REPORT OF THE WORKSHOP
ON
ECOLOGICAL IMPACTS OF SOLAR ENERGY CONVERSION

Held at

Arizona State University

Tempe, Arizona

May 11 and 12, 1978

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Duncan T. Patten

Department of Botany and Microbiology

Arizona State University

Tempe, Arizona

85281

MASTER

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Workshop: Ecological Impacts of Solar Energy Conversion

Objectives

This workshop was designed to bring together expertise from industry, academia and consulting to discuss and refine our understanding of the impacts of solar energy conversion. This was done in two phases. The first phase involved a review of the research program recommended by Patten in his Final Report to the Department of Energy titled "Solar Energy Conversion: An Analysis of Impacts on Desert Ecosystems". Included in this review was an attempt by the workshop participants to prioritize the impact parameters and establish some form of research program to evaluate these impacts.

The second phase of the workshop was to establish priority research and program needs for monitoring the impacts of the planned Solar Thermal Power System to be constructed near Barstow, California. This monitoring and research program is to be designed to be applicable to other proposed solar powered systems and should include impacts of all phases of construction, operation and maintenance.

Recommendations for research and monitoring needs were to be made primarily in relation to processes "unique" to solar conversion systems and limited mainly to ecosystem parameters. The participants recognized that other more general environmental impacts such as those from wet cooling towers or more macro-environmental impacts such as heat loss from the central towers could not be ignored in the discussion of the impacts on ecosystem parameters.

Participants and Agenda

A list of the participants and the agenda for the two day workshop are included at the end of this report.

General Background Presentations

Four presentations were given to provide the participants with background material to enable a more comprehensive discussion of the research and monitoring needs associated with solar energy conversion systems. The following summaries cover some of the major points or concepts presented in the general background talks and resulting from brief discussions following the talks.

A. "Solar Conversion Systems: A General Overview." Eugene Frankel, Department of Energy

1. Solar energy use has an optimistic future.
2. Solar technologies include: small units such as those for homes, solar thermal electric and photovoltaic.
3. Environmental impacts include social and economic as well as physical environmental and ecological. The latter two impacts are the concern of this workshop. All of these impacts relate to the legal aspects of EIS's.
4. Environmental impacts are not always deleterious. Beneficial consequences may be identifiable as a form of impact.
5. Different types of solar conversion systems were presented in illustrations. The question of the differences in impact of different types of collectors was posed as

an issue to be addressed during the workshop.

6. The time schedule for future development of solar collector systems suggests completion of the first STPS at Barstow to be 1981 and beginning of development of the second central receiver power plant 1981-82. Small scale photovoltaic systems will come on line during this period and repowering systems will be tested.

B. "Theoretical Impacts of Solar Conversion Systems."

Stanley Smith, Arizona State University

The material presented represented a review of much of the theoretical impact concepts presented in the Final Report.

1. A brief discussion of major impacts on climate, soils and hydrology, and biota brought out the following impacts:

- a. Climatic

- (1) Humidity changes due to water vapor released from cooling towers.
- (2) Fugitive dust due to clearing of site and potential increase in wind turbulence.
- (3) Change in wind patterns above and below reflectors.
 - (a) Due to presence of reflectors and possibly the central tower.
 - (b) Due to change of the pattern of heating of surface air layers.
- (4) Redistribution of thermal energy due to unusual thermal albedo.
- (5) Heat releases from central tower.

(6) Air pollution

Steam Turbine - will not occur

Gas Turbine - particulate, SO_2 , and NO_2 releases.

b. Soils and Hydrology

(1) Wind and water erosion - may be extensive unless cleared surface is stabilized.

(2) Water withdrawal.

(3) Soil compaction - potentially serious and irreversible.

(4) Off-site erosion - if site is elevated and artificially surfaced.

(5) Salt drift from cooling towers.

(6) Chemical additives in heliostat wash water.

(7) Chemical waste discharges from central receiver and laboratories.

c. Biota

(1) Semi-productive land may be removed unless revegetation is allowed.

(2) Weeds may be problem.

(3) Animals will be largely removed during construction activities. Construction of fences will preclude animal immigration back into site.

(4) Effects of reflected (and misdirected) light on wildlife behavior.

