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ENVIRONMENTAL READINESS DOCUMENT

SOLAR THERMAL POWER SYSTEMS

August 1979

U.S. Department of Energy
Assistant Secretary for Environment

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FOREWORD

Environmental Readiness Documents are prepared periodically to review and evaluate the environmental status of an energy technology during the several phases of development of that technology. Through these documents, the Office of Environment within the Department of Energy provides an independent and objective assessment of the environmental risks and potential impacts associated with the extensive use of the technology.

This Environmental Readiness Document was prepared to assist DOE in evaluating the commercial readiness of solar thermal power systems technology with respect to environmental issues. An effort has been made to identify potential environmental problems that may be encountered based upon current knowledge, proposed and possible new environmental regulations, and the uncertainties inherent in planned environmental research.

This document is one of several assessments of energy technologies prepared for DOE management and public review. It is being distributed so that persons having interests and responsibilities in this area can provide DOE with additional information and comments.

Ruth C. Clusen

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Assistant Secretary for Environment

ACKNOWLEDGMENT

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CONTENTS

SECTION I. SUMMARY STATEMENT ON ENVIRONMENTAL ACCEPTABILITY OF SOLAR THERMAL POWER SYSTEMS

Two main categories of solar thermal power systems (STPS) are under development, the central receiver and distributed collector systems. The central receiver ("power tower") systems may provide power up to 500 MWe. Distributed collectors are to be used in 0.5- to 10-MWe applications, powering irrigation systems or as components in total energy systems.

Major environmental concerns associated with the development and deployment of STPS have been identified in areas such as site selection, environmental impacts of construction and working fluid leaks, and hazards from glare or leaks.

By the time a scale-up decision must be made on central power applications, most of the required research on environmental problems will be completed or underway. Therefore, the program for the development of solar thermal power systems should not be delayed by lack of environmental information.

Conclusions on the environmental acceptability of STPS are summarized in Table 1-1.

TABLE 1-1. CONCLUSIONS FOR STPS

	Probability 0.1 Low	Low-Med	0.5 Med	Med-High	0.9 High
Information: The probability of developing adverse information in the conduct of environmental R&D	X				
Delays: *The probability of technology program delays in event of an adverse finding	X				
Costs: The probability of increased energy costs in event of adverse finding	X				

*Probability of Technology Program Delays:

Low: Assessment of environmental factors will be substantially complete prior to commercialization.

Med: Assessment of environmental factors will be concurrent with DOE commercialization development.

High: Assessment of environmental factors will not be complete until after commercialization.

SECTION II. INTRODUCTION

This Environmental Readiness Document (ERD) is one of a series of independent reviews prepared by DOE's Office of Environment (EV) on the subject of environmental concerns associated with energy technologies which are candidates for commercialization.

An Environmental Readiness Document is prepared at appropriate times in the development cycle of a technology program to inform decisionmakers of the present environmental status of an energy technology. An ERD summarizes the professional judgments of EV scientists on the magnitude of potential environmental concerns for which current information is incomplete. When new information is available and it is appropriate to the timing of the decision process, the ERD will be updated.

The document addresses the uncertainties about environmental aspects of STPS that remain to be resolved through research and development. The resolution of these uncertainties may require adjustments in the technology program before it can be commercialized. Table 1-1 shows the probabilities that commercialization of the technology may encounter adverse findings from research which will lead to increased mitigation costs or delays in commercialization.

The impacts and concerns presented in the document are treated generically without reference to specific predetermined sites unless these are known. Hence, specific site implications are not generally included in the assessment.

The report contains two main sections, III and IV, as well as an Appendix. Section III highlights the characteristics of the technology, provides a status report on the technical and environmental R&D programs, presents a milestone chart representing a relationship between a considered commercialization schedule and relevant environmental R&D, and reviews the environmental concerns significant to the technology. Information pertinent to the technology R&D program was drawn from the technology program office and the current Environmental Development Plan.

Section IV examines the likelihood and consequences of adverse findings, the problems and uncertainties stemming from current or anticipated environmental regulation, and potential costs of environmental controls. On this basis, an assessment of the existing or potential barriers to commercialization is made.

Appendix A presents a tabulation of outstanding environmental concerns. (These concerns are an updated version of those appearing in the 1977 EDP.) Research required to resolve these concerns is also listed with estimated costs. The research requirements represent the present judgment of EV scientists and engineers. They are presented as a reference for all interested research participants. As such, this listing is not meant to describe the Federal Environmental R&D plan for STPS.

The lack of appropriate National Environmental Policy Act (NEPA) documentation can cause a significant delay in the development and commercialization cycle. However, no attempt has been made in the presentation to identify formal NEPA requirements (the type of NEPA document required and its schedule). There is a prescription, however, that Programmatic Environmental Reviews, as appropriate, will be prepared pursuant to 10-CFR-711, "Compliance with the National Environmental Policy Act" (Federal Register Vol. 43, No. 35, February 21, 1978), prior to DOE's taking action to commercialize any technology or process.

SECTION III. TECHNOLOGY PROGRAM AND MAJOR ENVIRONMENTAL CONCERNS

A. TECHNOLOGY

By focusing sunlight, solar collectors can heat a working fluid which then drives a turbogenerator. This solar thermal electric technology is now based on two systems, the distributed collector system and the central receiver ("power tower") system (Figure 3-1).

Both systems collect direct sunlight and concentrate it to heat a working fluid, thereby converting solar energy to thermal energy. Working fluids under consideration include high pressure water, superheated steam, hydrocarbon oils, molten salts, and liquid metals.

The central receiver system is more likely to provide electricity on a scale required by the utility industry. Overall efficiencies are now less than 20% but that should increase as facilities scale up from 10 MWe. Current designs call for one or two towers surrounded by fields of tracking heliostats (mirrors) that focus solar energy at one or more points on the receivers.

Distributed collectors use parabolic or segmented mirrors and achieve overall conversion efficiencies in the 12 to 25% range. Distributed collectors have potential applications in irrigation pumping and small solar power systems.

Two types of thermodynamic cycles are being investigated for the conversion of thermal energy to mechanical energy and then to electricity. These are the Rankine cycle and the Brayton cycle. A Rankine cycle uses vaporized fluids, such as superheated steam, to power a turbine. The source of the vapor can be either boiler/superheater tubes within the receiver unit or a heat exchanger in which the hot receiver working fluid transfers its thermal energy to a separate turbine working fluid. The Brayton cycle uses a gas as the working fluid. An open cycle (air) Brayton engine, similar to that used in jet aircraft, is being investigated for solar thermal conversion applications. Also under consideration is a closed cycle Brayton engine which utilizes helium as the working fluid.

