attempts to develop new styles of life is the development of decentralized energy sources. The sources of energy individuals in these movements are attempting to utilize include many of those considered in this BPP: solar heating and cooling of buildings, wind energy conversion, bioconversion, and hydroelectric. Technical advances made in the ERDA programs in these areas may be used to advantage by these groups. Thus a possible social impact of the ERDA program is a furtherance of this social movement. The impact of this movement on the economy, on the demand for energy in the Nation, and on the environment should be assessed and the role of decentralized energy systems in furthering that social movement ascertained.

Milestones: Preliminary study during next few years. If this movement continues to grow further research would be justified.

Technology Timetable: No definite timetable, but as technological advances are made in the various ERDA programs they may be adopted.

Priority: B

Severity: A - The social and economic structure of such movements differs drastically from the American norm.

Extent: C - This movement is still quite small.

Need: B - There has been extensive study of these movements, but the role of energy sources should be assessed.

Urgency: B - Growth of these movements is rapid, but will not represent a major social group in the near future.

Estimated Cost:

$100,000 per year for the next few years.

Program Unit

Technology: Solar - Large-Scale Solar Thermal Conversion

King-Muir Category: Environmental Transport Processes

Program Unit Title: Local Heat and Water Balance at Solar Thermal Facilities

Scope: Large-scale solar thermal power plants will partially cover large land areas with mirrors or collectors. The local heat and water balance will be affected thru shading, reduction of albedo, production of local heat sources, reduction of surface winds, and possibly additional water introduced by mirror washing. An understanding of these local meteorological effects is necessary to properly assess the closely related ecological effects (see Program Unit for Large-Scale Solar Thermal Conversion entitled "Local Ecological Effects"), as well as the regional and global climate impacts of widespread deployment of solar thermal devices (see Program Unit for Solar Generic entitled "Global and Regional Climate Alterations"). This research will use micrometeorological modeling to understand the effects as a function of the local terrain and the parameters of the heliostats, central tower, cooling towers and thermal storage. Meteorological measurements will be made before and after construction of Central Receiver and Distributed Collector pilot plants to provide input to and verification of the model.

Milestones: Initial Modeling and baseline measurements - at least 1 year before pilot plant construction. Monitoring of meteorological parameters, model extended to larger systems and alternative technological approaches - During the operation of pilot plant.

Technology Timetable:		
	Solar Test Facilities	1976-78
	10 MW Central Receiver Pilot Plant	1980
	Distributed Pilot Plant	1981
	Hybrid Pilot Plant	1982
	Demonstration Plants	1984-86

Priority:

Severity: B - Largely unknown but potentially significant.

Extent: B - Widespread use of technology will effect larger land areas than other technologies.

Need: A - Effects largely unknown. Knowledge needed to assess desirability of this type of solar conversion.

Urgency: A - Construction of pilot plant provides an excellent opportunity to understand the effects before continued development and commercialization.

Estimated Cost:

$150,000 per year through demonstration phase.

Program Unit

Technology: Solar - Large-Scale Solar Thermal Conversion

King-Muir Category: Ecological Effects

Program Unit Title: Local Ecological Effects of Solar Thermal Facilities

Scope: Commercial solar thermal power plants will partially cover large land areas with mirrors or collectors. Much of the land surface may be disturbed during construction. Evaporation rates, surface temperatures and surface winds will be reduced, and additional water may be introduced through mirror washing. Many of the proposed solar devices would permit coexisting vegetation and, presumably, some form of animal life. The devices may (via shading and moisture retention) provide a more benign environment than under natural conditions. It has been suggested that the area might become suitable for agriculture. Concentrated solar flux zones may be hazardous to birds or insects. This research will initially characterize the ecosystems in representative areas of the southwestern U.S. where most solar plants are expected to be located. The construction and operation of the pilot and demonstration facilities will provide opportunities to investigate alterations in the ecosystem. These studies, in conjunction with studies of the local climatic effects (see Program Unit for Large-Scale Solar Thermal Conversion entitled "Local Heat and Water Balance"), will be used to evaluate the ecological effects for other potential sites, alternative types of vegetation, and various designs for solar devices.

Milestones: Begin initial field measurements and characterizations as potential sites are designated. Complete preliminary assessments of ecological effects when pilot plants become operational. Complete refined evaluations and comparative assessments for projected commercial plants - thru demonstration phase.

Technology Timetable:

Solar Test Facilities	1976-78
10 MW Central Receiver Pilot Plant	1980
Distributed Pilot Plant	1981
Hybrid Pilot Plant	1982
Demonstration Plants	1984-86

Priority: A

Severity: B - Significant modifications of the local ecology are expected that may be considered beneficial or detrimental.

Extent: B - Impact could be significant since relatively large areas are projected; however, sites are expected to be remote from human populations.

Need: A - No definitive investigations have yet been done. Generalized assessments and comparative evaluations of impacts will be needed in determination of preferred siting areas.

Urgency: A - Research should be initiated soon so that effects can be assessed at forthcoming test facilities and pilot plants.

Estimated Cost:

$150,000 per year through demonstration phase.

Program Unit

Technology: Solar - Large-Scale Solar Thermal Conversion

King-Muir Categories: Health Effects

Program Unit Title: Occupational Hazards of Heat Transfer and Storage Media

Scope: Various organic fluids (e.g., silicon oils), inorganic salts (e.g., alkali and alkaline-earth nitrates, sulfates and phosphates) and other compounds are being considered for high temperature (300-600°C) use as heat transfer fluids or for change-of-phase, sensible heat or chemical energy storage. Large amounts of material will be required for thermal storage. Benign materials will be used where practical, but some materials may present an occupational hazard if mishandled or if involved in accident situations. This research will investigate the potential health effects in the event any of the materials were to be accidently released. The work will concentrate on materials that are new, not well characterized, or known to be hazardous.

Milestones: Ongoing assessment in parallel with development and testing of the materials and subsystems in which they are utilized.

Technology Timetable:

Solar Test Facilities	1976-78
10 MW Central Receiver Pilot Plant	1980
Distributed Pilot Plant	1981
Hybrid Pilot Plant	1982
Demonstration Plants	1984-86

Priority: B

Severity: B - Accidental release should be rare, but toxicity of some materials may be high.

Extent: C - Effects should be confined to immediate vicinity of plants, most of which are expected to be remote.

Need: B - A preliminary understanding of potential effects will be needed before new or unusual materials can be objectively evaluated.

Urgency: B - This effort should keep pace with development of the materials and their commitment to ERDA pilot and demonstration projects.

Estimated Cost:

$250,000 per year through demonstration phase.