(5) Salt drift from cooling towers.

(6) Establishment of favorable microsites for plants and animals within array fields.

2. The effects of shading, wind deflection, and compaction and aboveground destruction are related to ecosystem parameter response. Table 1 shows these interrelationships as well as a composite impact of all disturbance factors.
3. Abiotic and biotic hypotheses were very briefly presented but the handouts were to be used in later discussions. The hypotheses are as follows, the biotic hypotheses are related to whether the construction site is preserved or cleared.

- a. Abiotic

- (1) Solar radiation input at the ground surface will be substantially reduced in collector arrays.
- (2) Compaction of soil will be considerable.
- (3) Soil moisture will increase with site succession, becoming greater than in the open desert.
- (4) Air, surface and soil temperatures will be reduced in the day within the array and will have less diurnal fluctuation.
- (5) Soil erosion will initially be high and will decrease with site succession.
- (6) Wind speed will be reduced, but turbulent mixing may increase.
- (7) Long-wave radiation lost from the ground will be reduced.
- (8) Albedo of the collector area will initially be very high, decreasing with site succession.

Table 1. Evaluation of the effects of shading, wind deflection, and compaction and aboveground destruction on ecosystem parameters.

PARAMETER	SHADING	WIND DEFLECTION	COMPACTION & ABOVEGROUND DESTRUCTION	TOTAL
<u>RADIATION</u>				
Available Direct	--	0		--
Available Diffuse	--	0		--
Thermal Loss	-	0	+	-
Net Radiation	--	0	-	--
<u>TEMPERATURE*</u>				
Air Temperature	-/-	+/-	-/-	-/-
Radiant Temperature	-/+			-/+
Surface Temperature	-/?	+/-	-/-	-/-
Soil Temperature	-/-	+/-	-/-	-/-
Heat Flux	-/-	+/+	-/-	-/-
<u>MOISTURE</u>				
Infiltration**	+	+	-/-	-/+
Evaporation	-	-	-	-
Transpiration	+	+	-	-/+
ET	-	0	-	-
Humidity	+	+	-	+
Soil Moisture	+	+	-	+
<u>BIOTA</u>				
Photosynthesis Rate	+	+	-	++
Leaf Temperature	-	+	-	-
Leaf & xylem water potential	+	+		+
1° Production	+	+	-	++
2° Production	+	+	-	++
Diversity**	++/++	0	-/-	-/+
Animal Density**	++/++	+	--/-	--/+
Soil Organisms**	+/++	+	--/-	-/+

** Denoted short term/long term changes

+ Increased

++ Substantially increased

- Decreased

-- Substantially decreased

* Denotes day/night changes

b. Biotic - Site Preserved

- (1) Plant and animal density and diversity will increase with time.
- (2) Photosynthesis (1^0 production) will be greater within the array than in the open desert.
- (3) Density of desert annuals, weeds, and grasses will increase within the array.
- (4) Insect numbers and diversity will increase.
- (5) Soil microorganisms, nematodes, arthropods, and burrowing animals will initially decrease, increasing with time and becoming greater than in the open desert.
- (6) Temporal patterns of animals and plants may shift.

c. Biotic - Site Cleared

- (1) Animal populations will be largely removed.
- (2) Initial plant communities will be ephemeral and weedy in nature.
- (3) Plant production will increase with time.
- (4) Animal species composition will be significantly different than in the open desert.

C. "Proposed Research Needs: A General Program."

Duncan T. Patten, Arizona State University.

This presentation reviewed some of the research recommendations made in the Final Report. The steps represent a sequential and in most cases a chronological series of research steps to analyze, validate, test and monitor

ecological impacts of solar conversion systems. This presentation was designed to generate questions for the workshop to address.

1. Theoretical analysis of impacts is the first step in a research program. This was presented by Stanley Smith. Relative to this phase of the research, have we asked the right questions, identified the significant ecosystem parameters that are effected, and developed the correct hypotheses for testing.
2. Validating or testing the theoretical ecosystem responses may be the next research phase. This needs to be done early, prior to major construction of a STPS. This can be done through studying impacts of existing solar conversion systems such as solar powered irrigation pump systems or through developing simulation sites. How applicable these validation tests might be to the actual STPS impact is a question for the workshop to address.
3. Testing of impact responses through use of alternative methods needs to be analyzed. In addition, variations in collectors, size of collector array, packing factors and different construction methods need to be studied relative to the response of different ecosystem types.
4. Baseline data must be taken prior to construction and monitoring at the Barstow STPS. Baseline and monitoring data were suggested but the workshop was charged to add specifics to this aspect of the research program.