Both the distributed and the centralized solar thermal electric systems require thermal storage subsystems using various media warmed by surplus heat while the receiver is operating. This stored heat is then used to warm the working fluid and drive the turbogenerators during dark or cloudy periods. As the centralized STPS become larger and receiver temperatures increase, a system releasing surplus heat to the atmosphere will also be necessary. Cooling towers, dry or wet, are included in current designs.

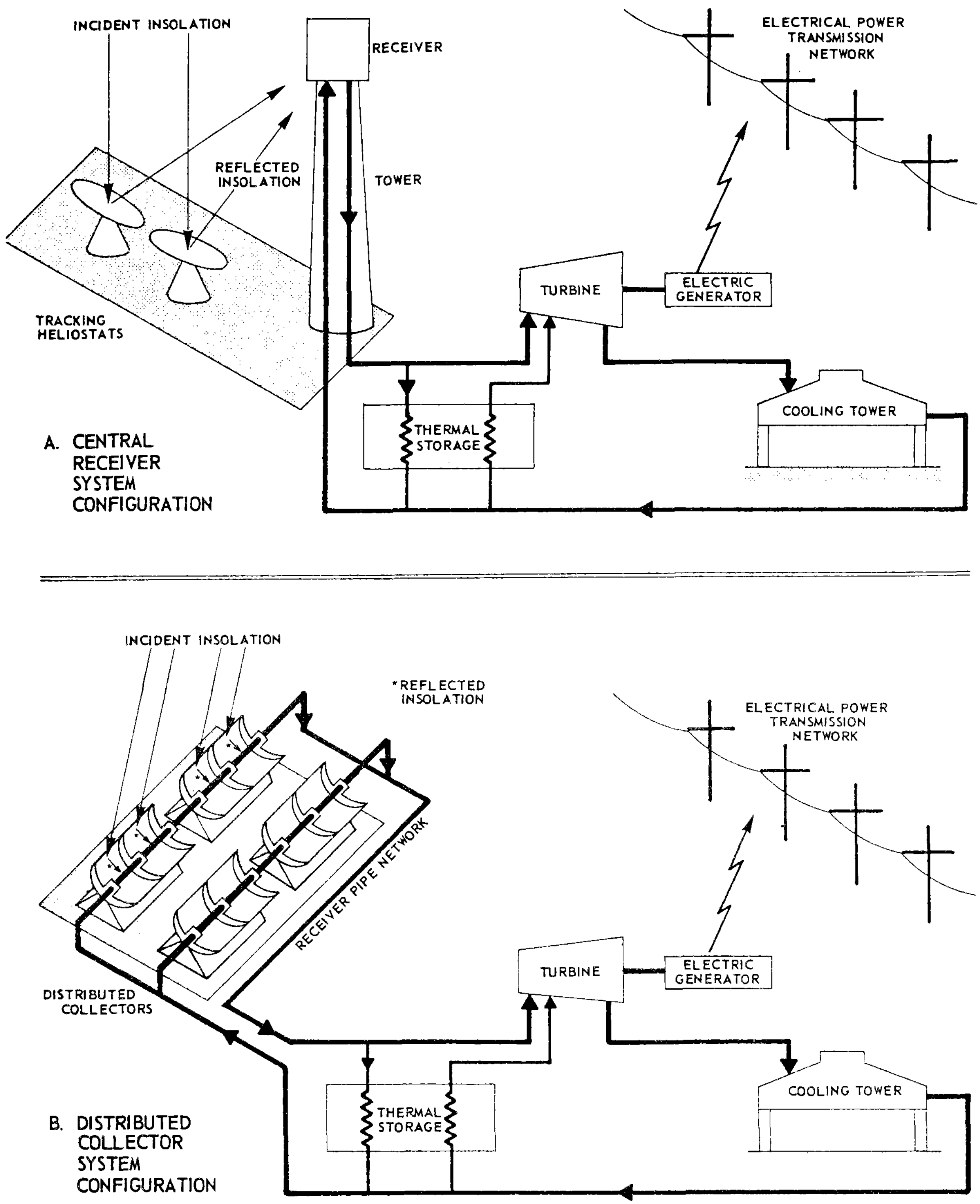


FIGURE 3-1. SOLAR THERMAL POWER SYSTEM CONFIGURATION

Auxiliary power systems may also be needed, either at the site or elsewhere on the utility grid. Another form of system integration involves the design of solar total energy systems. These will use thermal energy rejected from the electricity generating subsystems of distributed collectors to provide space heating and cooling.

In summary, solar thermal power systems utilize solar radiation to heat a working fluid to a temperature high enough to power a turbine. The turbine's mechanical output can be used to drive an electric power generator which produces electricity.

B. SIGNIFICANT ENVIRONMENTAL CONCERNS

Initial deployment of large scale, centralized receiver facilities will probably occur in the desert ecosystems of the Southwest. Therefore, environmental concerns result from the aridity of the region and the fragility of its ecosystems.

Some of the concerns discussed in Section 4 and presented in Appendix A include impacts caused by intensive use of land, uncontrolled release of toxic fluids, and runoff into neighboring ecosystems.

C. PROGRAM STATUS

1. Technology Program

The Solar Thermal Power Systems Program has three program areas:

- Central Power Applications
- Dispersed Power Applications
- Advanced Thermal Technology

Central Power Application programs focus upon large thermal plants ranging from 10 MWe to 500 MWe, potentially forming an integral part of existing electric utility networks. Current designs should achieve working fluid temperatures of approximately 540°C but doubling that is a 1985 technical objective. A 10-MWe demonstration plant is under construction in Barstow, California, and should begin operation in 1981. Central receiver systems that replace fossil fuel combustion equipment at conventional power plants may be in operation by 1984, and the first full-scale all-solar system should be on-line about 1988. Projected energy contributions from STPS have been estimated in various studies, three of which are compared in Table 3-1.

TABLE 3-1. PROJECTED STPS ENERGY CONTRIBUTIONS

Study	YEAR 2000	2020
MITRE[1]	0.35	2.9 quads
Solar Domestic Policy Review	0.4 (maximum practical)	-
CEQ[2]	1.4	5-10 quads

To visualize the scale of possible deployment, note that each quad would require the construction of 800 power tower facilities (100 MWe) or their equivalent, and even 0.4 quad would require 320 power towers.

Three types of utility applications have been identified:

- Solar/Storage Systems. These solar plants are characterized by the use of energy storage subsystems. The options being developed are a baseline system (a central receiver plant using steam conversion), near-term alternatives to the baseline system (e.g., central receiver systems using sodium heat receiver/steam-Rankine cycle; distributed collector systems), and advanced systems for longer term development (e.g., central receiver or distributed collector systems using very-high-temperature Brayton engines).

- Solar/Fossil Hybrid Systems. This application involves the combined use of solar thermal and fossil fuel technology in new power plants.

- Repowering of Existing Fossil-Fueled Power Plants. The third central power system under consideration involves the retrofitting of existing fossil fueled power plants with solar thermal technology.