Program Unit

Technology: Solar - Small-Scale Solar Thermal Conversion

King-Muir Category: Integrated Assessment

Program Unit Title: Environmental Assessment of Agricultural, Process Heat and Total Energy Systems

Scope: These systems are scaled to the requirements of, and located at or near to, the energy use site. They will be integrated with communities, institutions, and farms that include buildings,roads, parking lots, and the like. Separation of the environmental effects of the energy system alone may prove quite difficult. The proposed research would provide a continual monitoring of the developments in this field from an environmental viewpoint. The proposed research would assess the impact on local ecosystems, the potential release of toxic materials and fluids, and the effect on the local climate.

Milestones: Continuous assessment of developments. Thru pilot and demonstration phase.

Technology Timetable: Construction of pilot and demonstration facilities Late 1970's thru middle to late 1980's.

Agricultural Pilot and Demonstrations	1976-1983
Process Heat Pilot and Demonstrations	1976-1987
Total Energy Systems Pilot and Demonstrations	1981-1986

Priority: B

Severity: B - Effects are similar to those of the buildings, roads, parking lots, etc. with which the systems will be integrated.

Extent: B - Widespread use is possible but the effects will be local to the energy use site.

Need: C - Effects are similar to those of existing structures. Attempts to isolate effects from energy system alone may prove difficult.

Urgency: B - Near term construction of pilot and demonstration facilities provides an opportunity to monitor developments spread deployment.

Estimated Cost:

$100,000 per year thru demonstration phase.

Program Unit

Technology: Solar - Solar Heating and Cooling of Buildings

King-Muir Category: Environmental Transport

Program Unit Title: Alteration of Urban Heat Islands

Scope: Widespread use of solar heating and cooling will alter the heat balance of urban areas in a number of ways. The arrays of collectors will modify the albedo of the area. The use of solar energy will partially supplant the combustion of fossil fuels and the importation of electricity into the region, thus decreasing those sources of heat. Solar cooling units have a low efficiency, so they must dispose of larger amounts of waste heat than electrical units with the same cooling capacity. These effects will combine to make some (probably small) change in the local meteorology of urban areas with some possible effects extending downwind from the city. This program will use meteorological modeling techniques to estimate the possible effects.

Milestones: Complete two years after initiation of the ERDA demonstration program an assessment of the effects of full utilization of solar heating and cooling in urban areas.

Technology Timetable:

Demonstrate residential/commercial heating	1975-1981
Demonstrate residential/commercial heating and cooling	1979-1981
Advanced system development	1975-1979
Improved subsystem development	1975-1986

Priority: C

Severity: C - Will be only a minor alteration of the total environmental impact of urbanization.

Extent: A - If the technology succeeds, it will be widely used in all major US cities.

Need: B - Measurements and modeling have been conducted on the urban heat island effect. An extension of that effort to include effects of solar utilization is needed.

Urgency: C - Installation of solar heating and cooling systems will be primarily on new buildings, so market penetration will be gradual.

Estimated Cost:

$100,000 for one year.

Program Unit

Technology: Solar - Solar Heating and Cooling of Buildings

King-Muir Category: Health Effects

Program Unit Title: Toxicity of Heat Storage and Transfer Media

Scope: The research and development program for solar heating and cooling of buildings includes the development of liquids for heat transfer (e.g., ethylene glycol), salts (e.g., sodium and calcium salt hydrates) and organic waxes (e.g., paraffin) for heat transfer by change of phase, corrosion inhibitors, and refrigerants (e.g., ammonia and fluorocarbons) for solar cooling. These substances may be widely used in homes and commercial buildings. They will be released by leaks, accidents, and by maintenance that requires periodic flushing of the system. These substances may thus present a health hazard to the general population. This program will assess the toxicity to humans, and the possible concentration in the food chain of such substances developed in the ERDA program of component and system development.

Milestones: Ongoing assessment as heat storage and transfer media are developed and used in demonstrations.

Technology Timetable:

Demonstrate residential/commercial heating	1975-1981
Demonstrate residential/commercial heating and cooling	1979-1981
Advanced system development	1975-1979
Improved subsystem development	1975-1986

Priority: B

Severity: B - Release of these substances will be limited, but their toxicity may be high.

Extent: B - Success in the advanced technology development may lead to widespread use.

Need: A - A large number of substances are being considered, few of which have been used widely, so little toxicity data exist. New information will be needed to establish usage procedures.

Urgency: B - This effort should proceed in parallel with the demonstration of new media in ERDA demonstration projects.

Estimated Cost:

$250,000 per year for about ten years.

Program Unit

Technology: Solar - Solar Heating and Cooling of Buildings

King-Muir Category: Ecological Effects

Program Unit Title: Ecological Effects of Heat Storage and Transfer Media

Scope: The research and development program for solar heating and cooling of buildings includes the development of liquids for heat transfer (e.g., ethylene glycol), salts (e.g., sodium and calcium salt hydrates) and organic waxes (e.g., paraffin) for heat transfer by change of phase, corrosion inhibitors, and refrigerants (e.g., ammonia and fluorocarbons) for solar cooling. These substances may be widely used in homes and commercial buildings. They will be released by leaks, accidents, and by maintenance that requires periodic flushing of the system.

A large community using solar heating and cooling will be a nearly continuous source of the substances in the sewage system. The ecological effects of sewage disposal will thus be changed in severity and kind. This research will investigate the ecological consequences of the release of the various media to the extent that they differ in kind or amount from existing practices.

Milestones: Ongoing assessment as heat storage and transfer media are developed and used in demonstrations.

Technology Timetable:

Demonstrate residential/commercial heating	1975-1981
Demonstrate residential/commercial heating and cooling	1979-1981
Advanced system development	1975-1979
Improved subsystem development	1975-1986

Priority: C

Severity: C - Release of these substances will be limited, and their incremental effects on existing practices may be minor.

Extent: B - Success in the advanced technology development may lead to widespread use.

Need: A - A large number of substances are being considered, few of which have been widely used. Thus little information on their ecological effects is available.

Urgency: C - This effort should preceed widespread deployment of heating and cooling devices using new or not well understood substances.

Estimated Cost:

$100,000 per year for about ten years.

Program Unit

Technology: Solar - Solar Heating and Cooling of Buildings

King-Muir Category: Health

Program Unit Title: Toxicity of Construction Materials

Scope: Solar heating and cooling systems for buildings will generally employ standard construction materials (copper, glass, aluminum, etc.), but a few new or unusual materials may be used in advanced components. These include plastics for cover sheets on solar collectors, and various materials that would be deposited as thin layers on collecting surfaces to reduce the radiant loss of energy (selective surfaces). These materials may be gradually released to the environment by erosion or corrosion, or combustion products may be released by fire. The toxicity of any unusual materials proposed for widespread utilization should be assessed in advance of marketing. This program will assess the occupational hazards during production, the rates of release in normal use, the products released in fires, and the health effects of the released substances.