5. The Barstow STPS could be used to test variables within the collector array and with construction methods. Such factors as vehicular traffic, washing frequency, ground surface preparation, construction intensity and packing factor variability need to be studied.
6. Future research dealing with ecological impacts of solar conversion systems should be based on data obtained from the earlier phases of the impact studies.

D. "Solar Thermal Power System at Barstow." Alexander Klein, Solar 10 MW Project Office, Department of Energy.

This presentation was designed to familiarize the workshop participants with the specifications and processes of the 10 MW solar thermal power central receiving system to be constructed near Barstow, California.

1. Ground breaking should be in the first quarter of 1979. Initial operations are planned for September 1981.
2. The design is to produce the equivalent of 10 MW for eight hours in the summer and for four hours in the winter.
3. Theoretically the plant is designed to collect all solar energy and store that which is not used immediately for later energy production. 10 MW can be produced from direct on line solar power and 7 MW from stored power.
4. Approximately 20% of the solar energy hitting the mirrors is converted to useable electric energy. This level of efficiency is based on energy losses from reflection,

tower heat loss, energy conversion to steam and turbine efficiency.

5. Energy storage of heated oil will be in an above ground storage tank approximately 50 ft diameter and 65 ft high.
6. Environmental testing is consolidated in the test plan, however, the 10 MW STPS is primarily designed to test the economic feasibility of solar energy conversion in a central receiving system.

E. "Environmental Impacts of the Barstow Facility." Charles Bell, Environmental Improvement Agency, San Bernardino, California.

This presentation was based, in part, on Mr. Bell's earlier preparation of the Environmental Impact Assessment for the Barstow STPS.

1. The site being used for the 10 MW STPS is an abandoned field (20 to 35 years). There are existing fossil fuel power facilities on site and future coal gasification facilities and other construction will be developed on site, probably upwind of the 10 MW STPS location.
2. Potential misdirected glare does not seem to be serious and the site has FAA approval.
3. A major environmental problem with the site is the fugitive dust that comes from off site and will be potentially developed on site.
4. Ground surface must be controlled but the county is discouraging paving.

5. 200 to 220 acre feet of water will be needed each year for cooling requirements. This must not be "polluted" water.
6. Vegetation and wildlife disturbance around the 160 acre site will be minimal but weed and pioneer species developing on site may be a problem.
7. Visitor impacts could be a problem.
8. Cooperation between the 10 MW STPS operating company and those doing monitoring in terms of instrumentation and sampling should be well established but may never fully develop.

A General Research Program

The general research ideas presented here as a result of small group discussions were designed to be generic in nature but it is obvious that the group discussions were oriented around the impacts of the Barstow 10 MW facility.

The groups were asked to (1) review the research design in the Final Report and to suggest modifications and (2) suggest the research directions to be taken by those who will be doing future solar conversion impact research.

1. Prime concern was with the differences in impact on site and off site. On site construction may totally destroy any vegetation or soil structure while off site disturbances during construction may be significant but with some "natural" ecosystem parameters relatively undisturbed.

2. Vegetative recovery within the collector array, a response to the abiotic environment created by the facility may be the only biotic studies useful on site. This should include studies dealing with introduction of exotic or economically important soil surface stabilizing plants. It should be recognized that different deserts may have different exotic revegetation plant species that will be successful.
3. Ecosystem parameters that appear to be critical to measure in baseline and monitoring studies include:
 - a. Fugitive dust and wind patterns
 - b. Rainfall pattern changes around large collector arrays
 - c. Soil moisture response to heliostat wash water
 - d. Evaporation rates
 - e. Erosion rates
 - f. Soil temperatures
 - g. Energy budget
 - h. Species diversity
 - i. Species habitat (abiotic) changes.
4. Research can be done to permit development of predictive capabilities.
 - a. Create changes that may be induced by the collector array to determine abiotic and biotic changes. Abiotic changes may be measured at the actual solar conversion site but biotic changes may have to be measured at a solar collector simulation site, in order to develop predictive data.

