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SIDE EFFECTS OF RENEWABLE ENERGY SOURCES

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Revised Edition
December, 1982

EPRD Report #15

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FOREWORD

The Side Effects of Renewable Energy Sources project (SERES) was established to identify aspects of renewable energy that could have undesirable impacts on the environment and to identify steps that could be taken to reduce such impacts.

This project was initiated by Jan Beyea and Larry Medsker as a proposal to the National Science Foundation, Science for Citizens Program. Since his appointment as a Public Service Science Resident, Dr. Medsker has assumed responsibility for carrying out the research and writing for this Report. The work has been done in consultation with Dr. Jan Beyea, Senior Energy Scientist, and Dr. Glenn Paulson, Vice President for Science, at the National Audubon Society. Helpful advice has also been contributed by Dr. Rachelle Hollander, Program Manager for Science for Citizens.

Dr. Larry Medsker is currently on the faculty of the New Jersey Institute of Technology in the Department of Computer and Information Science. Most of this report was prepared while he was on the faculty at Fordham University. The views expressed in this report are those of the author and do not necessarily reflect the views of the National Science Foundation

The Science for Citizens program was established by the NSF Office of Science and Society to increase the knowledgeable participation of both scientists and nonscientists in the resolution of major public issues involving science and technology. A goal has been to provide scientific and technical expertise to the public so that citizens can better understand and participate in decisions on policy issues.

The National Audubon Society, founded in 1905, is a national environmental organization dedicated to protecting the land, air, and water on which all life depends. Thus, Audubon is concerned with the powerful impact of the production and use of energy on our environment with special concern for the effects on wildlife and its habitat.

Awareness of the serious ecological impact of energy systems has led the Society to expand its staff in this area. A new environmental policy research

department has been formed to carry out policy studies on energy systems, as well as other areas of environmental interest. The Society has recently released the Audubon Energy Plan (81 Aud)--a practical plan for obtaining adequate energy in the United States while protecting the environment. Other studies in progress are directed to population pressures, land use issues, and the impact of conventional energy systems on wildlife (see ref. 81 Pla).

A draft of this report was examined by outside reviewers for errors and omissions. We are indebted to Paul Bente (Bioenergy Council), Ken Bossong (Citizens' Energy Project), Chris Flavin (Worldwatch Institute), Thomas Johansson (University of Lund, Sweden), Lionel Johns (Office of Technology Assessment), Jose Goldemberg (University of Sao Paulo, Brazil), James Huning (Jet Propulsion Laboratory), Alan McGowan (Scientists' Institute for Public Information), David Pimental (Cornell), Steven Plotkin (Office of Technology Assessment, Howard Ris (Union of Concerned Scientists), Marc Ross (University of Michigan), and Gordon Thompson (Union of Concerned Scientists). Most of the specific suggestions and recommended additions to tables have been incorporated in the final report.

A few reviewers suggested that additional work be done to reorganize the information presented in the report according to the relative significance of the energy technologies and the side effects discussed. Although work on relative rankings has been an on-going part of the overall project, and although a preliminary listing of high-risk side effects is included in Table 6, the major goal of this first report has been to establish a comprehensive survey of side effects that would be as free as possible from value-based interpretations and rankings. As such, this data base provides a solid foundation for the difficult process of quantitatively estimating risks and ranking the renewables. Further discussion of rankings is found on Page 8.

INTRODUCTION

Environmental consequences, produced by the implementation of energy systems, have been the subject of considerable research and writing--especially in regard to the use of nonrenewable sources such as coal, nuclear and oil. The use of these energy systems is accompanied by risks for which monetary costs can be assigned, as well as risks that are difficult to quantify in economic terms.

The burning of fossil fuels is the major cause of air pollution. Increasing CO_2 levels pose a global threat of climate changes, and acid rain contaminates soil and surface waters, destroying fish and plant life. Reliance on foreign oil also threatens U.S. security--economically because of cutoffs and the effects on the balance of trade, and militarily because reckless responses to an oil embargo might be considered.

Likewise, the use of nuclear power poses a threat as radioactive substances accumulate in reactors and waste storage sites. The development of nuclear power is also accompanied by the spread of nuclear weapons. Large groups of people face potential exposure to releases of radioactivity as a result of mismanagement, operator error, or sabotage.

Other environmental impacts of nonrenewable energy sources include the damage due to strip mining and the overuse of water supplies--especially in arid areas of the West. The many envionmental consequences of nonrenewables have severe effects on wildlife and plants, as well as on humans.

The prospect of alternative, renewable sources of energy are accompanied by the hope of significant diminution of environmental risks. The impacts mentioned above could be eliminated or

drastically reduced with the more efficient use of energy and with the conversion to renewable sources. With these new energy systems comes, too, the opportunity to implement them responsibly; i.e., with environmental concerns in mind at their inception.

In addition to being potentially compatible with good environmental practices, the use of renewable energy and efficient use of all energy systems would enable a significant reduction in our dependence on foreign oil and our production of radioactive materials. Thus, the risk of war and other threats to national security would be reduced.

Environmental groups and others have been promoting a variety of renewable sources and conservation plans as environmentally benign alternatives to conventional energy systems. However, relatively little attention has been focused on potential problems that could arise. Used on a sufficiently large scale and without due consideration of environmental impacts, some renewables might turn out to be less desirable than conventional systems. For instance, attention has been drawn to the indirect impact of certain solar technologies that require the use of polluting energy sources to prepare their construction materials. It is important for those advocating renewable energy to investigate thoroughly any potential problems that could make that source unacceptable. The importance of <u>how</u> renewables are used needs to be emphasized. In this way, bad choices can be avoided and decisions can be made early in the development of an energy technology to lessen the environmental harm. We will therefore be going into the solar age with our eyes open.

The environmental impact of the use of renewable energy systems has been receiving some attention recently; however, both more study and greater public awareness are needed. As indicated in the reference sections of this report, a number of studies focus on aspects of particular renewables. An excellent review article by Holdren <u>et al</u>. (80 Hol) discusses a methodology for a comprehensive study and lays the foundation for comparisons among several major renewables. The

National Academy of Sciences, through its Committee on Nuclear and Alternative Energy Systems (CONAES), as well as the Department of Energy, have presented limited discussions of other subsets of the renewable sources (80 CON, 79 DOE).

Still needed is a comprehensive treatment that

* Covers all significant renewables, including energy efficiency measures and geothermal energy,#
* Establishes a basis for comparison among renewables,
* Identifies potential ways to alleviate adverse effects,
* Relates the environmental concerns directly to problems affecting wildlife and its habitat, and
* Looks at the implications for aesthetics, public health and safety, and global threats to human survival.