Milestones: Ongoing effort in parallel with the development and demonstration of new construction materials for solar systems for buildings.

Technology Timetable:

Demonstrate residential/commercial heating	1975-1981
Demonstrate residential/commercial heating and cooling	1979-1981
Advanced system development	1975-1979
Improved subsystem development	1975-1986

Priority: C

Severity: C - Rates of release in normal use will be low because components will be designed for long service life. Release in fires will be substantially same as from present buildings and furnishings.

Extent: B - Use of solar heating and cooling will be extensive, but amount of materials in any one building will be small.

Need: B - To the degree these materials are unique, they will require new research

Urgency: C - Use of advanced materials will be gradual as they are used in systems in new buildings.

Estimated Cost:

$200,000 per year for about ten years.

Program Unit

Technology: Solar - Solar Heating and Cooling of Buildings

King-Muir Category: Integrated Assessment

Program Unit Title: Urban Planning for Solar Energy Utilization

Scope: The use of solar heating and cooling imposes certain restrictions on the design of buildings and their surroundings. For example, the limited amount of solar energy falling on a square foot of roof limits the height of a solar building to a few floors. Furthermore the building must be sited so that the view to the sky in the south is unobstructed. This limits the proximity of buildings, and may limit the amount of trees nearby. Thus, a city planned for utilization of solar energy may be low density, and buildings may be sited in exposed areas, and trees may be limited. In this program the socioeconomic and aesthetic consequences of such urban plans will be studied.

Milestones:

Effort should be initiated in advance of design of new developments that employ solar energy as part of the basic city design. Assessment should be completed by the conclusion of the ERDA demonstration program.

Technology Timetable:

Demonstrate residential/commercial heating	1975-1981
Demonstrate residential/commercial heating and cooling	1979-1981
Advanced system development	1975-1979
Improved subsystem development	1975-1986

Priority: B

Severity: B - The potential alterations of the functionality and appearance of cities may be drastic.

Extent: C - This problem is significant only when the design of the city is based on the use of solar. Thus only new cities are impacted.

Need: B - The design considerations involved are new and their consequence unknown , but influence of research results on urban planning may be minor.

Urgency: B - Full cities or communities designed to use solar heating and cities will arrive only late in the demonstration phase.

Estimated Cost:

$200,000 for three years.

Program Unit

Technology: Solar - Photovoltaic

King-Muir Category: Transport

Program Title: Local Heat and Water Balance at Photovoltaic Facilities

Scope: If utilized for central plant generation photovoltaic conversion will require a coverage of large land areas with photovoltaic cell arrays or, possibly, combinations of mirrors and cells. The local heat and water balance will be affected by shading, change of surface albedo, reduction of surface and velocity, altered water runoff, etc. An understanding of these effects is necessary to properly assess the closely related ecological effects (see Program Unit entitled "Local Ecological Effects of Photovoltaic Facilities"), as well as the regional and global climate impacts of widespread deployment of such photovoltaic arrays. (See Program Unit entitled "Global and Regional Climate Alterations"). The effects of the photovoltaic facilities are expected to be similar to those described in the Program Unit entitled "Local Heat and Water Balance at Solar Thermal Facilities." The research for this Photovoltaic Program Unit will be based on that accomplished under the Solar Thermal Unit.

Milestones: Initial assessment (based on results of similar research for solar thermal conversion) following decision to develop photovoltaic arrays for central plant generation. Further research as needed to investigate differences between effects of solar thermal and photovoltaic facilities, and effects at new potential

Technology Timetable:

Demonstration projects using cells from commercial suppliers	1976-1984
Pilot plant for large area silicon sheet production	1984
Large-scale production of thin-film cells or cells of novel materials	beyond 1986

Priority: C

Severity: B - Long range effects are unknown and may be important

Extent: B - Large area use is possible. May be eased by increase of conversion efficiencies.

Need: C - The effects are largely unknown. A methodology for analysis will be available from the corresponding program unit for solar thermal.

Urgency: C - Effects should be known prior to major economic decisions.

Estimated Cost:

$100,000 per year starting at decision for large-scale deployment.

Program Unit

Technology: Solar - Photovoltaic

King-Muir Category: Ecology

Program Title: Local Ecological Effects of Photovoltaic Facilities

Scope: If utilized for central plant generation photovoltaic conversion will require a coverage of large land areas with photovoltaic cell arrays or, possibly, combinations of mirrors and cells. Evaporation rates, surface temperatures and surface winds will be reduced. The devices may permit coexisting vegetation and, presumably, some form of animal life. The environment may be more benign than under natural conditions. The ecological effects are expected to be similar to those described in the program unit entitled "Local Ecological Effects of Solar Thermal Facilities." The research for this Photovoltaic Program Unit will be based on that accomplished under the Solar Thermal Unit.

Milestones: Initial assessment (based on results of similar research for solar thermal conversion) following decision to develop photovoltaic arrays for central plant generation. Further research as needed to investigate differences between effects of solar thermal and photovoltaic facilities, and effects at new potential sites.

Technology Timetable:

Demonstration projects using cells from commercial suppliers	1976-1984
Pilot plant for large area silicon sheet production	1984
Large-scale production of thin-film cells or cells of novel materials	beyond 1986

Priority: C

Severity: B - Long range effects are unknown and may be important

Extent: B - Large area use is possible. May be eased by increase of conversion efficiencies.

Need: C - The effects are largely unknown. A methodology for analysis will be available from the corresponding program unit for solar thermal.

Urgency: C - Effects should be known prior to major economic decisions.

Estimated Cost:

$100,000 per year starting at decision for large-scale deployment.

Program Unit

Technology: Solar - Photovoltaic

King-Muir Category: Health Effects

Program Title: Health Hazards of Solar Cell Production

Scope: The processes for (mass) production of silicon photovoltaic cells and arrays require the use of series of toxic inorganic and organic materials such as halosilanes. The use of these materials will be primarily an occupational hazard. In this research program a thorough investigation into the degree of toxicity and its impact on health will be carried out for the toxic chemicals used in large scale production of cells. The investigation will also include cadmium sulfide and other inorganic and organic compounds and their processing techniques as ERDA develops solar cells using these materials.

Milestones: Preliminary assessment before construction of pilot cell fabrication facility.

Technology Timetable:

Demonstration projects using cells from commercial suppliers	1976-1984
Pilot plant for large area silicon sheet production	1984
Large-scale production of thin-film cells or cells of novel materials	beyond 1986

Priority: A

Severity: A - The toxicity of some of the materials is high.