- b. Limit the testing to a few variables and develop predictive models based, in part, on ecosystem models already developed for the deserts. Data from early monitoring and simulation sites may be used to set the process ranges within the model.
5. Monitoring research should be an active rather than passive program. This means that there should be some on site controlled modifications or manipulations to determine alternative impact responses. Along with any monitoring there should be a control site at some distance from the solar conversion facility.
6. The hypotheses presented in the Final Report were considered reasonable and in most cases testable through either simulation or monitoring. Five years of monitoring, especially that dealing with vegetation recovery or reestablishment, was considered an inadequately-short period of time for study. The present Barstow site has been recovering from agriculture for 20 to 35 years and has not regained a natural state, although evidence of soil and vegetational stabilization is obvious.

To set priorities on hypotheses it was suggested that a matrix be developed examining various collector types and solar conversion systems versus a ranking of the hypotheses. Although this may identify hypotheses more specific to one type of system, it should still give useful generic information on ecosystem response to solar conversion impacts.

A Monitoring Program for the Barstow 10 MW Central Receiver Facility

Following presentation of the specifications of the Barstow facility by Alex Klein and a discussion of environmental impacts by Charles Bell, the workshop participants worked in three groups to develop recommendations on monitoring procedures. These groups were (1) micro and macrometeorology, (2) soils and the hydrological cycle and (3) biotic responses.

All the groups recommended that baseline studies should be started immediately, on and off site, at the Barstow facility.

A general discussion brought out some ideas that were to be considered by each small discussion group.

1. The actual construction site will, in all probability, have the existing ecosystem totally destroyed.
2. Revegetation and vegetation recovery may be the only on site biotic consideration. Simulating conditions may be the only way to look at revegetation.
3. Adjacent ecosystems should also be considered in terms of impacts.
4. Consideration should be given to the types of data that can be obtained in 5 years as well as the types of data that need longer sampling periods.

The following recommendations came from each of the small working groups:

Micro and Macrometeorology

1. Weather stations should be set up outside the periphery of the heliostat field and inside the field at appropriate positions.
2. A system of monitoring sites with power conduits, etc. should be put in during the construction process covering a transect across the heliostat field for spot monitoring of air temperature, wind velocity, soil moisture and temperature profiles, etc.
3. Glass panels simulating heliostat mirrors be placed in the field immediately to monitor corrosion processes, etching, etc. by the already existing fugitive dust and sand blowing across the site.
4. Aerosol monitoring and monitoring of current existing airborne pollutants (SO_2 , NO_x) should be established as soon as possible.
5. Studies of thermal plumes above collectors should be studied. (Dave Slade of DBER/DOE might be a possible information source for analysis of this problem.)
6. The entire monitoring system should be set up with consideration given to scaling up to the 100/300 megawatt plant.
7. Heliostat maintenance, cleaning, etc. puts some constraints upon location of the inside monitoring sites and must be taken into consideration in locating the placement of monitoring stations.

Soils and the Hydrological Cycle

1. Soil microtopography changes should be looked for on the leeward side of the collectors, especially the collector bases.
2. Wind breaks should be established as soon as possible, especially on the west side of the site.
3. Airborne particulates and wind direction and velocity should be monitored at different heights (0.5, 1.0, 2.0, 5.0, and 10.0 meters). Towers should be established on the windward and leeward sides of the facility outside of construction activity and in the middle of the facility. Baseline measurements should be initiated immediately. The weather towers might be available from NOAA.
4. Soil compaction and infiltration rates should be monitored before and after construction. Soil moisture and water potential, and precipitation should be monitored after construction.
5. Precipitation drip-through should be studied based on heliostat design. Favorable microsites for revegetation might be established.
6. The periodicity and amount of heliostat washing should be monitored and the amount of water loss below the heliostats should be measured.
7. The quality of the wash water should be considered in terms of revegetation response.