Dispersed Power Application programs focus on small scale, "on-site" uses. Potential applications include irrigation pumping and small solar power systems wherever electricity costs are high. An irrigation experiment will be underway in 1979, and a site will be selected in 1979 for a small community application. Similar systems will be used to develop agricultural and industrial process heat during the 1980s (see Solar Agricultural and Industrial Process ERD).

Three systems have been identified for dispersed power:

- Solar Total Energy Systems. These systems are designed for "cascading" energy use, i.e., the thermal energy rejected from the electricity generating subsystem is used to provide space heating and cooling, domestic water heating, and process heat needs. Applications will be in the 0.5- to 10-MWe range.

- Small Solar Power Systems. These solar plants will be in the 1- to 5-MWe range, and will likely be utilized in municipally-owned power systems. Both line-focusing and point-focusing distributed collector/concentrator subsystems are being considered for small power systems.

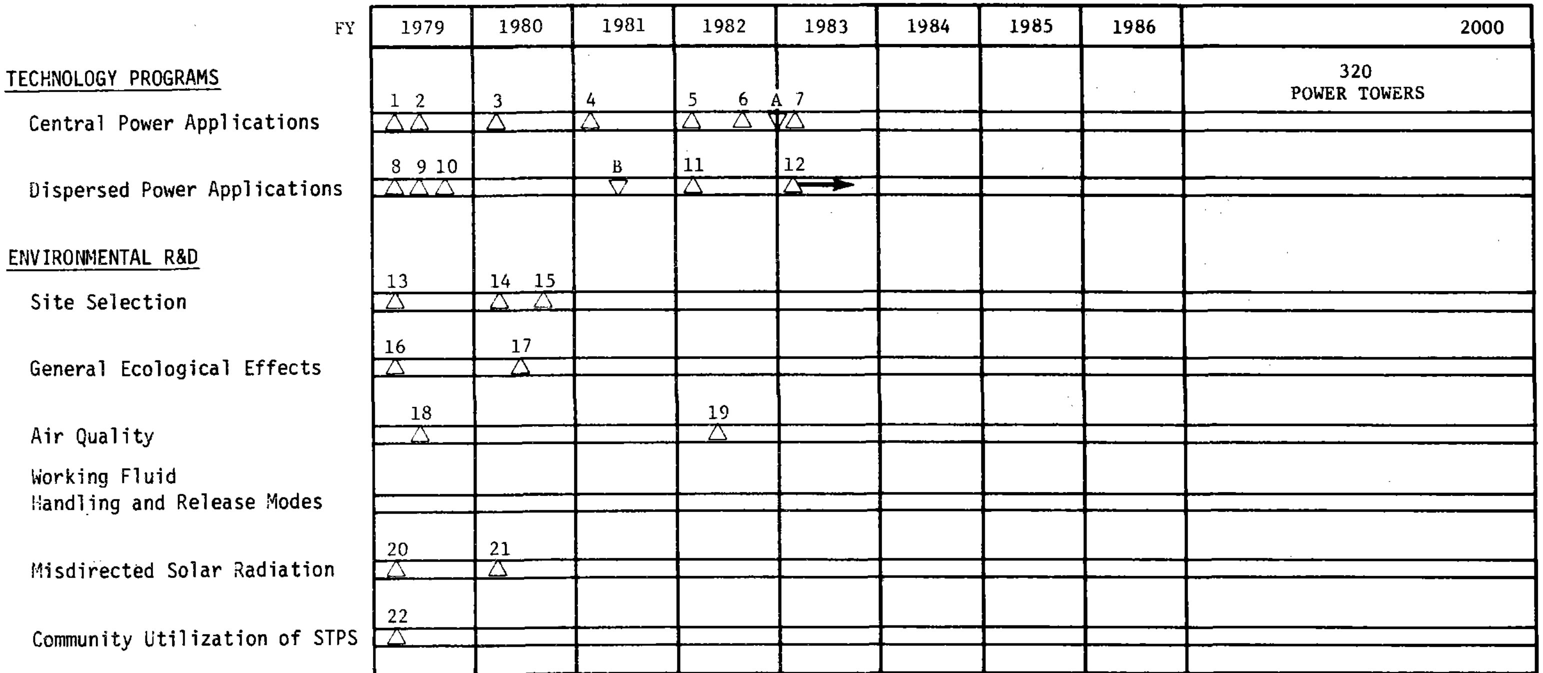
- Irrigation Pumping Systems. This application involves the replacement of fossil-fueled irrigation pumps with small (under 500 kW) solar-powered systems. Electrically-powered pumps are longer range candidates for replacement.

Advanced Thermal Technology includes the definition of potential applications, screening for cost-effective systems and development of essential subsystems. For example, studies on new reflector materials or working fluids are supported under this program.

2. Environmental Program

In Figure 3-2, milestones for current, planned, and possible environmental research projects are compared with technology schedules. Studies on environmental effects (ecological and microclimatic), air quality impacts , working fluid impacts, and heliostat problems are either on-going or planned. However, research on site selection is not yet in place. As much as $2,000,000 in additional support may be needed for FY 1980 and beyond to complete all environmental studies. (This does not include the $150,000 required to do an 18-month ecological baseline study at one or more sites.) See Appendix A for details.

From Figure 3-2, it appears that most of the required environmental studies will be completed or underway well before major developments in the solar thermal power technology.



MILESTONES:

Central Power Applications

1. Start Construction of 10 MW Baseline Project
2. Begin 50 MW Repowering Study
3. Begin 50-300 MW Solar Hybrid Studies
4. Construction of 25 MW Repowering Project
5. Operation of 10 MW Baseline Project
6. Construction of 50 MW Repowering Project
7. Construction of 50-300 MW Projects

Dispersed Power Applications

8. Operation of Irrigation Experiment
9. Small Community Application
10. Construction of Total Energy Systems
11. Industry Demonstration Projects Begin
12. Industry Demonstration Projects Continue

Environmental R&D

13. Land Requirements Quantification
14. Planning Methodology
15. Water Availability
16. Continued Ecological Monitoring
17. Microclimate Simulations
18. Field Tests on Molten Sodium
19. Monitor Gas Production
20. Assess Heliostat Hazards
21. Monitor Heliostat Installation
22. Technology Assessment of Onsite Use

Symbols: Program Milestone △

Decision Point ▽

Activity Bar

DECISIONS:

A. Scale-up Decision 1/83

B. Decision of Need for Commercial Applications 4/81

FIGURE 3-2. SOLAR THERMAL POWER SYSTEMS TECHNOLOGY AND ENVIRONMENTAL MILESTONES

SECTION IV. ENVIRONMENTAL ANALYSIS AND ASSESSMENT

Large scale centralized STPS are land and capital intensive. Sites for early development will probably be in remote areas of southwestern deserts. The primary environmental concerns will be worker safety on-site, and ecological impacts off-site.