Extent: B - Effects will be limited to production plants and their vicinities.

Need: A - A relatively new industry will be greatly expanded and is likely to employ new chemicals and processes.

Urgency: A - Assessment should be available prior to the decision on favored process in 1978.

Estimated Cost:

$300,000 per year until decision on process is made.

Program Unit

Technology: Solar - Photovoltaic Conversion

King-Muir Category: CMM

Program Unit Title: Characterization of Materials Released from Photovoltaic Cells

Scope: Potentially toxic materials may be released from photovoltaic cells in two ways. First, the outer cover material (such as glass or a transparent plastic) may be gradually eroded with loss of material to the air. Second, a catastrophic release of products from all the materials in the cell may occur in a fire. This second may be of great importance in applications of photovoltaic cells on roofs of residential and commercial buildings. Material may also be released by disposal of cells. Materials for cells include cadmium sulfide (which is under active development) and possibly other cadmium compounds. The immediate research effort will concentrate on characterizing the types of cadmium compounds released during combustion of cadmium sulfide cells, and the compounds formed by chemical transformation during the dispersal process. If other, potentially toxic, materials are developed for solar cells these materials will be investigated as well.

Milestones: Assessment of gradual release of cover materials should follow tentative selection of cover material and preceed final selection. Assessment of cadmium hazard should be started immediately and completed within a few years.

Technology Timetable:

Demonstration projects using cells from commercial suppliers	1976-1984
Pilot plant for large area silicon sheet production	1984
Large-scale production of thin-film cells or cells of novel materials	beyond 1986

Priority: A

Severity: A - Cadmium is a well established health hazard.

Extent: A - Installation on most residential and commercial buildings is long term goal of program.

Need: B - Effects of cadmium are now under investigation. Releases in combustion of cadmium sulfide need investigation.

Urgency: A - Research on low-cost cadmium sulfide cells is in progress.

Estimated Cost:

$100,000 per year for several years to investigate cadmium. Further costs expected as solar cell development proceeds.

Program Unit

Technology: Solar - Photovoltaic Conversion

King-Muir Category: Health Effects

Program Unit Title: Toxicity of Materials Released from Photovoltaic Cells

Scope: Potentially toxic materials may be released from photovoltaic cells in two ways. First, the outer cover material (such as glass or a transparent plastic) may be gradually eroded with loss of material to the air. Second, a catastrophic release of products from all the materials in the cell may occur in a fire. This second may be of great importance in applications of photovoltaic cells on roofs of residential and commercial buildings. Material may also be released by disposal of cells. Materials for cells include cadmium sulfide (which is under active development) and possibly other cadmium compounds. The immediate research will concentrate on the toxic effects of cadmium compounds released during combustion of cadmium sulfide cells. (See Program Unit under CM&M entitled "Characterization of Materials Released from Photovoltaic Cells.") If other, potentially toxic, materials are developed for solar cells, these materials will be investigated as well.

Milestones: Assessment of gradual release of cover materials should follow tentative selection of cover material, and precede final selection. Assessment of cadmium hazard should be completed before any large scale production of cadmium sulfide cells.

Technology Timetable:

Demonstration projects using cells from commercial suppliers	1976-1984
Pilot plant for large area silicon sheet production	1984
Large-scale production of thin-film cells or cells of novel materials	beyond 1986

Priority: A

Severity: A - Cadmium is a well established health hazard.

Extent: A - Installation on most residential and commercial buildings is long-term goal of program.

Need: B - Effects of cadmium are now under investigation. Releases in combustion of cadmium sulfide need investigation.

Urgency: A - Research on low-cost cadmium sulfide cells is in progress.

Estimated Cost:

$250,000 per year through first fabrication pilot plant.

Program Unit

Technology: Solar - Wind

King-Muir Category: Transport

Program Unit Title: Meteorological and Climatological Effects of Wind Energy Facilities

Scope: It is probable that very large arrays of wind turbines would have detectable meteorological and perhaps regional climatological effects. An understanding of the local meteorological effects is necessary to properly assess the closely related ecological effects (see Program Unit for Wind entitled "Ecological Effects of Wind Turbine Arrays"), as well as the regional and global climate impacts of widespread deployment of wind turbines (see Program Unit for Solar Generic entitled "Global and Regional Climate Alterations"). Prior to the construction of such arrays, it is important to have gained an understanding of the likely magnitude of the effects; appropriate constraints can then be placed on array size and siting to assure that the impacts are acceptable. The effort envisioned here will require a coordinated program of computer modeling, wind tunnel, and field measurements. The program should include research to elucidate poorly understood vertical transport mechanisms in the atmosphere.

Milestones: The data needed to establish a verified predictive capability should be identified and experimental programs to obtain that data should be keyed to the technology development schedule for pilot and demonstration plant construction. Model verification should then proceed.

Technology Timetable:

100 KWe Scale Turbine	1976
First Megawatt Scale Turbine	1978
10 MWe Multi-unit demonstration	1980
100 MWe Multi-unit demonstration	1981

Priority: B

Severity: B - Potentially serious impacts may result from inappropriate scale or siting of major facilities.

Extent: B - Wide scale distribution with major utilization of wind energy technology, but limited to wind resource regions.

Need: B - Problem is unique and will require new approach to wind and meteorological modeling.

Urgency: A - The ERDA technology development schedule calls for major utilization of wind power systems by about 1985. Siting and array size decisions would be made by 1983.

Estimated Cost:

$200,000 per year through demonstration phase.

Program Unit

Technology: Solar - Wind

King-Muir Category: Ecological Effects

Program Unit Title: Ecological Effects of Wind Turbine Arrays

Scope: Because wind power systems leave most of the land within the array relatively undisturbed, the use of the land for additional purposes is anticipated. However, constraints on siting and land use can only be evaluated after the impacts of the facilities on wildlife and domestic grazing animals have been determined. The following potential impacts should be included in the investigation: the effect on bird and insect populations of arrays of high speed rotating blades; the "scarecrow" effect of large wind turbines on the spatial distribution of wildlife populations; the effect of wind turbine noise and infrasonic pressure waves on wildlife and domestic grazing animals.

Milestones: Ecological effects of wind power systems should be studied beginning with the first 100 KW single turbine facility, through the operation of the 100 MWe demonstration plants.

Technology Timetable:

100 KWe Scale Turbine	1976
First Megawatt Scale Turbine	1978
10 MWe Multi-unit demonstration	1980
100 MWe Multi-unit demonstration	1981

Priority: B

Severity: B - Effects are unknown but some species may be adversely affected.