The goal of the SERES project is to address the above needs. Specifically, the objectives have been to search the literature, identify environmental impacts, and propose ways to mitigate undesirable side effects. This study seeks to establish an extensive and comprehensive basis for the quantitative evaluation of issues that affect policy decisions. Early identification of uncertainties and gaps in knowledge will allow time for the necessary research and development to ensure that problems can be resolved or alternative energy systems can be chosen. Thus, an outcome of this project would be to alert environmental groups and other concerned citizens to potential problems and to propose solutions that will assure that alternative technologies will meet the expectations of those who want environmentally benign energy systems.

#The definition of rewewable is not precise. For example, even the breeder reactor, if restricted to fuel from the ocean, could be considered renewable (Private communication of a preprint from B. L. Cohen). This report has been limited to those energy sources most often mentioned as likely alternatives to conventional systems.

THE REPORT OVERVIEW

In this report, nine major renewable sources of energy are examined for environmental side effects in accordance with preselected criteria and guidelines. For each renewable, a number of side effects were identified, and qualitative descriptions were compiled, along with a bibliography of recent references. A part of this report is a set of extensive tables that catalog the various stresses, potential consequences, and possible mitigating factors.

The information presented here represents the initial step toward establishing a SERES data base that will include for each type of renewable energy

* Environmental stresses organized by category (land, water, air, etc.)
* Ecological consequences
* Possible mitigating factors and actions
* Other data that can be used as input to models for projecting trends and for various calculations related to environmental side effects

This data base will be updated as new information becomes available and will be available for use in ongoing work.

The report provides a comprehensive view of side effects resulting from use of those renewable energy sources most likely to be available in the next decade. The Report will also serve as the basis for future work in the SERES Project that will provide quantitative evaluations of the significance of the various side effects.

The present work demonstrates that even renewable energy sources have environmental risks, and that seemingly benign technologies can, if care is not taken, have very undesirable consequences.

The following considerations should be kept in mind in further investigations of these and other renewables:

* A systematic approach is important in order to ensure that important, but unapparent, aspects are not missed,
* Case studies are very useful for measuring and demonstrating side effects and risks. In the case of aspects that are difficult to quantify (aesthetic factors, e.g.), detailed case studies may be the only way to illustrate the importance of certain side effects.
* Complete cycles (e.g., harvesting or mining, transporting, manufacturing or processing, constructing, operating, maintaining, decommissioning) must be considered so that the full impact is determined and fair comparisons can be made.
* "Scale" and "time-frame" are important categories to consider; e.g., long- or short-range nature of effects, small- or large-scale impacts.

In regard to the above categories, some preliminary attempts to display the information gathered in this study are shown in the tables found in the summary section of this report.

Rankings

Aside from a preliminary listing of high-risk side effects, given in Table 6, detailed rankings of renewable energy technologies and side effects were intentionally excluded from this report. The main goal of the report has been a comprehensive catalog of possible side effects with a minimum of value-based interpretations.

To the extent that rankings are possible, they are both difficult to make and temporary. For example, new engineering information may become available by the time the rankings are published. Also, the importance of a particular technology can shift dramatically as a result of technological breakthroughs or as a result of a rapid increase in fossil fuel prices. Furthermore, as attention is focussed on the problems ranked most serious, solutions may be developed that change the original ranking.

Perhaps a more fundamental difficulty with rankings is the fact that different people judge impacts differently. To some, the loss of a wild river to a hydroelectric facility is much more serious than increased risk to human health from wood stove air pollution. Rankings can become subjects of contention that divert energies away from more productive work.

We believe that rankings should be kept separate from the non-controversial task of cataloging energy side effects. Even side effects that appear to be relatively insignificant from a national perspective can have serious local impacts that should not be ignored. Research into mitigation strategies for all potential side effects should be carried out. To that end, the existence of a catalog of possible impacts could make ideas for mitigating actions come to mind.

Recurrent Side Effects

The use of renewable energy sources involves the tapping of natural flows of energy in the environment. If the source is used in a sustainable fashion, the energy is removed at a rate that is comparable to that at which energy is being naturally replenished. To accomplish this, however, requires conversion technologies that operate on dispersed, in some cases intermittent, sources.

This shared characteristic of renewable energy sources leads to common side effects. In some cases, large systems, such as windmill farms, are required in order that energy can be collected in sufficient quantities to be practically useful. This means, for example

* large land requirements.
* disruption of wildlife habitats,
* increased demand for materials required for construction with the accompanying environmental impacts associated with manufacturing the materials,
* health and safety problems connected with construction, operation, and maintenance of energy facilities,
* potential air and water pollution from the release of working fluids and other chemicals (e.g., cleaning solutions), and
* use of (often nonrenewable) energy for manufacturing construction materials and for transporting resources or equipment.

Details on these and resource-specific side effects are presented in the next section of this report.

SURVEY OF SIDE EFFECTS

The results presented in the following tables are qualitative summaries of information on side effects, arranged according to the type of renewable energy source. This particular view of the SERES data base catalogs the various potential effects without assessing relative importance. These results form the basis for the ongoing work of quantifying, where possible, the significance of the various side effects.

Description of Tables

For each renewable, a summary of the technical aspects is first given, followed by charts of information grouped according to generic side effect. At the end of each section is found an abbreviated list of references on the environmental aspects of the renewable energy source being presented.

The information on environmental side effects is summarized in the tables according to the following columns:

* Stress--altered environmental conditions (e.g., water pollution) that arise from activities associated with the use of energy systems.
* Consequences--responses (e.g., losses, damage, and accidents) associated with environmental stress.
* Mitigation--ways in which environmental stress might be eliminated or reduced.

Further work is in progress to estimate impacts, assess risk levels, rank the renewable options, and propose tactics for achieving mitigation.

1. BIOMASS ENERGY

Biological processes use sunlight to create biological matter which therefore can be considered a source of solar energy. Broad categories of biomass resources are

* Plant matter (80-90% of current resources)
* Animal and human wastes
* Refuse

A number of technologies are currently being developed and improved to convert biomass into various forms of energy (see Table 1).