Smaller scale, dispersed receiver STPS are likely to be located near areas already developed for agriculture or industry. The primary environmental concerns will be protection of health and property.

A. CONCERNS

Table 4-1 lists the environmental concerns and analyzes their significance. Some concerns identified in this table are generic in nature and include elements common to both centralized and dispersed receiver systems, such as fluid management and misdirected reflections from collectors. Other concerns are specific to centralized receiver systems, such as effects of the technology on desert ecosystems. The need for planning guidelines for local governments contemplating incorporation of STPS tends to be specific to dispersed receiver systems.

All of the concerns are judged to be realistic, partly because of lack of observational data or operational experience with the technology, and partly because elements of the technology have a history of high risk. The hazardous nature of proposed working and thermal storage fluids is recognized. Severe burns can be caused by molten salts or hot hydrocarbon oils. The hazard of misdirected radiation from heliostats has already been experienced. With regard to on-site operations, both are occupational hazards where risks can be greatly mitigated by definition of, and compliance with, safety standards and procedures, many of which are already known.

1. General Ecological Effects (Concerns 2, 3, and 4)

Construction and maintenance of heliostat fields could significantly modify native communities and impact surface and groundwater conditions. The nature of these effects will depend on the details of the heliostat field. Some designs would require paving or chemically treating the field to control dust or vegetation which interferes with heliostat operation. Other designs might require initial denudation of the field followed by regrowth of vegetation under the mirrors. Since the microclimate under the mirrors will be cooler and moister than under natural conditions, this environment will probably support different vegetation. In all cases, the native ecosystems in the fields would essentially be destroyed.

TABLE 4-1. SIGNIFICANCE OF CONCERN OF SOLAR THERMAL POWER SYSTEMS

Environmental Concern	Status (State of Knowledge)	Research Time	Likelihood of a Finding Adverse to Technology Development*	Additional Mitigation Cost ($)**	Program Delay	Environmental Risk of Proceeding with Technology Development
Column Content Concern Statement as provided in Appendix A	Present Knowledge of: -severity of hazard -adequacy of control	Years of required research (as in Appendix A)	Estimate of probability of adverse finding (high, medium, or low) and character if likely adverse finding	The total cost (direct) and indirect) of controls that may be required in the event of adverse finding	Period of program delay that may result from adverse finding	Assessment of risk of proceeding with technical development schedule in light of state-of-environmental knowledge, research schedule, and uncertainty of research outcome
1. Institutionally Related Environmental Impediments. Generic locations for early development of central STPS will probably be in southwestern deserts. The technology is land and water intensive.	Technology requirements are well enough known to define site requirements. (a) Land requirements are probably larger than early estimation of 1 or 2 sq. mi/ 100MWe, if a large exclusion area is included to reduce risk to public or misdirected heliostat reflection, and/or to reduce fugitive dust from other activities. Convenient large tracts of land may not be in the public domain (see: BLM Desert Management Plan, DOD Military reservation requirements, Status of Indian lands, and Railroad right of ways). Preliminary study has been completed to identify potentially serviceable sites.	2-3 years. Need to identify candidate STPS sites soon in cooperation with BLM. Questions of land title and water rights should be addressed immediately.	(a) Low - about 5,000 sq. miles of desert in California alone is presumed available from early studies.	(a) May require purchase of small parcels of land to complete tract or secure water rights.	Resolution of land title and water rights questions could cause significant delays. Exploration for mineable water may be necessary.	None.
	(b) Availability of water at sites identified in (a) not known. Easily accessible water is presently allocated to other purposes. Water could be mined from ancient aquifers but quality and quantity uncertain.		(b) High - Water rights and allocations are likely to be the determining factor in desert siting.	(b) Water delivery cost currently underpriced.		
	(c) Transmission line corridors, service and access roads may represent a greater threat to desert environment than the site proper.		(c) Low-land is available.	(c) Cost may increase if indirect route required to avoid sensitive or restricted areas. In summary, additional costs are not expected to be significant.		

*LOW -- 0.1-0.3 probability of occurrence
MEDIUM -- 0.4-0.6 probability of occurrence
HIGH -- 0.7-0.9 probability of occurrence
**These are order of magnitude of cost estimates

TABLE 4-1. SIGNIFICANCE OF CONCERN OF SOLAR THERMAL POWER SYSTEMS

Environmental Concern	Status (State of Knowledge)	Research Time	Likelihood of a Finding Adverse to Technology Development*	Additional Mitigation Cost ($)**	Program Delay	Environmental Risk of Proceeding with Technology Development
2. General Ecological Effects. The generic location for early development of central STPS will probably be in southwestern deserts. Desert ecosystems are poorly understood. What is known indicates that they are fragile, and it is certain that disruption of such ecosystems will either be irreparable or very long lasting. One consequence is that many of the supporting systems to STPS, which are common to conventional technologies, cannot be ignored on the grounds that their impacts are fully understood. In addition to the ecological effects of the STPS desert site proper, effects of cooling tower drift, transmission corridors, access and service roads, changes in ground water level, and construction activities must be addressed as if specific to central STPS.	Development of an STPS site will certainly destroy the natural ecosystem on and immediately adjacent to the site. Transmission line corridors and service roads historically have provided access to otherwise remote areas for recreational purposes, which, in turn, impact a much larger area than the primary site and roads combined. Productivity in desert ecosystems is almost entirely dependent on a delicately balanced water budget. Construction activities and Boom Towns associated with remote sites impact a much larger area than the final developed site. Studies are in progress to follow ecological changes during the development and operation of the 10 MWe STTF at Barstow, CA; and to study ecological and microclimate effects of different solar collector systems.	3-5 years. Ecological questions are not likely to be completely answered before decisions will be made regarding STPS development. Fundamental research on desert ecosystems should be encouraged in parallel with technology development.	Low - Barring catastrophic events ecological systems respond to insult very slowly. The significance of possible findings is subject to a value judgment based upon attitudes of proper use of desert lands. May restrict site selection.	----------- N/A	Probably dependent upon attitude of environmental groups. Much of the desert area potentially useful for STPS is characterized as perturbed successional stages following intensive land use, whether from grazing, military maneuvers, or recreational vehicles. There is a real possibility that some desert areas could be enriched or "improved" by development. A great deal of the concern for the consequences of disrupting desert ecosystems arises from the novelty of the technology and lack of knowledge of the sensitivity of desert species and the workings of desert ecosystems.	Medium - If they occur, undesirable latent effects are likely to be irreversible. Effects, however, are likely to be highly site specific. It is important that candidate sites be identified for timely assessment.