Extent: B - Wide scale distribution with major utilization of wind energy technology, but limited to wind resource areas.

Need: B - The effects of large scale arrays are unknown, but probably not drastic.

Urgency: B - Program should be keyed to pilot and demonstration plant construciton schedule.

Estimated Cost:

$100,000 per year through demonstration phase.

Program Unit

Technology: Solar - Wind

King-Muir Category: Transport

Program Unit Title: Electromagnetic Interference from Wind Turbines

Scope: Large wind turbines may, in certain locations, interfere with electromagnetic waves such as television signals. To the extent that this potential impact is real, it could have a considerable influence on siting. The proposed research would use computer modeling of electromagnetic wave propagation to investigate this phenomena.

Milestones: Research completed one year after start.

Technology Timetable:

100 KWe Scale Turbine	1976
First Megawatt Scale Turbine	1978
10 MWe Multi-unit demonstration	1980
100 MWe Multi-unit demonstration	1981

Priority: B

Severity: B - Not currently known, but could be severe to affected parties, such as television viewers.

Extent: C - Limited to small areas.

Need: B - Information apparently lacking, but techniques exist to to provide answer.

Urgency: A - Research should be completed before siting of wind turbines.

Estimated Cost:

$50,000 for one year.

Program Unit

Technology: Solar - Ocean Thermal Conversion

King-Muir Category: Ecological

Program Unit Title: Productivity of Water from Ocean Thermal Plants

Scope: Ocean thermal conversion plants will pump immense quantities of nutrient rich water from ocean depths (about 600 meters) to the surface or near the surface. These waters could support a productive ecosystem with a fish population that could be an important food source if ocean thermal conversion becomes widespread, or they could produce undesirable species. This enhanced productivity, coupled with other surface effects (see Program Unit on Local Oceanographic and Meterological Effects) may also affect the pre-existing deep water species. Research to clarify the nature of the ecosystems that will be supported by the plumes from ocean thermal plants will first involve an assessment of existing knowledge of the productivity potential of deep waters and the nutrients which will limit surface growth. This will be followed by analysis of deep waters and some small-scale experiments at potential sites of ocean thermal pilot plants, and finally by monitoring during operation of pilot and demonstration plants.

Milestones: Preliminary assessment of productivity based on existing knowledge, measurements and detailed assessment prior to construction of pilot plant. Ongoing monitoring during opeation of pilot and demonstration plants.

Technology Timetable:

Ocean based component tests	1979-80
Decision to build 25 MWe pilot plant	1979
First operation of pilot plant	1983
Operation of 100 MWe demonstration plant	1984

Priority: A

Severity: A - Major alteration of surface ecosystems expected by change in nutrient limitations.

Extent: B - Effects will be noted throughout the plume from the plants.

Need: A - Major uncertainty exists about the type of ecosystem that will be established.

Urgency: A - Information should be available before decision to proceed with pilot plant.

Estimated Cost:

$200,000 per year through pilot plant construction. Monitoring program will be expensive, but cost sharing with the technology is expected.

Program Unit

Technology: Solar - Ocean Thermal Conversion

King-Muir Category: Transport

Program Unit Title: Local Oceanographic and Meterological Effects

Scope: The operation of a ocean thermal conversion plant will alter the local surface temperature, the temperature gradient to depth, and possibly increase local turbulence and currents. These effects, plus the possible biological "pasture" or the artificial surface film (if used to increase surface temperature) will affect the local albedo and the overall energy balance in the vicinity of the plant. The net effect is currently unknown. The research effort will make baseline measurements of appropriate parameters followed by measurements at the pilot and demonstration plants. These measurements will be incorporated into models to assess the net effects.

Milestones: Baseline measurements and preliminary modeling prior to pilot plant construction. Continuing measurements and modeling during pilot and demonstration phase.

Technology Timetable:

Ocean based component tests	1979-80
Decision to build 25 MWe pilot plant	1979
First operation of pilot plant	1983
Operation of 100 MWe demonstration plant	1984

Priority: B

Severity: B - Unknown and possibly of minor importance.

Extent: B - Successful commercialization will result in many plants.

Need: B - Qualitative guesses have been made but quantitative studies are lacking.

Urgency: A - Preliminary studies should be completed before construction of pilot plant.

Estimated Cost:

$150,000 per year through demonstration phase. Costs of oceanographic vessels should be shared with other measurement programs.

Program Unit

Technology: Solar - Ocean Thermal Conversion

King-Muir Category: Ecological

Program Unit Title: Entrainment and Destruction of Deep Ocean Species

Scope: Ocean thermal conversion plants will pump up immense quantities of water from ocean depths (about 600 meters). This will result in entrainment, and subsequent destruction by sudden pressure change, of deep sea organisms. Research to assess the damage to deep sea ecosystems will proceed with an initial assessment based on a survey of literature on deep ocean communities. When sites for pilot and demonstration plants are selected, research will be initiated to characterize community structure at those sites and other sites for comparison with emphasis on species diversity, standing crops, productivity, and detritus characterization.

Milestones: Preliminary assessment of species kill rates prior to construction of pilot plant. Site-specific measurements after selection of sites for pilot and demonstration plants. Ongoing monitoring during operation of plants.

Technology Timetable:

Ocean based component tests	1979-80
Decision to build 25 MWe pilot plant	1979
First operation of pilot plant	1983
Operation of 100 MWe demonstration plant	1984

Priority: B

Severity: A - Essentially all organisms brought to surface will be killed.

Extent: C - Only small fraction of volume of water at depth will be affected.

Need: B - Knowledge of deep sea species is fragmentary, but much data exists that could be usefully analyzed.

Urgency: B - Preliminary estimate should be available before construction of pilot plant.

Estimated Cost:

$100,000 per year for initial assessment. Measurement and monitoring program will be expensive, but costs are expected to be shared with the technology.

Program Unit

Technology: Solar - Ocean Thermal Conversion

King-Muir Category: Ecological

Program Unit Title: Chemical Releases from Ocean Thermal Plants

Scope: Ordinary operation of ocean thermal conversion plants may involve release of biocides. The large surface areas that must be kept clean for heat transfer make this a potentially important problem. The toxicity to ocean species of these agents should be assessed. In addition, accidents, such as collisions by ships, may release the working fluid used in the plant cycle (ammonia, freon, etc.). The toxicity of these fluids should also be assessed. Finally, such plants may use films over the surface of the ocean to increase the surface temperature of the water. The impact of this film on the surface species, by release of toxic agents or by reduction of the dissolved oxygen level should be assessed.

Milestones: Preliminary assessment can be made after initial design of the pilot plant is established and procedures for maintaining clean heat transfer surfaces established.