Table 1 a　　Table 1 b

CONVERSION PROCESSES	RESOURCES
* Direct Combustion	* Cellulosic Materials (e.g., wood and crop residues)
* Thermochemical Conversion --Pyrolysis --Gasification --Liquefaction	* Agricultural crops --Starches --Sugars --Oilseeds (e.g., sunflower)
* Biochemical Conversion --Fermentation --Aerobic and Anaerobic Digestion	* Wastes--animal and human * Refuse * Acquatic Crops (e.g , ocean kelp and freshwater and marine water hyacinths
* Mechanical Extraction (e.g., pressing seeds to obtain oil)	* Natural products from plants (e.g., oil-like hydrocarbon compounds from Euphorbia and Copaiba plants)

In table 2 are shown the projections by the National Audubon Society and the Office of Technological Assessment for the possible contributions of biomass energy sources to the national energy supply in the year 2000. According to both projections, biomass would supply the largest contribution among all of the renewable sources of energy (see Table 2). except for conservation.

Although most renewables have certain land requirements, biomass technologies are unique in the extent to which prime farmland and forests might be used. For example, a large-scale program for liquid fuels from food-quality biomass could result in direct competition with the use of crops for food. Because of the variety of resources and conversion technologies, biomass energy systems have potential side effects in all categories of environmental concern. A danger is that overuse and poor management could lead to unsustainable, and therefore non-renewable, systems.

Table 2 Projected contributions of biomass energy by the year 2000.

Resources	Audubon Plan[a)]	OTA Forecast[b)]
Wood	5.8 Quads	5-10 Quads
Grasses and Legumes	--	0-5
Grains	0.3	0-1
Crop Residues, Garbage, Animal Manure	2.8	0.9-1.5
TOTAL	8.9 Quads	5.9-17.5 Quads

a) (81 Aud) and private communication from Jan Beyea. The values in the table are from the original Audubon Plan, which is to be revised periodically.

b) (81 OTA)

BIOMASS ENERGY

(Growing and Harvesting)

Environmental Stress (Alterations of land, water, air, wildlife, flora)	Consequences	Mitigation
LAND		
New conversions of land for forests and crops.	Competition with other needs. Possible land shortages, forcing marginal lands into production.	Avoid economic subsidies for energy crops.
Increased use of marginal lands.	Pressure on protected forests, grasslands and marshland.	Restrict land conversions.
Excessive removal of crop residues. Whole-tree removal. Change of land contours. New roadways for access to crops and forests.	Increased erosion; loss of nutrients and organic matter; lower productivity and increased use of fertilizers.	Use best agriculture and silviculture management techniques. Harvest crop residues and trees in sustainable manner. Discourage whole-tree removal. Post-leaf-fall harvesting of trees.
WATER		
Water required for growing.	Water shortages, especially in marginal land areas.	Avoid siting energy farms in water-short areas.
Runoff of soil, nutrients, pesticides into water.	Contamination of water supplies with nutrients and soil. Eutrophication. Sedimentation.	Prevent excessive erosion (see above).
Aquatic crops: local alteration of water content due to emissions of organic matter, fertilizers, and construction materials.		

BIOMASS ENERGY

(Growing and Harvesting)

Environmental Stress	Consequences	Mitigation
AIR		
Dust emission from crop harvesting. Release of insecticides, fungicides, and, herbicides. Release of soil particles from wind erosion.	Health hazards for farm workers, especially from chemicals applied by aircraft.	Safety gear for workers.
Debris and odors from refuse collection.	Aesthetic and public health problems. Possible loss of recreational and residential areas nearby.	Enforce public health rules.
Emissions associated with production of energy and materials required for planting, harvesting, and transporting crop and forest fuels.	Increased air pollution in manufacturing and energy production regions.	Use energy-efficient equipment and renewable energy.
Marine farms: bringing up cold, deep ocean water could release CO_2. Possible net CO_2 increase due to unsustainable harvesting of forests and crop residues.	Local weather changes, fog generation. Global warming from CO_2 buildup.	Monitor CO_2 release. Use good forest management.
DIRECT IMPACT ON WILDLIFE AND FLORA		
Intensive forest management. Brush removal, deforestation, conversion of marshland and grassland. Increased use of insecticides, fungicides, and herbicides.	Disruption of wildlife habitats; possible loss of certain species. Loss of grassland and marshland ecosystems. Loss of flora, contamination of animal food chains.	Exclude critical habitats from development. Emphasize forest sources--discourage use of wetlands. Conservative use of monocultures.
Accumulation of logging residues	Fire hazard.	Require good logging practices.
Marine farms: exposure of organisms to colder water and construction materials.	Loss of certain fish from that area.	

BIOMASS ENERGY

(Growing and Harvesting)

Environmental Stress	Consequences	Mitigation
OTHER STRESSES		
Release of pathogens from municipal and animal waste collection sites.	Public and worker health problems from exposure to pathogens.	Enforce public health ordinances.
Increased work activity in planting, harvesting, and transporting of energy crops	Increased number of accidents (high rate for workers in that occupation).	Improved, safe equipment. Promote awareness of safety problems and precautions.

BIOMASS ENERGY

(Conversion Processes)

Environmental Stress (Alterations of land, water, air, wildlife, flora)	Consequences	Mitigation
LAND		
New use of land for disposal and treatment of sludge, stillage, and other residues from conversion processes. Disruption of land for construction projects and later for transport of resources and conversion residues.	Competition for land. Possible degradation of soil quality from heavy metals and other contaminants in residues--especially if used as fertilizers or soil conditioners.	Monitor and remove harmful substances before dumping or returning residues to the soil. More research on the effects of toxic substances propagated by use of residues as fertilizers.
WATER		
Water consumption required in some conversion technologies for cooling or for working fluid.	Increased demand for water--possible shortages.	Choose conversion processes that minimize the use of water. Avoid siting facilities in water-short areas.
Disposal of residues in water.	Water quality degradation from heavy metals and from organic matter with high O_2 demand.	Choose sites away from aquifers. Monitor and process wastes before releasing. Reuse residues to produce fertilizer or to produce methane.
Aquatic farms: possible release of materials from corrosion, residues, and equipment.	Contamination of freshwater.	

BIOMASS ENERGY

(Conversion Processes)

Environmental Stress	Consequences	Mitigation
AIR		
Emission of CO_2 particulates, organics from boilers.	Increased level of polyorganic matter (POM) in the air.	Require pollution control technologies. Monitor small, decentralized facilities.
Products of incomplete combustion from residential wood stoves.	Indoor and local outdoor air quality. degradation; health problems, carcinogens.	Develop control technologies for residential stoves. Discourage use of coal in wood stoves.
Local outdoor smoke accumulation from residential stoves.	Potential health problems; aesthetic losses; annoyance to some people.	Enforce local ordinances.
Emissions from nonrenewable fuel combustion at distilleries.	Increased levels of nitrogen and sulfur compounds could contribute to health problems and cause more acid rain.	Use pollution control technologies.
Emissions associated with production of materials used to build conversion facilities.	Increased air pollution in manufacturing areas.	
More evaporative and aldehyde emissions from vehicles when alcohol is mixed with gasoline.	Air quality degradation in some respects; however, reduction in pollution from sulfur and nitrogen compounds.	Develop vehicles that use pure alcohol fuels. Develop catalytic equipment.
DIRECT IMPACT ON WILDLIFE AND FLORA		
Disruption of habitats to build conversion facilities-especially if siting close to biomass growing areas.	Disruption of ecosystems, contamination of food chains. Possible loss of some species in the area of the facility.	Avoid critical habitats as disposal sites.
Contamination of natural areas from dumping sludges and residues.		