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MEDIUM -- 0.4-0.6 probability of occurrence
HIGH -- 0.7-0.9 probability of occurrence
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Environmental Concern	Status (State of Knowledge)	Research Time	Likelihood of a Finding Adverse to Technology Development*	Additional Mitigation Cost ($)**	Program Delay	Environmental Risk of Proceeding with Technology Development
3. Microclimatic Effects. Large central STPS will cause local changes in patterns of absorption of solar radiation and thermal albedo. These will probably be accompanied by changes in air flow which will be further modified by the heliostat arrays. The magnitude of these changes will be closely coupled to the facility design and the management strategy applied to the ground surface in the heliostat field. These variables plus disturbances caused by construction activities, such as fugitive dust, may have significant effects on adjacent ecosystems.	Modeling has been done which predicts reduction in soil surface temperatures, reduced evapotranspiration, and shading within the heliostat field. Air flow changes across the heliostat field are likened to changes caused by a forest with clearly defined borders. Studies are in progress at the 10 MWe STTF near Barstow, CA to monitor microclimatic and ecological conditions before and during construction, and during STTF operation. It is unlikely that catastrophic effects will be observed in adjacent ecosystems As a consequence more subtle indicators of ecosystem change must be followed. The study is programmed to continue through FY 1981. Microclimatic and ecological effects of different solar collector systems is also under study and is scheduled for completion in FY 1980.	2-3 years.	Low - if modeling predictions are verified by field study. Some expense can be anticipated for control of fugitive dust during construction. If changes in the adjacent ecosystem occur it is likely they will be traced to altered water balance. Might be mitigated by irrigation.	------------ N/A	Insignificant.	Very low - Effects if they occur should be restricted to a relatively small area around the heliostat field. Some alteration of adjacent ecosystem may be acceptable. Acceptability, however, must be determined on a site specific basis.

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TABLE 4-1. SIGNIFICANCE OF CONCERN OF SOLAR THERMAL POWER SYSTEMS

Environmental Concern	Status (State of Knowledge)	Research Time	Likelihood of a Finding Adverse to Technology Development*	Additional Mitigation Cost ($)**	Program Delay	Environmental Risk of Proceeding with Technology Development
4. Air Quality. There is a possibility that the high temperature produced at the receivers in systems concentrating solar radiation may initiate chamical reactions in the atmosphere to generate harmful pollutants such as nitrogen oxides from oxygen and nitrogen. STPS receivers located in areas with poor air quality or adjacent to conventional power plants might produce a variety of other pollutants. Degradation in air quality from evaporation of working, storage, cooling, and cleaning fluids may be significant in case of accident or improper fluid management.	Poor. However, studies are in progress, and are proposed, to study fate of molten sodium released to environment and chemical and physical characterization of likely STPS fluids.	2-3 years.	Medium - If concern is proven to be justified, constraints on location of STPS may result. It is unlikely that STPS operation in areas of good air quality would compromise air quality below federal standards by pollutants formed at the receiver. If pollutants are formed, the rate of production may be a function of the dwell time of the air mass next to the receiver. Problem, if real, might be mitigated by controlled air flow around receiver. Except for catastrophic events, evaporation problems should be controllable.	N/A	Additional cost less than 3-7%.	Low.
5. Working Fluid Handling and Release Modes. Candidate working/storage fluids for STPS include liquid sodium, sodium hydroxide, hydrocarbon oils, and eutectic salts. In addition undefined cleaning solutions may be used routinely to clean heliostat surfaces. Mishandling of these fluids represent a serious threat to plant personnel. Accidental or emergency release of the fluids could cause fire, explosions, contamination of surface and ground water, and impact both aquatic and terrestrial ecosystems. Normal system flushing represents similar threats and introduces a problem of waste disposal. The fluids of concern and the consequence of their release is dependent on whether the facility is centralized or dispersed, and the nature of the ecosystem impacted.	All fluids identified are currently used in other industries. Procedures for their safe handling are known. Existing water quality regulations will closely control potential fluid release. The consequences of accidental spills or runoffs on desert ecosystems are not known. Projections of effects vary from disastrous to inconsequential. The consequences of fluid releases on agricultural ecosystems are not known. They are presumed to be serious because of proximity to commercial crops. This may be mitigated by use of lesser volumes of fluids and possibly less toxic fluids.	2-3 years.	Low - Uncontrolled, intentional or accidental release of large quantities of working fluids on or adjacent to the STPS site is presently unacceptable. Research is required to determine the degree of control necessary. Potential effects of spillage and resulting control requirements may be site specific.	N/A	Additional cost less than 10%.	Low

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5. Working Fluid Handling and Release Modes. (cont'd)	Methods for disposal of used fluids are not clearly defined. Depending on regulatory body involved, wastes may require transport to a Class I disposal site.					
6. Misdirected Solar Radiation. Misalignment of heliostats during operation, or accidental reflections of solar radiation from heliostats during installation, are serious hazard to workers in centralized STPS. A lesser but significant hazard is also associated with dispersed STPS. Consequences of misdirected solar radiation range from fire, to bodily harm, to glare in off-site areas.	Considerable research has already been done concerning optical effects and safety procedures for heliostat alignment during power plant operations. Off-site problems associated with misdirected reflections appear to be limited to glare. The seriousness is dependent on plant design and consequent focal length. Ecological effects of glare whether as an accident or in normal operation need to be considered. For example, what will the effect of glare from normal operations be on bird behavior? A comprehensive assessment of potential hazards and development of guidelines and standards for heliostat manufacture, transport, and installation has not been done. Preparation of guidelines and standards is proposed for FY 1979, hopefully in time to be applied, tested, and modified during installation of the heliostats at the 10MWe STTF near Barstow, CA in FY 1980	1 year.	Very low - Primary concern is with defining adequate safety procedures. May increase cost of installation slightly by either slowing rate of installation or through cost of protective equipment.	N/A	None - Experience at the 5MWe STTF at Albuquerque should provide reasonable interim guidelines.	Low - Wildlife may be attracted, repelled, or unaffected by C/P site glare. Exclusion area around site may be desirable for public safety.

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7. Community Utilization of STPS. The location of dispersed STPS are likely to be near urban, industrial, and agricultural areas. Integrating STPS technology into the social and institutional structure requires resolution of such issues as land use, sun rights, zoning, and consumer/utility interfaces. These issues should be addressed prior to the availability of the technology.	The issues can be reasonably identified but the information required by local government for reasonable planning and decision making is neither readily available nor in a useful form. Preparation of guidelines for local governments as to issues to be considered, options for dealing with those issues and the likely consequences of different policy options is in progress.	2 years.	Low.	------------	None - Guidelines could enhance utilization of dispersed STPS by providing procedure for phasing technology into community requirements.	None.