Technology Timetable:		
	Ocean based component tests	1979-80
	Decision to build 25 MWe pilot plant	1979
	First operation of pilot plant	1983
	Operation of 100 MWe demonstration plant	1984

Priority: B

Severity: B - Many species might be susceptable to these chemical agents.

Extent: B - Large volumes of water will be treated.

Need: C - Significant experience exists with the common chemical agents used.

Urgency: B - Design decisions for pilot plants will probably not require this research to be performed first.

Estimated Cost:

$50,000 per year through pilot plant construction. Future technological development involving new chemicals may require additional costs.

Program Unit

Technology: Solar - Ocean Thermal Conversion

King-Muir Category: Characterization, Measurement and Monitoring

Program Unit Title: Instrumentation for Characterization of Ocean Communities

Scope: Wide deployment of ocean thermal conversion facilities may cause significant biological changes over large areas of the ocean. Total productivity may be increased and species composition may change. Characterization of the changes and subsequent monitoring will involve large area surveys of open ocean to measure biological, physical and chemical parameters. Use of existing sampling methods could involve prohibitive costs (e.g., ships and manpower necessary for surface sampling over a large area). Initial research in this program unit will assess methods now used in freshwater ecology and in land survey techniques and their possible adaptation for use in a marine environment. Such techniques might include remote sensing by infrared photography together with back-up analysis using fast-towed apparatus to assay large areas. Additional development of instruments capable of surveying intermediate ocean depths (500 - 1,000 meters) may be necessary.

Milestones: Preliminary assessment after successful demonstration of large scale plant. Additional research concurrent with development of new plants.

Technology Timetable:	Ocean based component tests	1979-80
	Decision to build 25 MWe pilot plant	1979
	First operation of pilot plant	1983
	Operation of 100 MWe demonstration plant	1984

Priority: C

Severity: A - Ocean thermal conversion can disrupt surface ecosystems by changing nutrient limitations.

Extent: B - Effects are to be detected throughout the lume from many plants.

Need: C - Many instruments are already available or will be developed by other technologies.

Urgency: C - Widespread deployment of ocean thermal is not expected in the immediate future.

Estimated Cost:

$150,000 per year, survey and adaptation.
$300,000 per year, development of new apparatus.

Program Unit

Technology: Solar - Bioproduction

King-Muir Category: Transport

Program Unit Title: Effects of Energy Farms on Surrounding Areas

Scope: Extensive energy farms will affect surrounding areas chemically, ecologically and meteorogically. Large scale change of dominant vegetation may alter wind and temperature patterns. Vast cultivation of marine species may change ocean temperature profiles. This research will consist of micrometeorological modeling and measurement.

Milestones: Initial assessment and baseline measurements completed during construction of large land or aquatic demonstration facilities.

Major conclusions finished before operation of demonstration plants.

Technology Timetable:

Crop and forest residue pilot plant	1979
Feedlot pilot plant	1979
Terrestrial biomass pilot plants	1980
Marine biomass pilot plant	1980

Priority: C

Severity: C - Likely to resemble existing vegetation in most effects.

Extent: A - Large areas surrounding an energy farm may be affected.

Need: B - Many effects can be predicted from agriculture; aquatic transport requires more attention.

Urgency: C - Study should be completed concurrent with operational phase of a large demonstration facility.

Estimated Cost:

$100,000 per year through demonstration phase.

Program Unit

Technology: Solar - Bioproduction

King-Muir Category: Integrated Assessment

Program Unit Title: Land and Water Requirements of Energy Farms

Scope: Grassland and forest biomass production is potentially in direct competition with agriculture and paper pulp industries for land and water uses and for resource and capital requirements (farm equipment, fertilizers, etc.). Similarly, marine production may compete with ocean food production. Harvesting of marine biomass may interfere with local fishing industries. This study will provide assessments of possible land sites and ascertain their potentials for alternative production of food and other commodities. In addition, favored marine locations will be examined for their present and future potentials as food producing areas.

Milestones: Begin study of land and water use, concurrent with silvaculture, agriculture, and aquaculture pilot facilities. Finish study prior to decisions to begin construction of large scale demonstration plants.

Technology Timetable:

Crop and forest residue pilot plant	1979
Feedlot pilot plant	1979
Terrestrial biomass pilot plant	1980
Marine biomass pilot plant	1980

Priority: A

Severity: A - The most productive land both for photosynthetic efficiency and harvesting ease is probably the most desirable land for food production.

Extent: A - Contiguous land areas of more than 125 mi^2 each, potentially totalling as much as 5% of U.S. land area will be affected. Large marine areas may also be used.

Need: A - This is probably the dominant consideration as to whether this technology should proceed. Information is needed to clarify the issue.

Urgency: B - Impacts on food and paper industries must be well understood prior to decisions to build large scale deomonstration facilities.

Estimated Cost:

$200,000 per year through pilot phase.

Program Unit

Technology: Solar - Bioproduction

King-Muir Category: Ecological Effects

Program Unit Title: Ecosystem Effects of Energy Farms

Scope: Forced monocultures which simplify the local plant community may drastically alter the natural food chain and disrupt or eliminate important natural species. In marine systems, impacts could be especially acute since a dense surface crop would reduce light penetration, greatly reducing the underater algae which form the basis of much of the marine food chain. Additional effects that may be particular to energy farms include ash recycling, plant growth regulators, and infestation of surrounding areas by fast growing, genetically adapted plant species. This research will involve an initial assessment based on existing agricultural practice and knowledge of marine ecosystems. The assessment will identify areas where further research is needed. Since most ecological impacts tend to be site specific, further research must await selection of the potential sites and crops.

Milestones: Begin study and baseline assessment prior to construction of large land or aquatic demonstration facilities. Major conclusions prior to operation of demonstration plants.

Technology Timetable:

Crop and forest residue pilot plant	1979
Feedlot pilot plant	1979
Terrestrial biomass pilot plants	1980
Marine biomass pilot plant	1980

Priority: B

Severity: A - A natural growth pattern will be replaced by a forced growth system, severely distrupting local biota.

Extent: B - Up to 5% of U.S. land area and significant marine areas, however, buildup is likely to be gradual.

Need: B - Most land effects can be predicted from current agriculture effects. Marine effects are largely unknown.

Urgency: B - The total effects on local ecosystems should be understood prior to operation of large demonstration facilities.

Estimated Cost: $150,000 per year.

Program Unit

Technology: Solar - Bioproduction

King-Muir Category: Health

Program Unit Title: Energy Farmworker Health

Scope: Energy farms pose health problems to workers which are similar to those occurring in existing agriculture. Preliminary research should investigate these hazards. Additional investigations are needed to understand new potential health hazards which are particular to energy farms. These investigations will ascertain possible harmful effects of additional pollutants from biocides and pesticides, ash recycling, and use of growth regulators and stimulators. It will closely monitor worker's health during operation of pilot and demonstration facilities.