BIOMASS ENERGY

(Conversion Processes)

Environmental Stress	Consequences	Mitigation
OTHER STRESSES		
Safety features lacking in some brands of wood stoves.	Home burn and fire accidents.	Include safety features in manufacture of stoves.
Toxic gases produced in gasifiers (e.g. ammonia, H_2S, cyanide, phenols) High-pressure, hot gases produced in boilers and distilleries. Sludges and residues may have to be transported to dump sites.	Hazards to workers; especially at small farm on-site facilities	Use good chemical handling practices. Publicize safety problems and precautions.
Energy and chemicals, concrete and other materials are needed for the construction and use of conversion facilities.	Possible shortages of some materials. Increased energy demand from non-renewable sources.	Use renewable energy and energy-efficient equipment.
Barriers to navigation due to presence of sea and freshwater farms.	Shipping accidents.	Use adequate signalling equipment. Keep farms out of navigation lanes.

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2. ENERGY EFFICIENCY

Energy conservation plans and the use of higher-efficiency equipment are renewable energy sources in as much as energy is continually being saved. That saved energy might otherwise have to be supplied from non-renewable sources. Major areas in which energy efficiency improvements can be made are summarized in Table 3.

Energy efficiency efforts can also lead to environmental side effects. An example is the possibility of indoor air pollution resulting from reduced air infiltration after conservation measures have been applied. Other effects unique to energy efficiency are health and safety problems that could arise from changes in conventional processes, techniques, and lifestyles (e.g., temperature setback in winter).

Table 3 Summary of Energy Efficiency Measures

Measures	Comments and Examples
Tightening Buildings	Insulation, Caulking, Storm windows; House doctors
Efficient Appliances	Purchase of new appliances with improved efficiency (e.g., heat pumps, washers, refrigerators)
Retooling of Factories	Changes in industrial processes and physical plant to make use of lower-energy techniques (e.g., automatic control of combustion processes, lighting systems, changes in feedstocks, and new catalysts).
Heat Recovery and Cogeneration	Industrial heat recovery systems: sequential use of steam for electricity and other uses.
Efficient Transportation	New designs of vehicles for higher fuel efficiency; shift to vehicles with diesel engines; reduction in freight transport; changes in driving habits and bicycling to reduce gasoline use.
Computerization	Automatic controls using computers. Changes in lifestyles (e.g., electronic funds transfer, home information systems). More use of communications systems to reduce travel.

ENERGY EFFICIENCY

Environmental Stress (Alterations of land, water, air, wildlife, flora)	Consequences	Mitigation
LAND		
Harvesting of forest products for cellulose insulation. Stresses associated with intensive forest management (See BIOMASS ENERGY - Growing and Harvesting.)	Increased forest land requirements. Erosion, loss of nutrients (See BIOMASS Energy - Growing and Harvesting.)	Encourage use of lowest quality waste paper for manufacture of insulation.
WATER		
Requirements for water in open-cycle heat pumps.	Contribution to possible water shortages.	Discourage use of water heat pumps in water-short areas.
Runoff associated with forest and agricultural crops.	Water pollution.	Prevent excessive erosion.
AIR		
Buildup of radon, smoke, fumes in tight houses.	Low-level radiation hazards from radon products. Air quality degradation; health problems.	House-doctor checks for high radon levels. Ventilate cooking and furnace areas. Seal off basement in new construction.
Chlorofluorocarbon (CFC) leaks from heat pumps. Outgassing of formaldehyde from some insulation.	Health hazard from inhalation.	Appliance standards to minimize leaks. Avoid use of insulation containing formaldehyde.
Air pollution from cogeneration facilities.	Air pollution sources moved closer to residential areas.	Restrict cogeneration facilities to use of natural gas.
Over reliance on automatic controls can lead to greater levels of incomplete combustion and particulate emissions.	Air quality degradation from particulate emissions.	Avoid use of automatic controls where difficult to maintain. Further study required on problems with automatic controls.

ENERGY EFFICIENCY

Environmental Stress	Consequences	Mitigation
AIR (continued)		
In harvesting products for cellulose insulation, poor forest management could lead to net CO_2 increase.	Addition to global warming potential.	Demand sustainable use of forests. Use low-quality waste paper for manufacture of insulation.
Higher rate of particulate emission from vehicles with diesel engines; increase in nitroarene compounds.	Potential increase in cancer in humans and genetic modifications in flora and fauna.	Modify combustion process to minimize nitroarene formation in diesel particulates (e.g., afterburn treatments). Do not relax levels of permissable emissions. Alert the public to the importance of properly adjusted engines; include checks in vehicle inspection. More research on biological consequences of nitroarenes.
DIRECT IMPACT ON WILDLIFE AND FLORA		
Disruption of forest lands for harvesting material for cellulose insulation.	Possible loss of certain species.	Good forest management. Avoid use of forests that have critical habitats.
OTHER STRESSES		
Heat buildup due to improperly installed insulation (e.g. around electrical outlets).	Fire hazards.	Use proper insulation procedures. Enforce housing codes.
Workers installing insulation may be exposed to fiberglass, intense heat, danger of falling.	More worker accidents and injuries.	Promote awareness of safety problems and precautions.

ENERGY EFFICIENCY

Environmental Stress	Consequences	Mitigation
OTHER STRESSES (continued)		
Reduced lighting in the work place.	Eye fatigue for workers doing fine work (e.g., sewing and machining). Vitamin D deficiency among workers in artificial lighting.	Investigate consequences before reducing lighting. Consider work requirements. Use daylighting. Plan for it in the design of office buildings.
Increased demand for materials and energy needed for manufacture of insulation.	Shortage of some materials. Use of non-renewable energy in manufacture of insulation.	Discourage production of synthetic insulation (energy intensive).
Possible higher replacement frequency for newly-designed appliances.	Increased demand on materials and energy for manufacture.	Quality control and testing to design reliable appliances.
Increased demand for substitution materials in new efficient appliances and vehicles (e.g., oil-based plastics).	Possible shortage of some materials needed for other purposes.	Avoid use of materials potentially in short supply.
Reduced temperatures due to thermostat setback.	Hypothermia leading to illnesses and deaths.	
Workers in retooled factories have to adjust to new procedures.	Chance of more accidents than with old system--at least initially.	Provide retraining opportunities and sufficient transition time.
More small cars on the highways for higher fuel efficiency.	Lower accident rates but greater severity.	Automatic seat belts and/or air bags. Improved safety design in vehicles.
More bicycles on the streets.	More accidents between bike riders and vehicles.	Bike lanes, separation from vehicles.
Reduced lighting in public places.	Increased incidence of crime.	Retain lighting in likely crime areas.