*LOW -- 0.1-0.3 probability of occurrence
MEDIUM -- 0.4-0.6 probability of occurrence
HIGH -- 0.7-0.9 probability of occurrence
**These are order of magnitude of cost estimates

The ecological impacts of desert-sited solar central power plants are of particular concern. These plants will require large tracts of land for heliostat fields, 2 square miles (5.2 million square meters) or more per 100-MWe capacity.[3] Large-scale deployment of heliostat fields could modify or destroy desert communities either directly or by changing adjacent microclimate. Since the desert ecosystem is finely balanced and therefore fragile, regeneration of native communities would take many years. Although only a few solar power plants will be built in the next 15 years, it is important to begin analyzing the possible adverse ecological effects. The issue is novel and lacks adequate observational data. Early assessment of the impacts associated with small-scale power plant deployment will yield sufficient data for projections of the adverse effects of widespread deployment. Mitigation strategies can subsequently be developed.

The following discussion is concerned only with desert-sited solar central power plants. Although the northern great plains include many potential sites,[4] all plants scheduled for near-term construction will be located in the southwest. Furthermore, the ecological impacts of dispersed power systems are not as yet a key concern, since most of these systems will likely be deployed in areas already modified for agricultural, industrial, or residential purposes.

After vegetation destruction, wildlife dependent either directly or indirectly on this vegetation will probably migrate to suitable areas. These adjacent areas would experience population increases and possible overcrowding effects. Additionally, the presence of STPS could significantly alter the habitats of rare or endangered species, e.g., the Gila monster, the spotted bat, and the spot-tailed earless lizard.[5]

Herbicides or chemical dust suppressors applied to the field could contaminate groundwater and ultimately drinking water supplies. Paving the heliostat field could also significantly impact both desert wash areas and groundwater conditions. Many wash areas could be graded and paved over, thus removing them as watering areas for many desert animals. This could result in the overuse of adjacent washes; plant and animal populations may be reduced because of insufficient water supplies. The paved surface, by concentrating precipitation runoff, may create gullies and/or alter stream beds thereby forming new washes while destroying existing ones.

Paving could decrease surface permeability, reducing infiltration and increasing runoff. Reduced infiltration could lower groundwater levels. In addition, depending upon the slope of the field and the underlying geologic conditions, the direction of the groundwater flow could be altered. Flow alteration could potentially affect groundwater availability for downstream consumers and spring formation.

2. Health and Safety Concerns (Concerns 5 and 6)

Handling and disposal of system fluids and wastes may result in serious pollution and safety problems. Candidate working/storage fluids for solar thermal power systems include liquid sodium, sodium hydroxide, hydrocarbon oils, and eutectic salts composed of sodium or potassium nitrates/nitrites. Accidental or emergency release of these fluids could cause fires and explosions, contaminate drinking water supplies, increase soil salinity, and impact both terrestrial and aquatic communities. Additionally, periodic system flushing for maintenance could result in the same health and pollution impacts, as well as reduce the effectiveness of conventional sewage treatment systems.

Of particular concern are the eutectic salts. Solar central power plants and various dispersed power applications may use these salts for working/storage fluids. In such instances, both plant personnel and area residents may be exposed to dangerous conditions should these salts be released. Skin contact with molten salts will result in severe burns; even contact with cold salts should be avoided since they are hygroscopic and will absorb water from tissues.[6] The eutectic salts are also potentially serious fire hazards. When heated to temperatures above 716°F (380°C), as during a fire, these salts rapidly decompose releasing oxygen and thereby fuel an existing fire. At higher temperatures (around 1832°F or 1000°C), or when subjected to extreme shock, closed containers of these substances can rupture or explode and ignite adjacent combustibles. Fire problems are further compounded by the release of toxic nitrogen oxides during sodium nitrate/nitrite decomposition. These fumes are irritants of the respiratory tract causing congestion of the throat and bronchi and the edema of the lungs.[6]

Flushing or accidental release of eutectic salts or nitrate/nitrite additives (used in water-based systems) could contaminate groundwater, local waterways, and soils. For desert-sited solar power systems, groundwater containing nitrates and nitrites may enter aquifers, which are the primary sources of drinking water in arid regions. These salts could also enter waterways located near dispersed power applications. Thus, drinking water supplies could be contaminated. Ingestion of such water might result in the toxic effects described in the discussion on potable water contamination. Eutective salts and nitrate/nitrite additives released to soils could increase soil salinity, killing vegetation and soil microfauna, as well as disrupting nutrient cycling. This could significantly impact farms utilizing solar irrigation pumping systems.

In addition, release of nitrates and nitrites into lakes and rivers could stimulate floral growth resulting in reduced dissolved oxygen levels and high biological oxygen demand. Disposal or leakage of other additives (used in water-based systems), such as phosphates, sulfates, and sulfites may also cause similar algal and plankton blooms. The Environmental Protection Agency maximum allowable concentration of sulfates in fresh water used for drinking water supplies is 250 milligrams per liter (mg/l), while the maximum concentration of sulfites for freshwater aquatic life is 0.002 mg/l.[7]

Hydrocarbon oils are potential safety and pollution hazards. At temperatures of 355°F (180°C), the oil vapors will combust if exposed to air; at temperatures of approximately 382°F (194°C), the liquid oil itself will combust. Hot hydrocarbon oils will cause severe burns if they come in contact with the skin. Oil contamination of nearby soils would likely kill any vegetation and prevent regrowth. The release of heavy oils could also significantly degrade water quality. Oils can coat and suffocate aquatic organisms, as well as add to the biological oxygen demand. Furthermore, if ingested in large quantities, these high molecular weight compounds exhibit anesthetic effects and, at the same time, an increasing irritant action as molecular weight accrues. As a result, the EPA has stated that oil should be essentially absent from raw water used for drinking supplies.

Some advanced solar thermal electric designs have proposed using liquid sodium as a heat transfer medium. Either small or large ruptures in such systems could release sodium to the working area. When exposed to air, elemental sodium burns to form sodium monoxide (Na_2O) and sodium peroxide (Na_2O_2). Both oxides of sodium, upon contact with water directly or moisture in the air (or on flesh), are readily converted to sodium hydroxide (NaOH). A similar result is obtained when elemental sodium directly contacts water forming, through a vigorous reaction, sodium hydroxide and hydrogen gas. This latter reaction could generate sufficient heat to ignite combustibles; in addition, the released hydrogen could burn explosively.[5]

Whether in the form of an aerosol, a solid, or in concentrated solution, sodium hydroxide can be quite harmful. It is an extremely corrosive material; in concentrated form, NaOH causes burns and deep ulceration, with ultimate scarring. Mists, vapors, and dusts of this compound cause small burns, and contact with the eyes, either in solid or solution form, rapidly causes severe damage to the delicate tissue. Inhalation of the dust or concentrated mist can cause damage to the upper respiratory tract and to lung tissue, depending on the severity of the exposure. If aerosols of the sodium oxides were inhaled or contacted by moist skin, similar problems would be encountered, since the oxides would form sodium hydroxide upon contact with tissue moisture.[6]

There is a possibility of nitrogen oxide production due to high temperatures at the power tower, but this must be assessed further. The consequences to the off-site area bordering an STPS facility of normal glare, misdirected reflections, controlled or accidental fluid releases, normal runoff, lowering water tables, or microclimatic changes are uncertain. In all cases, the environmental risk of proceeding with technology development is low. It is likely that if significant effects are found they can be mitigated, or they will represent a siting constraint rather than a technological barrier.