Milestones: Studies should be concurrent with pilot plant and demonstration facility operation.

Technology Timetable:

Crop and forest residue pilot plant	1979
Feedlot pilot plant	1979
Terrestrial biomass pilot plants	1980
Marine biomass pilot plant	1980

Priority: C

Severity: B - Harmful levels of metals, pathogens and biocide poisons may occur, as well as lung diseases.

Extent: C - Limited to certain occupational groups.

Need: C - Much of the necessary information is available.

Urgency: B - Study should be concurrent with operations phase of pilot or demonstration facility.

Estimated Cost:

$100,000 per year through demonstration phase.

Program Unit

Technology: Solar - Bioconversion

King-Muir Category: Ecological Effects

Program Unit Title: Ecological Effects of Effluents from Bioconversion Facilities

Scope: Combustion and pyrolysis of biological material can emit air pollutants including particulates, toxic gases, trace metals and aromatic hydrocarbons. The ash may be recycled as a nutrient but, especially for urban wastes, may contain toxic metals. These effluents will differ in kind among the various feedstock materials and from fossil fuels. Fermentation can release odiferous and toxic gases such as sulfides; this can be acute in the case of catastrophic breakdown of fermentation. Pathogenic microorganisms may be released. A fermentation waste product, sludge, will differ in biological and chemical composition depending on the feedstock. This research will investigate the effects on terrestrial ecosystems of the airborne effluents, the storage of wastes prior to conversion and the disposal of ash, sludge or other by-products of the conversion process. The effect of fresh-water systems of water-borne effluents, and leaching from waste storage will be investigated. The fate of pathogenic microorganisms released from fermentation facilities will be studied.

Milestones: Continued research as new processes are developed. Site specific initial studies prior to pilot construction of pilot or demonstration facilities. Evaluation of alterations to ecosystems subsequent to construction and operation of the facilities.

Technology Timetable:

Crop and forest residue pilot plant	1979
Feedlot pilot plant	1979
Terrestrial biomass pilot plant	1980
Marine biomass pilot plant	1980

Priority: A

Severity: A - New and potentially severe pollutants may be produced by bioconversion of previously unconverted materials.

Extent: B - Extent will be less than for fossil fuels unless bioproduction becomes a significant factor.

Need: B - Pollutants from some processes are similar to those of fossil fuels, but new chemical compounds are possible. Fermentation has unique effluents.

Urgency: A - Demonstration plants are in or near operation for many processes.

Estimated Cost:

$200,000 per year through demonstration phase.

Program Unit

Technology: Solar - Bioconversion

King-Muir Category: CM&M

Program Unit Title: Characterization of Effluents from Bioconversion Facilities

Scope: Combustion and pyrolysis of biological material can emit air pollutants including particulates, toxic gases, trace metals and aromatic hydrocarbons. The ash may be recycled as a nutrient but, especially for urban wastes, may contain toxic metals. These effluents will differ in kind among the various feedstock materials and from fossil fuels. Fermentation can release odiferous and toxic gases such as sulfides; this can be acute in the case of catastrophic breakdown of fermentation. Pathogenic microorganisms may be released. A fermentation waste product, sludge, will differ in biological and chemical composition depending on the feedstock. This research will characterize and measure the effluents from the various bioconversion processes as they are developed. If necessary, new instrumentation will be developed for rapid and accurate determination of the constituents.

Milestones: Continued research as new processes are developed.

Technology Timetable:

Crop and forest residue pilot plant	1979
Feedlot pilot plant	1979
Terrestrial biomass pilot plant	1980
Marine biomass pilot plant	1980

Priority: A

Severity: A - New and potentially severe pollutants may be produced by bioconversion of previously uncovered materials.

Extent: B - Extent will be less than for fossil fuels unless bioproduction becomes a significant factor.

Need: B - Pollutants from some processes are similar to those of fossil fuels, but new chemical compounds are possible. Fermentation has unique effluents.

Urgency: A - Demonstration plants are in or near operation for many processes.

Estimated Cost:

$200,000 per year through demonstration phase.

Program Unit

Technology: Solar - Bioconversion

King-Muir Category: Transport

Program Unit Title: Dispersal and Transformation of Effluents from Bioconversion Facilities

Scope: Combustion and pyrolysis of biological material can emit air pollutants including particulates, toxic gases, trace metals and aromatic hydrocarbons. The ash may be recycled as a nutrient but, especially for urban wastes, may contain toxic metals. These effluents will differ in kind among the various feedstock materials and from fossil fuels. Fermentation can release odiferous and toxic gases such as sulfides; this can be acute in the case of catastrophic breakdown of fermentation. Pathogenic microorganisms may be released. A fermentation waste product, sludge, will differ in biological and chemical composition depending on the feedstock. This research will investigate the dispersal of the effluents via air transport of the gasious and particulate matter, and water transport of particulates, dissolved inorganic nutrients, and other pollutants, to downstream areas. Chemical transformations during transit will also be studied. The chemical composition and amount of the effluents will provide the starting point for this research (see Program Unit entitled "Characterization of Effluents from Bioconversion Facilities").

Milestones: Initial investigations during pilot phase of each process. Site specific meteorological and hydrological modeling to determine the transport possibilities of these effluents. Chemical research, as required, to determine the transformation properties of the effluents.

Technology Timetable:

Crop and forest residue pilot plant	1979
Feedlot pilot plant	1979
Terrestrial biomass pilot plant	1980
Marine biomass pilot plant	1980

Priority: A

Severity: B - Dispersal of harmful effluents may be a severe problem.

Extent: A - Nearly all urban areas may use bioconversion of urban waste.

Need: B - Many transport mechanisms are predictable from experience with fossil fuels.

Urgency: A - Demonstration plants are in operation for many processes.

Estimated Cost:

$200,000 per year through demonstration phase.

Program Unit

Technology: Solar - Bioconversion

King-Muir Category: Health

Program Unit Title: Health Effects of Effluents from Bioconversion Facilities

Scope: Combustion and pyrolysis of biological material can emit air pollutants including particulates, toxic gases, trace metals and aromatic hydrocarbons. The ash may be recycled as a nutrient but, especially for urban wastes, may contain toxic metals. These effluents will differ in kind among the various feedstock materials and from fossil fuels. Fermentation can release odiferous and toxic gases such as sulfides; this can be acute in the case of catastrophic breakdown of fermentation. Pathogenic microorganisms may be released. A fermentation waste product, sludge, will differ in biological and chemical composition depending on the feedstock. Waste disposal in landfills may contaminate soil, run-off water and underground aquifiers. Research is needed to ascertain the nature and effects of these pollutants on local populations. Synergistic effects should be studied in conjunction with other technologies. Use of large amounts of cultivated waste organic materials may require extensive land area for storage and pre-treatment of materials, thus creating problems of disease vector control. For fermentation, this may be especially acute since conversion times are lengthy (several days to a week). Continued research may be necessary as new pollutants are identified.