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*Discusses environmental side effects.

3. DIRECT SOLAR HEATING AND COOLING

Solar heating and cooling systems are used to convert incident sunlight to thermal energy for space heating and hot water systems. Passive systems make use of improved construction and design to capture solar radiation directly for warming living space. The distribution of heat can occur by radiation, conduction, and convection. Active systems use secondary working fluids that are heated by solar radiation and then circulated by means of pumps in order to distribute heat for immediate use or for storage systems. Because of the intermittent nature of sunlight, storage systems and/or conventional backup systems (often electric resistive heating) are required.

Table 4.

Systems	Comments and Examples
Passive Architectural Designs	South-facing windows, glazed windows, thermal mass storage in walls and floors
Flat-plate Collectors	Glass-encased areas in which working fluid is exposed to solar radiation. Produces temperatures in 140-180°F range.
Other Collectors and Auxiliary Equipment	Concentrators, tracking systems, etc., can be used to produce higher temperatures
Ice Blocks	Collection of ice in winter. Insulated storage for later use in warm weather for air conditioning.
Storage Ponds	Collection of solar energy in saline ponds (e.g., to supply energy needs on farms).

DIRECT SOLAR HEATING AND COOLING

Environmental Stress (Alterations of land, water, air, wildlife, flora)	Consequences	Mitigation
LAND		
Potential increase in urban sprawl since direct small-scale collection favors low-density, low-rise housing. Storage ponds have some land requirements.	Increased competition for land.	Avoid use of prime land for housing. Consider intermediate-scale low-rise housing.
WATER		
Evaporative cooling towers may be used for air conditioning and for some cogeneration facilities.	Addition to water shortage.	Use closed-cycle cooling. Otherwise, avoid siting in water-short areas.
Possible release of chemicals (e.g., working fluids) during maintenance, accidents, or decommissioning.	Chemicals, such as ethylene glycol, may contaminate water supplies.	Careful design of equipment. Choose chemicals with environmental impact in mind.
Possible leaks of anti-corrosive and antifouling additives (in evaporative cooling towers). Possible chemical leaks from saline ponds.		
AIR		
Release of toxics from working fluids (e.g., anticorrosive additives).	Air quality degradation.	Choose chemicals for working fluids to minimize risks from toxics.
Outgassing from plastics, epoxies, coatings, and insulation (e.g., S, Si, silicate particles). Release of particles due to degradation or disposal of collectors. Release of toxics in fires.		

Environmental Stress	Consequences	Mitigation
AIR (continued)		
Pollution associated with manufacture of materials used in the construction of collectors and storage systems.	Air quality degradation.	Use pollution control technologies.
Radon gas released from rock storage systems and concrete walls.	Health hazard from low-level radiation	Choose rocks with low radon release. Develop techniques to seal off radon sources from living space.
Possible Freon releases during operation and decommissioning.	Addition to ozone depletion.	Careful design and proper disposal procedures.
DIRECT IMPACT ON WILDLIFE AND FLORA		
Cutting and clearing of trees and other plants to avoid shading collectors. Collectors may cause shadows on some plant areas.	Disruption of plant ecosystems and habitats--especially in new housing communities. Loss of certain species in that area.	Design structures and select sites to minimize clearing and cutting. Avoid critical habitats.
Glass collector covers may cause reflections of sunlight.	Glare nuisance. Disruption of natural habitats.	
Passive solar structures with large glass areas may be barriers to bird and insect movement.	Possible bird and insect kills.	
OTHER STRESSES		
Installation and maintenance of collectors requires rooftop work.	Chance of accidents and injuries.	Proper design for safe access to collectors.
Presence of large areas of glass for collectors and windows.	Residential accidents and injuries from broken glass due to accidents, earthquakes, storms, etc.	Promote awareness of safety problems and precautions.

Environmental Stress	Consequences	Mitigation
OTHER STRESSES (continued)		
Presence of chemicals in collector systems--especially in more exotic, high-performance systems.	Worker injuries and health problems from exposure to chemicals (e.g., liquid sodium and fluorocarbons).	Promote awareness of safety problems and precautions.
Entrance of molds and fungi into room interiors from working fluids and storage systems.	Allergy and other health problems for some people.	Ensure adequate separation and sealing-off from living space.
Fires may be caused by overheating.	Public and residential hazards. Possible release of toxic chemicals.	Better education, design standards, etc. to ensure proper and thoughtful construction.
Physical presence of rooftop collectors. New designs required for passive structures. Possible loss of shade trees to expose collectors to sunlight.	Possibly architecturally unpleasing. Glare distractions. Aesthetic losses.	Thoughtful selection of collection site--especially in new house construction.
Energy required for manufacture of chemicals and construction materials (steel glass, aluminum, concrete). Electricity required for fans and motors (active systems). Storage systems may use batteries.	Possible use of nonrenewable energy in the manufacture of materials and production of electricity.	Use renewable energy sources and energy-efficient equipment. Minimize use of synthetic materials (more energy intensive).
Disruptions in work and living patterns due to prolonged cold and cloudy weather.	Loss of productivity and income. Possible illnesses and deaths if backup energy systems are inadequate or delayed.	Education and design standards to ensure the use of adequate backup systems.

DIRECT SOLAR HEATING AND COOLING REFERENCES

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*Discusses environmenal side effects

4. HYDROPOWER

Water impounded behind dams represents stored gravitational energy, and, when allowed to flow through turbines, produces useful mechanical or electrical energy. Most large sites are already being used, but future benefit from hydropower could be obtained by upgrading existing facilities and adding or reconditioning turbines at existing small dams.

Another role for hydroelectric facilities is the use in pumped storage systems. Excess power from the hydroelectric plant or from other energy sources (e.g., wind energy or photovoltaic systems) would be used to pump water to the reservoir. Energy could be retrieved later by allowing the water to flow back through the turbines.