3. Land Use and Institutional Issues (Concerns 1 and 7)

To the extent that sites for early large scale centralized STPS are limited to southwestern deserts, site selection must be acknowledged as a potential problem that may impact both rate and cost of exploitation. Land requirements may be larger than the 1 or 2 $mi^2/100$ kW currently envisaged. A larger exclusion area may be required to reduce production of fugitive dust by other activities or to reduce risk to public of misdirected reflections.

Many convenient large tracts of land may not be available. The Bureau of Land Management is currently developing a desert management plan which includes identification of areas for protection under the National Wilderness Protection Act. Military reservations, Indian lands, and railroad rights-of-way further partition the apparent continuous desert expanses. It should be noted that easily accessible water is currently allocated to other purposes and that present water delivery costs are underpriced. Purchase of small parcels of land may be necessary to either secure water rights or complete a tract.

Environmental impacts of supporting subsystems to STPS, which are common to other power generation technologies, such as cooling towers, transmission line corridors, access and service roads, and construction towns are acute in desert environments, where disruptions are likely to be either irreparable or very long lasting. In fact, recreational use of service roads for access to remote areas characteristically has impacted areas many times the size of the site the road was intended to service.

Because STPS is relatively material intensive per unit power delivered, pollutant residuals and associated occupational hazards will result from STPS materials manufacture. The significance of this is a question of the scale of STPS use, but is regarded as a minor near-term concern. Long-term implications are being evaluated by DOE.

B. IMPACT OF REGULATORY STANDARDS

As shown in Table 4-2, Water Quality Standards are the predominant controlling regulations. Taken in conjunction with the Toxic Substances Control Act, all fluids may require collection and disposal at approved site. Objections by groups challenging restricted use of deserts or impairment of scenic beauty should not be underestimated. Examples include ORV (off-road vehicle) clubs vs. BLM and Thousand Palms, California vs. power transmission lines.

TABLE 4-2. IMPACTS OF REGULATORY STANDARDS ON SOLAR THERMAL POWER SYSTEMS

LEGISLATION	POLLUTANT/ENVIRONMENTAL CONCERN	CURRENT/PROPOSED STANDARDS	POSSIBLE NEW STANDARDS
<u>Clean Air</u> NSPS PSD Non-Attainment Visibility	With the exception of particulate release during construction and emissions due to accidental leakage, air pollution is not presently known to be associated with this technology.		
<u>Clean Water</u>	-Disposal of system fluids and wastes -Accidental leakage of heating fluid -eutectic salts -phosphates -sulfates/sulfites -hydrocarbon oils -sodium hydroxide	Oil and hazardous pollutant effluent limitations regulate spills of such pollutants from all potential sources including fixed facilities. Oil discharges specifically regulated. Thermal discharge requires NPDES permit.	Best Management Practice levels will be set to control runoff of toxic and hazardous material from individual indutrial sites due to poor housekeeping (leaks)
Resource Conservation and Recovery Act	Disposal of system fluids and wastes		
Toxic Substances Control Act	Chromate Borate Nitrate/nitrite Sulfate/sulfite Arsenate Benzoate salts Glycols Chlorinated phenols	The chemicals used as corrosion inhibitors may be designed as a a "significant new use" in accordance with Section 5 of TSCA.	Regulations for "significant new uses" will be developed in the future.
Federal Pesticides Control Act	Herbicides and chemicals from heliostat construction.	Herbicide use is restricted and users require certification.	

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APPENDIX A

MAJOR ENVIRONMENTAL REQUIREMENTS AND R&D

APPENDIX A - MAJOR ENVIRONMENTAL REQUIREMENTS AND R&D

Concerns	Requirements and R&D	Estimated Research Completion Time (yr)	Resources ($)		Environmental R&D "Uncertainties"
			Project Status*	Additional **	
1. Institutionally Related Environmental Impediments Generic locations for early development of central STPS will probably be in southwestern deserts. The technology is land and water intensive.					
1.1 Land requirements are probably larger than early estimation of 1 or 2 sq. mi/100MWe, if a large exclusion area is included to reduce fugitive dust from other activities. Convenient large tracts of land may not be in the public domain (see: BLM Desert Management Plan, DOD Military reservation requirements, status of Indian lands, and Railroad right of ways).	1.1 Assess land requirements for individual sites, total land requirements, land availability, competition for land use, and legal/institutional barriers constraining the acquisition of land. Develop criteria for site selection. Develop plan for dealing with factors (particularly institutional factors) that constrain land use.	2	Not in place.	$200K.	Considerable uncertainty attaches to problems of land use and site selection.
1.2 Availability of water may severely restrict site selection either because of alternative water demands or cost of delivery.	1.2 Assess water requirements for individual sites, total water requirements, water availability (from point of view of both quantity and proximity to probable sites), competition for water use, and legal/institutional barriers to water use. Develop plan for dealing with institutional and other factors that constrain water use.	2	Not in place.	$200K.	Considerable uncertainty is associated with the question of water availability.

*Ongoing, planned, or not in place
**FY 1980 to completion

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Concerns	Requirements and R&D	Estimated Research Completion Time (yr)	Resources ($)		Environmental R&D "Uncertainties"
			Project Status*	Additional**	
1.3 Transmission corridors and access roads may represent a greater threat to desert environment than the site proper.	1.3 Assess needs, land availability, and adverse impacts associated with the construction of transmission corridors and access roads. Identify and characterize major needs and impacts. Develop plan for mitigating constraints and impacts.	1-2	In place, but in support of transmission corridors for conventional power plants.	$150K.	Plans for dealing with special problems associated with transmission corridors and access roads are not defined and constitute a source of uncertainty.