Milestones: Identify possible pathogens and pollutants and survey existing knowledge of their harmful effects. Additional investigation of possible new health problems where gaps in existing knowledge occur and where new toxicants are identified. Careful assessment of health effects during operation of pilot and demonstration plants.

Technology Timetable:

Crop and forest residue pilot plant	1979
Feedlot pilot plant	1979
Terrestrial biomass pilot plant	1980
Marine biomass pilot plant	1980

Priority: A

Severity: B - Serious health hazards may result.

Extent: A - Conversion plants will probably be sited in or near many urban areas.

Need: A - Some proposed conversion processes may release exotic pathogenic species. Synergistic effects may also prove important.

Urgency: A - Demonstration plants are in operation for many conversion processes.

Estimated Cost:

$300,000 per year through demonstration phase.

Program Unit

Technology: Solar Energy - Tidal Energy Conversion

King-Muir Category: Integrated Assessment

Program Unit Title: Assessment of Environmental Impact of Tidal Energy Conversion

Scope: Should tidal power be developed, it could have serious consequences for the ecology of bays, estuaries, and the ocean. Impacts on the fishing industry and recreational use could also result. This research would make an initial assessment based on existing literature and data on marine (and esp. estuarine) ecology. Subsequent research would be based on the need as established by the assessment.

Milestones: Initial assessment. At time of decision to develop technology. Subsequent research. Start 12 mo. after start of assessment.

Technology Timetable: Review of Potential 1976
Decision to develop?

Priority: C

Severity: A - Potentially serious disruption of ocean, bay and estuary ecology.

Extent: C - Current estimates of Tidal power potential make widespread development unlikely.

Need: B - Existing data on marine ecology may be inadequate.

Urgency: C - Tidal power is not currently under active development.

Estimated Cost:

Initial assessment $200,000.

Program Unit

Technology: Solar - Hydroelectric

King-Muir Category: Integrated Assessment

Program Unit Title: Assessment of Hydroelectric Environmental Impacts

Scope: The environmental impacts of hydroelectric power are primarily associated with the impoundment and subsequent controlled release of water. Innundation of land destroys the pre-existing ecosystem and raises questions of alternative land use. Downstream riverine, estuarine and marine ecosystems are disrupted by altered water flow rates and other factors. These impacts are shared with other such use of water for irrigation, flood control, recreation, pumped hydroelectric storage, shale oil and coal conversion, and cooling for thermal-to-electrical conversion processes. Many government agencies are concerned with, and have supported research on, these environmental impacts. The proposed research would provide an assessment of the environmental effects, the current status of research on the effects, and a more clearly established research role for ERDA than currently exists.

Milestones: Initial assessment and recommendations for subsequent DBER research effort. One year from start of project. Final assessement. Two years from start.

Technology Timetable: Already well developed.

Priority: B

Severity: A - Ecological impacts are substantial, but some amy be considered beneficial.

Extent: A - Impacts riverine, estuarine, and marine ecosystems as well as local environment.

Need: C - Other government agencies are involved with environmental aspects. ERDA's role is unclear.

Urgency: B - Future expansion of hydroelectric power is limited. However, impoundment of water for pumped hydroelectric storage, shale oil and coal conversion processes, and cooling may be imminent.

Estimated Cost:

$100,000 per year for two years. Further costs depend on recommendations for ERDA supported research.

IV. SUMMARY OF PROGRAM UNITS

	CMM	T	H	E	IA
A. SOLAR GENERIC					
1. National Economic Impacts					A
2. Residuals from Production of Solar Devices					B
3. Regional Land, Water, Demographic, and Aesthetic Impacts					A
4. Global and Regional Climate Alterations		B			
5. Decentralized Energy Sources and Social Movements					B
B. SOLAR THERMAL CONVERSION					
1. Local Heat and Water Balance at Solar Thermal Facilities		A			
2. Local Ecological Effects of Solar Thermal Facilities				A	
3. Occupational Hazards of Heat Transfer and Storage Media			B		
4. Environmental Assessment of Agricultural, Process Heat and Total Energy Systems					B
C. SOLAR HEATING AND COOLING OF BUILDINGS					
1. Alteration of Urban Heat Islands		C			
2a. Toxicity of Heat Storage and Transfer Media			B		
2b. Ecological Effects of Heat Storage and Transfer Media				C	
3. Toxicity of Construction Materials			C		
4. Urban Planning for Solar Energy Utilization					B
D. PHOTOVOLTAIC CONVERSION					
1a. Local Heat and Water Balance at Photovoltaic Facilities		C			
1b. Local Ecological Effects of Photovoltaic Facilities		C			
2. Health Hazards of Solar Cell Production			A		
3a. Characterization of Materials Released from Cells	A				
3b. Toxicity of Materials Released from Photovoltaic Cells			A		
E. WIND ENERGY CONVERSION					
1. Meteorological and Climatological Effects of Wind Energy Facilities		B			
2. Ecological Effects of Wind Turbine Arrays				B	
3. Electromagnetic Interference from Wind Turbines		B			
F. OCEAN THERMAL CONVERSION					
1. Productivity of Water from Ocean Thermal Plants				A	
2. Local Oceanographic and Meteorological Effects		B			
3. Entrainment and Destruction of Deep Ocean Species				B	
4. Chemical Releases from Ocean Thermal Plants				B	
5. Instrumentation for Characterization of Ocean Communities	C				
G. BIOCONVERSION					
1. Effects of Energy Farms on Surrounding Areas		C			
2. Land and Water Requirements of Energy Farms					A
3. Ecosystem Effects of Energy Farms				B	
4. Energy Farmworker Health			C		
5. Ecological Effects of Effluents from Bioconv. Facilities				A	
6. Characterization of Effluents from Bioconversion Facilities	A				
7. Dispersal and Transformation of Effluents from Bioconversion Facilities		A			
8. Health Effects of Effluents from Bioconversion Facilities			A		
H. TIDAL ENERGY CONVERSION					
1. Assessment of Environmental Impact					C
I. HYDROELECTRIC CONVERSION					
1. Assessment of Environmental Impact					B

☆ U.S. GOVERNMENT PRINTING OFFICE : 1977 0-240-979/20