HYDROPOWER

Environmental Stress (Alterations of land, water, air, wildlife, flora)	Consequences	Mitigation
LAND		
Land covered by water from new dam construction.	Increased demand for land - especially agricultural land	No new dam construction. Retrofit existing sites.
Loss of soil near reservoirs due to landslides, erosion, disruptions due to construction and new roads.	Deficiency of soil nutrients, decrease in the amount of fertile bottom land. Loss of coastal lands for recreational and aesthetic uses.	Design roads and facilities to minimize erosion.
Loss of flooding of downward lands, increased salt content there.	Change in soil characteristics. Possible change in usage of that land.	
Undercutting of downward river bed due to loss of sediment.	Lowering of water table.	
WATER		
Loss of free-flowing streams and wild rivers or changes due to variations in stream flow.	Possible local water shortage downstream. Loss of a scarce recreational and aesthetic resource.	No new dam construction Minimize flow releases in retrofitted dams.
Increased evaporation of water because the lake has a larger surface area and higher temperature than the river it replaces.	Loss of fresh water by evaporation and seepage Possible microclimate changes. Increased concentration of salts, minerals toxics, and organic matter; loss of a fresh water supply.	No new dam construction.
Sedimentation from erosion runoff. Stratification of nutrients and other chemicals in the lake.	Siltation, possible eutrophication and stagnation.	Careful planning to minimize erosion.

HYDROPOWER

Environmental Stress	Consequences	Mitigation
AIR		
No significant stresses.		
DIRECT IMPACT ON WILDLIFE AND FLORA		
Barrier to fish migration. Drastic change in fish ecosystem.	Interference with spawning. Possible loss of certain species.	Avoid disruption of critical habitats. No new dam construction. Minimize the size of flow releases.
Higher water temperature in lake, contrast to downstream river. Cold lake-bottom temperatures.	Direct impact on fish. Loss of some inland cold-water fisheries (e.g., trout streams). Possible microclimate changes.	Make use of special design features (e.g., fish ladders and intake screening)
Estuarine imbalance downstream.	Change in estuarine ecosystem. Possible loss of some species.	No new dam construction.
Change in woodland habitat for construction of reservoir.	Possible loss of some wildlife.	
Cutting and clearing near dam and lake during construction and use.	Loss of some plant species.	Avoid cutting and clearing of critical plant areas.
Lake water is quieter and allows deeper penetration of sunlight.	Higher phyloplankton growth and change in aquatic ecosystem.	
OTHER STRESSES		
Dam fail. Increased chance of earthquake from pressure of dam and reservoir.	Catastrophic loss of lives and homes.	Proper location of dams and houses. No new dam construction.
Relocation of people to make way for reservoir		

Environmental Stress	Consequences	Mitigation
OTHER STRESSES (continued)		
Increased demand for materials and energy for dam construction and manufacture of mechanical equipment.	Possible shortage of materials for other needs. Increased demand for non-renewable energy.	Minimize use of material for retrofitting old dams. Use renewable energy sources and energy-efficient equipment.
Large fluctuations of water levels in lakes and streams.	Inconvenience for use of recreational and residential facilities.	Negotiate schedules of flow releases to minimize the adverse effects.

HYDROPOWER

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*Disccusses environmental side effects

5. WIND ENERGY CONVERSION (WEC)

Wind energy is available because of uneven absorption of solar energy by the air - on a global basis - resulting in movement of air mass. Wind energy conversion systems are used to change the kinetic energy of the wind to useful mechanical energy or, by means of generators, to electricity. WEC systems are classified according to the rotating shaft axis orientation: vertical or horizontal. Provisions are required so that adjustments can be made to changes in windflow directions. The efficiency of WEC systems depends on siting (e.g., hilltops and offshore), the height of the tower, and proximity to other WEC machines (aerodynamic interference limitations).

WIND ENERGY CONVERSION (WEC)

Environmental Stress	Consequences	Mitigation
LAND		
WEC farms require land areas (e.g., grasslands); although multiple uses will reduce the requirements. More land would be used if additional transmission network is required.	Competition with other land needs.	Encourage compatible uses of land around WEC machines. Use efficient spacing for machines. Plan siting for feeding into existing power grids.
Disruption of land for roads and construction.	Reduced water retention capabilities. Loss of soil and nutrients.	Design roads and facility to minimize erosion.
WATER		
No cooling water needed.	Important advantage of WEC - no demand on water supplies.	
Possible release of chemicals during fires or other accidents from on-site storage media (e.g., batteries).	Contamination of nearby water supplies.	Proper siting away from water supplies.
AIR		
Chemical releases from storage media. Emission of materials from flywheel decomposition during a failure. Dust emissions during construction.	Possible air quality degradation.	Choose sites to minimize impact on residential areas.
Change on distribution of atmospheric constituents due to modified wind patterns during WEC operation.	Possible local weather changes (could be beneficial).	
Electromagnetic waves produced by moving parts. Reflections from towers.	Possible interference with TV, radio and microwave transmission.	Careful siting to minimize interference.

WIND ENERGY CONVERSION (WEC)

Environmental Stress	Consequences	Mitigation
DIRECT IMPACT ON WILDLIFE AND FLORA		
Cutting and clearing for facility and transmission lines.	Destruction of plants and natural habitats. Possible loss of some species.	Avoid disruption of critical habitats.
Barriers to wildlife movement.	Possible destruction of birds and insects colliding with wind machines.	Choose sites with migration and flight patterns in mind.
New source of noise.	Noise disruptions of wildlife habitats.	
Mountaintop and hilltop sitings are preferable from energy standpoint.	Loss of some natural mountain habitats.	
OTHER STRESSES		
Visibility of wind machines on ridges. Increased presence of transmission network (mainly for remote sites).	Loss of natural panoramas. Wind machines are aesthetically unpleasing to some people.	Involve public in choice of designs and sitings.
Noise during WEC operation.	Annoying noise. Nuissance in residential areas. Possible psychological effects and property damage from infrasound.	Proper design and orientation to minimize noise. Research on alternative designs. Modify facilities if infrasound research indicates hazards.
Facility operation hazards: blade fail, ice shedding, expulsion of parts, toppling towers.	Worker and public safety problems.	Fail-safe designs. Routine preventive maintenance.
Tall towers present hazards for workers who build and maintain facility.	Injuries from falls and accidents arising from the use of heavy equipment.	Promote awareness of safety problems and precautions.
Towers are obstacles for aircraft.	Possible air accidents.	Use proper visual warning equipment.
Materials (especially steel) and energy needed for construction of the facilities.	Increased demand for certain materials. Increased pollution and energy use associated with manufacture of materials.	Use renewable energy and energy-efficient equipment.