8. Soil surface stabilization should be attempted with different exotic and native species, especially grasses, in the different microsites identified under the heliostats. Microsite characteristics might be identified through simulation and grasses tested at simulation sites.
9. Wind power machines should be tested as a potential wind disruption mechanism.

Biotic Response

1. There is no rational reason for requiring heliostat fields be maintained in a natural condition, thus, revegetation of grasses, for example, or chemical surface stabilizers (oil) or paving can be used. All recommendations are based on the use of a vegetative cover.

On-site Recommendations.

1. Selection of the proper species for revegetation should be left up to qualified agronomists. Three or four types should be tried and supplemental watering may be necessary. Water supplement needs should be related to water availability on site.
2. Preconstruction on-site biota should be characterized: plants, soil microorganisms, vertebrate and invertebrate animals, including nematodes, macroarthropods, microarthropods, and soil mycorrhizae. These measurements should begin immediately. This may need to be done 2 or 3 times to obtain a complete list, but budget constraints may limit this to one onsite analysis only.

3. During construction nothing formal should be done onsite, an activity (construction) log should be kept, and before and during construction aerial photographs should be taken in color, color infrared, and black and white, along with ground-based photography.
4. Onsite characterizations may need to be done several more times during construction, depending on the status of the biota during construction (eg. growth of nuisance weeds).
5. After construction more onsite characterizations should be done to document colonization of the grass by other plants, animals and microbes.

Off-site Recommendations

Impacts to be considered before, during and after construction for the following:

1. Animal population and composition changes due to onsite animal changes.
2. Cooling tower drift pollution.
3. Possible spread of exotic plants into natural surrounding ecosystems.
4. Dust during construction.

Measurements to be made before, during and after construction

Preconstruction

1. Species composition and abundance in adjoining areas, close by and remote from the facility.
2. Species diversity where possible. This should be done once or twice.

3. Endangered species have not already been examined and should be considered.

Construction phase and post construction

1. Aerial photography as explained above. These measurements should be taken at least twice a year using a paired plots design.
2. Species composition, abundance and diversity as in the preconstruction phase.
3. Check for Valley Fever organisms in soil (*Coccidioides immitis*). Contact Dr. Milton Huppert at Long Beach Vet. Hospital for assay.
4. Any alterations occurring in the natural ecosystem adjacent to the facility should be immediately investigated and causes determined.

General Recommendations

A few general recommendations follow from the more specific recommendations of the working groups.

1. Weather and airborne particulate monitoring towers should be established immediately for baseline and later studies in a series outside and within the solar conversion facility site.
2. Construction will destroy the natural vegetation but dust control and site stability might best be done with the introduction of a grass ground cover. Revegetation and vegetation recovery studies are necessary either

on site or in areas with simulated, solar collector
array environmental characteristics.

WORKSHOP: ECOLOGICAL IMPACTS SOLAR ENERGY CONVERSION

Arizona State University
Memorial Union
Cochise Room #212
May 11 & 12, 1978

Thursday, May 11

8:30 am	Registration
8:50	Introduction of Participants
9:00	"Solar Conversion Systems: A General Overview" Eugene Frankel, Department of Energy
	Discussion
9:45	Break
10:00	"Theoretical Impacts of Solar Conversion Systems" Stanley Smith, Arizona State University
	Discussion
11:00	Trip to Solar Collector Simulation Study Site
12:00-1:30 pm	Lunch (Open)
1:30	"Proposed Research Needs: A General Program" Duncan T. Patten
2:15	Small group discussion
3:30	Break
3:45	Presentations from each group
	Synthesis of a General Research Program
5:00	Adjourn
6:00	Cocktails and Dinner

The Pattens
333 E. Geneva Drive
Tempe, Arizona 85282 Ph. (602) 966-6529

About 1.5 miles South of campus, five houses
East of College Avenue. We will arrange rides.