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**FY 1980 to completion

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Concerns	Requirements and R&D	Estimated Research Completion Time (yr)	Resources ($) Project Status*	Resources ($) Additional**	Environmental R&D "Uncertainties"
2. General Ecological Effects The generic location for early development of central STPS will probably be in southwestern deserts. Desert ecosystems are poorly understood. What is known indicates that they are fragile, and it is certain that disruption of such ecosystems will either be irreparable or very long lasting. One consequence is that many of the supporting systems to STPS, which are common to conventional technologies, cannot be ignored on the grounds that their impacts are fully understood.	2.1 Fundamental Research on desert ecosystems.	5	Ongoing		2.1 Desert ecosystems fragile - workings not well known -- resiliency of ecosystem low - possibility of irreparable damage.
	2.2 Study of ecological and microclimatic effects of different solar collector systems.	2	Ongoing	$65K	2.2 Microclimatic effects and subsequent ecological impacts undocumented. Probably function of solar collector design and dispersal, and management of soil surface beneath collectors.
	2.3 Ecological characterization and monitoring of the 10 MWe STTF at Barstow, California.	3	Ongoing	$350K	2.3 First opportunity to monitor both site and adjacent desert area before, during and after site development.
	2.4 Vegetation management and recovery studies at sites disturbed by STPS development.	2	Planned	$84K	2.4 Feasibility and/or practicality of revegetating disturbed area within the heliostat field to control erosion untested. Revegetation may be required if site decommissioned.
	2.5 Ecological characterization and monitoring of candidate STPS sites.	1½/site	---	$150K/yr/site	2.5 Most desert ecology problems highly site specific. Candidate sites should be identified early to permit assessment.

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3. <u>Microclimatic Effects</u> Large central STPS will cause local changes in patterns of absorption of solar radiation and thermal albedo. These will probably be accompanied by changes in air flow which will be further modified by the heliostat arrays. The magnitude of these changes will be closely coupled to the facility design and the management strategy applied to the ground surface in the heliostat field. These variables plus disturbances caused by construction activities, such as fugitive dust, may have significant effects on adjacent ecosystems.	Microclimatic effects are worthy of special note. However, they are considered as one aspect of ecological study. <u>The subject is addressed in items 2.2 and 2.3 currently in progress</u>.				

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Concerns	Requirements and R&D	Estimated Research Completion Time (yr)	Resources ($) Project Status*	Resources ($) Additional **	Environmental R&D "Uncertainties"
4. Air Quality There is a possibility that the high temperature produced at the receivers in systems concentrating solar radiation may initiate chemical reactions in the atmosphere to generate harmful pollutants such as nitrogen oxides from oxygen and nitrogen. STPS receivers located in areas with poor air quality or adjacent to conventional power plants might produce a variety of other pollutants. Air quality may be further degraded by release of working fluids to the atmosphere.	4.1 Analytical study and computer modeling to scope magnitude of problem.	1-2	Not in place	$75K	Concern equivocable. Effects could be amplified in area with low ambient air quality. Information on process-specific and site-specific impacts on air quality needs to be augmented.
	4.3 Conduct field tests to characterize behavior of molten sodium on release into the atmosphere. By measurement, characterize aerosol particles in terms of physical and chemical properties, determine chemical modification and atmospheric transport of particles, define deposition pattern of airborne material, and observe interaction with other chemicals.	1	•Ongoing		
	4.4 Evaluate sensitivity of the rat to short-term exposures by inhalation to molten sodium in aerosol form. Determine aerosol concentration that produces significant symptoms in 50% of exposed animals (ED_{50}).	2	Ongoing	$100K	
	4.5 Determine need for controls. Identify and assess candidate controls.	2	Not in place	$50K	
			•This is being supported by the nuclear (fission) and solar programs.		

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Concerns	Requirements and R&D	Estimated Research Completion Time (yr)	Resources ($) Project Status*	Additional**	Environmental R&D "Uncertainties"
5. <u>Working Fluid Handling and Release Modes</u> Candidate working/storage fluids for STPS include liquid sodium, sodium hydroxide, hydrocarbon oils, and eutectic salts. In addition undefined cleaning solutions may be used routinely to clean heliostat surfaces. Accidental or emergency release of the fluids could cause fire, explosions, contamination of surface and ground water, and impact both aquatic and terrestrial ecosystems. Normal system flushing represents similar threats and introduces a problem of waste disposal. The fluids of concern and the consequence of their release is dependent on whether the facility is centralized or dispersed, and the nature of the ecosystem impacted.	5.1 Assess potential on-site fluid release from centralized STPS facilities and potential worker health and safety problems. Develop safety guidelines as required, and identify liquid waste disposal requirements.	1	Planned	$62K	5.1 Nature and quantities of fluids uncertain but related to STPS design. Risk analysis as a function of plant design and fluids needs to be done. Management strategy for disposal of waste fluids undefined.
	5.2 Using tiered-testing system, characterize toxicity of working fluids.	3	Ongoing	$100K	
	5.3 Assess potential effects of working/storage fluid wastes or spills from centralized STPS facilities on desert ecosystems.	1	Planned	$70K	5.3 Fate of fluids in environment undefined. Uncertainty amplified by variety of environments potentially impacted by dispersed STPS.
	5.4 Assess potential for chemical contamination of soils and groundwater by fluid release from dispersed STPS.	4	Ongoing	$150K	5.4 Degree of fixation in soils rate of degradation, rate of transport or movement through soils, and plant toxicity as a consequence of controlled or accidental release uncertain.
	5.5 Assessment of control and containment systems.	2	Not in place for "power towers"	$150K	

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			Project Status*	Additional**	
6. <u>Misdirected Solar Radiation</u>					
Misalignment of heliostats during operation, or accidental reflections of solar radiation from heliostats during installation, are serious hazard to workers in centralized STPS. A lesser but significant hazard is also associated with dispersed STPS. Consequences of misdirected solar radiation range from fire, to bodily harm, to glare in off-site areas.	This is a straightforward operational safety problem involving development of procedures and/or devices (e.g., eye protection), and safeguards.				
	6.1 Assessment of potential hazards and development of guidelines and standards for solar collector manufacture, transport, and installation.	½	Planned	$50K	Misdirected reflections are known hazard on-site. Effect of glare off-site uncertain. May affect bird behavior.
	6.2 Monitor installation of heliostat field at 10 MWe STTF for compliance with guidelines. Modify guidelines and standards as required.	1	Planned	$50K	
7. <u>Community Utilization of STPS</u>					
The location of dispersed STPS are likely to be near urban, industrial, and agricultural areas. Integrating STPS technology into the social and institutional structures requires resolution of such issues as land use, sun rights, zoning, and consumer/utility interfaces. Issues, alternatives, and consequences of policy decisions need to be identified for local governments anticipating STFS development.	7.1 Technological impact assessment to identify issues raised by STPS, as well as alternatives and consequences of policy decisions.	2	On-going	$100K to completion	Conditions limiting utilization of small scale STPS uncertain.

*Ongoing, planned, or not in place
**FY 19[illegible] to completion

GLOSSARY

BLM	Bureau of Land Management
DOD	Department of Defense
DOE	Department of Energy
ERD	Environmental Readiness Document
EV	Office of Environment
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NSPS	New Source Performance Standards
PSD	Prevention of Significant Deterioration
STPS	Solar Thermal Power Systems
STTF	Solar Thermal Test Facility
TSCA	Toxic Substances Control Act

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