WIND POWER REFERENCES

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* Discusses environmental side effects

6. PHOTOVOLTAIC ENERGY

Photovoltaic cells use semiconductors that convert infrared and visible light into electric current. The most common type is the monocrystalline silicon cell. Others being researched use cadmium sulfide (CdS), polycrystalline silicon (Si), or amorphous Si. Associated equipment includes support structures and energy storage equipment. Residential and commercial users could connect to utility grids in order to sell excess power when available and to have backup power for periods of insufficient sunlight.

A wide range of applications of photovoltaic cells is being considered:

* Dispersed Residential Use
  Millions of homes could use arrays of cells to supply electrical energy.

* Large-scale Central Facilities
  - Land-based systems: farms of photovoltaic cells.
  - Solar Power Satellites (SPS): collection of solar energy in orbit, transmission to land-based receivers (rectennas) by means of microwaves.

PHOTOVOLTAIC ENERGY

Centralized Collection and Solar Power Satellites (SPS)

Environmental Stress	Consequences	
LAND		
Land areas required for collectors. Increased urbanization near sites.	Competition with other land needs.	Look for compatible uses of surrounding land. Avoid use of prime land.
Disruption of land for construction and roads.	Reduced capability for water retention	Design roads and facilities to reduce erosion.
WATER		
Water may be required for cooling.	Increased demand on water supplies.	Use closed-cycle cooling or dry cooling.
Runoff into water from construction. Release of cleaning fluid and cell materials during maintenance and disposal.	Water contamination.	Strict maintenance and disposal procedures to minimize releases. Good choice of chemicals and cell materials to reduce toxics.
AIR		
Emissions from accidents and fires.	Air quality degradation.	Choose sites away from residential areas. Choose materials to reduce hazards.
Dust emissions during construction.		
DIRECT IMPACT ON WILDLIFE AND FLORA		
Clearing and cutting for construction and roads. Structures present barriers to movement. Increased urbanization near site puts pressure on natural habitats.	Destruction of plants and disruption of natural habitats. Possible loss of some species.	Avoid disruption of critical habitats.

Centralized Collection and Solar Power Satellites (SPS)

Environmental Stress	Consequences	Mitigation
DIRECT IMPACT ON WILDLIFE AND FLORA (continued)		
Focussed light beams may be exposed to wildlife.	Possible injury of animals in direct contact with light beam. Direct injuries if exposed to intense beams.	Plan facility siting to accomodate wildlife living patterns.
SPS: plants and animals in the area of rectenna sites will be exposed to microwave radiation.	Possible long-term effects of irradiation. Temperature changes in exposed leaves.	Design rectenna sites to keep animals out of the irradiation area.
OTHER STRESSES		
Worker hazards associated with construction of large-scale power plants. Worker exposure to cleaning fluids and other chemicals during maintenance, disposal, and fires. Exposure to toxic materials in AC voltage boost equipment. Possible exposure to chemicals if lead-acid batteries are used for energy storage.	Accidents and injuries.	Promote awareness of safety problems and precautions. Choose chemicals to reduce risk of exposure to toxic chemicals.
Possible change in local temperature patterns.	Potential local weather changes.	Monitor climatic effects and make changes in facility operation as needed.
SPS: possible changes in vertical structure of stratosphere due to large number of rocket launches.	Atmospheric changes (e.g., acceleration of ozone problem).	
SPS: satellites also provide opportunity for military applications.	Another means of escalating weapons buildup. Increased risk of war.	Promote awareness of military applications.

PHOTOVOLTAIC ENERGY

Centralized Collection and Solar Power Satellites (SPS)

Environmental Stress	Consequences	Mitigation
OTHER STRESSES (continued)		
SPS: exposure of humans to microwave radiation--routine and accidental.	Long-term effects of low-level radiation.	Promote awareness of radiation safety problems.
SPS: increase in electromagnetic waves in the environment.	Possible interference with communication systems.	Involve the public in policy decisions. Careful siting of rectenna facilities.
SPS: large amounts of material and energy needed for construction of satellites and rockets. Large amounts of concrete and wood or aluminum required for construction of large-scale power plants.	Competition for materials needed for other purposes. Increased demand for some materials. Energy used for manufacture.	Use renewable energy and efficient equipment. Minimize use of scarce material.
Manufacture of cells requires use of substances such as arsenic, cadmium, and gallium.	Possible shortage of some substances,	Choose cell designs to conserve scarce substances.
Centralized collectors can alter landscapes and panoramas.	Visually unpleasing to some people. Could lose some recreational areas.	Avoid siting on prime recreational and inspirational land.

PHOTOVOLTAIC ENERGY REFERENCES

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*Discusses environmental side effects

7. SOLAR THERMAL ELECTRIC CONVERSION (STEC)

Large-scale conversion of solar radiation to electricity may be accomplished by using collectors such as linear concentrators, saline ponds, parabolic dish concentrators, and central receiver with heliostat field (mirrors that track the sun). The solar radiation is focused onto a receiver in the tower where electricity is generated. The conversion process (e.g., a Rankine-cycle steam system) would use a working fluid which is heated and then used in a turbine and generator system to produce electricity. For industrial applications, a system would need about ½-day storage capacity and a backup system.

SOLAR THERMAL ELECTRIC CONVERSION (STEC)

Environmental Stress	Consequences	Mitigation
LAND		
Land areas required for collectors. Increased population near the facility.	Competition with other land needs. Pressure to convert land for residential use and highways.	Look for compatible uses of land. Avoid conversion of prime land.
Disruption of land for construction and roads.	Change in soil retention abilities.	Design roads and facilities to reduce erosion.
WATER		
Water required for cooling in power plant. Increased demand for residential use.	Possible water shortages--especially in the Southwest where STEC plants are most practical.	Avoid siting in water-short areas. Use dry cooling towers.
Runoff into water supplies from construction site and roadways. Release of cleaning materials used for maintenance of mirrors.	Contamination of water supplies.	Use strict maintenance and disposal procedures. Choose chemicals to reduce pollution problems.
AIR		
Release of cleaning materials and other chemicals in accidents. Dust emissions during construction.	Air quality degradation.	Choose sites away from populated areas. Choose chemicals to reduce hazards.