WORKSHOP: ECOLOGICAL IMPACTS SOLAR ENERGY CONVERSION

Friday, May 12,

8:30 am	"Solar Thermal Power System at Barstow" Alexander Klein, Solar 10MW Project Office, DOE Discussion
9:30	Break
9:45	"Environmental Impacts of the Barstow Facility" Charles Bell, Environmental Improvement Agency, San Bernadino, California Discussion
10:45	<u>A Monitoring Program for the Barstow Facility</u> <u>and Similar Facilities: Research and Manipulation</u> General Group Discussion
11:15	Small Group Discussion Micro and macrometeorology Soils and the hydrological cycle Biotic responses
12:00-1:30 pm	Lunch (Open)
1:30	Reconvene Small Discussion Groups
2:30	Discussion groups report
3:15	Break
3:30	Small group synthesis of group reports
4:15	Presentation, general discussion and synthesis of small group reports
5:00	Adjourn

WORKSHOP PARTICIPANTS:

Dr. Duncan T. Patten
Department of Botany/Microbiology
Arizona State University
Tempe, Arizona 85281
602-965-3414

Dr. Charles H. Bell
Envir. Improvement Agency
Environmental Analysis Division
1111 E. Mill Street Bldg. #1
San Bernardino, CA 92415
714-383-3976

Dr. Roy E. Cameron
Division of Environmental Impact Studies
Argonne National Lab
Argonne, Illinois 60439
312-972-3181

Dr. Gary Cunningham
Department of Biology
New Mexico State University
Las Cruces, New Mexico 88003
505-646-3611

Dr. Eric Edney
Lab of Nuclear Medicine & Radiation Biology
900 Veteran Ave.
University of California
Los Angeles, CA 90024
213-825-2684

Dr. Eugene Frankel
Environmental and Resource Assessment Branch
Division of Solar Technology, Rm. #414
Department of Energy
600 E. Street, N.W.
Washington, D.C. 20545
202-376-1609

Dr. Lloyd W. Gay
School of Renewable Natural Resources
325 Biological Sciences East Bldg.
University of Arizona
Tucson, AZ 85721
602-884-4580 or -2313

Neil Hadley
Department of Zoology
Arizona State University
Tempe, AZ 85281
602-965-5084

Dr. Hayward Hamilton
Div. of Bio. Envir. Research
ASEV Germantown Rm. E 201
Department of Energy
Washington, D.C. 20545
301-353-5324

Dr. John Kirby-Smith
Lab of Nuclear Medicine and Radiation Biology
UCLA 900 Veteran Ave.
Los Angeles, CA 90024

Mr. Alexander Klein
Solar 10 Megowatt Project Office
9550 Flair Drive
El Monte, CA 91731
213-579-7574

Dr. Robert Lindberg
Environmental Sci. and Engineering Program Rm. #3677 Geology
University of California at Los Angeles
Los Angeles, CA 90024
213-825-7439 or 7675

Dr. John Ludwig
Department of Biology
New Mexico State University
Las Cruces, New Mexico 88003
505-646-3933

Dr. Melvin Marcus (M. J. Pasqualetti)
Department of Geography
Arizona State University
Tempe, AZ 85281
602-965-7475

Dr. Edward McBride
Black and Veatch Consulting Engineers
P.O. Box 8405
Kansas City, Missouri 64114
913-967-2038

Dr. Kenneth Nagy
Lab of Nuclear Medicine and Radiation Biology
UCLA 900 Veteran Ave.
Los Angeles, CA 90024

Dr. Park Nobel
Lab of Nuclear Medicine and Radiation Biology
UCLA 900 Veteran Ave.
Los Angeles, CA 90024

Thomas P. O'Farrell
611 Avenue H
Boulder City, Nevada 89005

Dr. Robert Ohmart
Department of Zoology
Arizona State University
Tempe, Arizona 85281
602-965-2932

Dr. Evan Romney
Lab of Nuclear Medicine and Radiation Biology
UCLA 900 Veteran Ave.
Los Angeles, Ca. 90024
213-825-4321

Mr. Stanley Smith
Department of Botany/Microbiology
Arizona State University
Tempe, Arizona 85281
602-965-3414

Dr. Ian Straughan
Research & Development
Southern California Edison
P.O. Box 800
Rosemead, California 91770
213-572-1944

Dr. Stanley R. Szarek
Department of Botany/Microbiology
Arizona State University
Tempe, Arizona 85281
602-965-7750

Dr. Fred Turner
Lab of Nuclear Medicine and Radiation Biology
UCLA 900 Veteran Ave.
Los Angeles, Ca. 90024
213-825-8773