SOLAR THERMAL ELECTRIC CONVERSION (STEC)

Environmental Stress	Consequences	Mitigation
DIRECT IMPACT ON WILDLIFE AND FLORA		
Clearing and cutting during construction.	Destruction of plants and disruption of natural habitats.	Avoid siting in critical habitats.
Pressure on desert habitats where STEC facilities most practical.	Possible loss of some species.	
Barriers to wildlife movement.	Disruption of migration patterns and flight paths.	Consider flight paths in siting.
Exposed, focussed light beam.	Animals could be injured by direct exposure to the light beam.	Design facility to keep animals away from light beam.
OTHER STRESSES		
Alteration of landscapes and panoramas.	Reduction in visual attractiveness. Loss of potential open recreational lands.	Include aesthetic considerations in the design. Avoid conversion of prime lands.
Exposure of workers to cleaning materials and light beam.	Injuries and long-term health effects.	Choose chemicals to reduce risks from toxics. Promote awareness of safety issues.
Possible effect on local thermal energy balance.	Might lead to local weather changes.	Monitor effect on climate. Modify design or close down if necessary.
Energy and materials (e.g. aluminum and concrete) needed for construction of the facility.	Pollution associated with manufacture and non-renewable energy production.	Minimize use of materials. Use renewables and efficient equipment.

SOLAR THERMAL ELECTRIC CONVERSION REFERENCES

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* Discusses environmental side effects

8. OCEAN THERMAL ENERGY CONVERSION (OTEC)

OTEC systems make use of temperature differences between ocean surfaces and deep waters. The differential requirement (> 36 F^{O}) favors U.S. sitings near islands in the Pacific and Caribbean, portions of the Gulf of Mexico, and offshore southern California. Siting is further constrained by availability of electrical transmission facilities, unless the OTEC system converts energy on site to other products (e.g., hydrogen, ammonia, aluminum).

Conversion technologies currently being developed include techniques to generate electricity through open and closed Rankine-cycle systems (see diagram). In closed-cycle setups, warm ocean water heats a secondary working fluid (e.g., ammonia). The resulting vapor is expanded in a turbine that is coupled to an electric generator. The cold ocean water then cools the exhaust which is pumped back to complete the cycle. OTEC systems will be designed to obtain useful power at temperature differences that are well below those at which conventional power plants operate.

OCEAN THERMAL ENERGY CONVERSION

Environmental Stress	Consequences	Mitigation
LAND		
On-shore support facilities may be required.	Competition for shoreline land.	Avoid siting in critical coastal areas.
WATER		
Release of chemicals - e.g. working fluids and anti-biofouling chemicals. Release of metal corrosion. Contamination from life support systems required for manned platforms. Possible oil spills from ship collisions with the OTEC facility.	Local water quality degradation. Disruption of local marine eco-systems.	Good choices for working fluids. Strict maintenance procedures and disposal methods. Design support systems with water quality in mind. Install signalling equipment for navigational safety.
Change in local oceanic properties due to ocean water displacement --possibly significant amount of heat removed from warm ocean currents.	Possible local weather changes and effects on ocean currents. Possible cooling effect in distant regions connected by slow, warm currents.	Monitor effects of facility operations and modify the use if necessary.
AIR		
Release of CO_2 from saturated deepwater brought to the surface.	Contribution to CO_2 buildup and global warming.	Monitor CO_2 emissions.
Emissions from life support systems. Emission of volatile working fluids and other chemicals.	Local air pollution.	Use pollution control technologies.

OCEAN THERMAL ENERGY CONVERSION

Environmental Stress	Consequences	Mitigation
DIRECT IMPACT ON WILDLIFE AND FLORA		
Disruption of coastal habitats due to presence of on-shore support facilities. Altered temperatures, currents, and nutrient patterns in the water.	Changes in habitat and migration patterns.	Avoid siting in critical coastal habitats.
Entrainment of organisms from cold water intake. OTEC facility presents barrier to sea life movement. Upwelling of nutrients.	Disruption of local marine ecosystem. Possible loss of some species.	Plan facility to avoid interference with critical sea life movement.
Release of metal corrosion and chemicals. Destruction of some plants from biocide release near the facility.	Disruption and contamination of local marine food supplies.	Strict procedures for maintenance, chemical handling, and disposal.
OTHER STRESSES		
Disruption of coastal areas by on-shore facilities.	Altered view of coastal area and interference with recreational uses.	Avoid conversion of prime coastal lands.
Construction, maintenance, and decommissioning required for large ocean platforms.	Accidents from work hazards.	Promote awareness of safety problems and precautions.
Chemicals and other materials must manufactured for construction and maintenance of facilities.	Increased demand on materials. Pollution and energy use associated with manufacturing.	Minimize use of materials. Use renewable energy and energy efficient equipment.
Possible political tension arising from sitings in international waters.	Potential conflicts over violations of international laws. Chance of war.	Avoid likely volatile situations. Negotiate clear agreements prior to construction.

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* Discusses environmental side effects

9. GEOTHERMAL ENERGY

Geothermal resources are in the form of heat stored in the earth and can be reached by drilling. The heat can then be brought to the surface in a fluid that can be used directly or for the generation of electricity. Residential and commercial use primarily takes the form of a district heating system or large institutional system.

Table 5.

Types of Resources	Comments and Examples
Hydrothermal Convection *Hot-Water *Vapor-Dominated	Water and steam trapped in fractured rocks or sediments. Currently in use directly or for electricity. About 30% of U.S. resources have temperatures greater than 300° F. Most of the resources with temp. greater than 200° F are in Western states --mostly California
Geopressured Reservoirs	Water and dissolved methane at moderately high temperatures and high pressures. Principally along the Gulf Coast
Hot, Dry Rocks	Relatively unfractured hot rocks at accessible depths and containing little or no water. Fracturing required for introducing and circulating a working fluid. Most of these resources are found in Western U.S.

GEOTHERMAL ENERGY

Environmental Stress	Consequences	Mitigation
LAND		
Geological stress--especially from use of geopressured brines.	Possibility of earthquakes, subsidence, sink holes.	Proper choice of site based on geological survey prior to construction. Reinject brines to reduce chance of subsidence.
Disruptions of land in the vicinity. of the energy facility for roads and construction.	Reduced ability for water retention, loss of soil and nutrients.	Design roads and facility to minimize erosion.
Release of chemicals from working fluids and from underground when circulated to sites of use.	Land may be contaminated by toxic substances. Damage to habitats.	Use closed-cycle systems.
WATER		
Water loss occurs from pumping down into rocks.	Contribution to possible water shortages.	Use closed-cycle systems. Otherwise avoid siting in water-short areas.
Release of chemicals from working fluids and from underground.	Toxic substances could enter water supplies.	Design system and choose chemicals to avoid toxic releases. Monitor water supplies.
AIR		
Metallic compounds, oxides, and water vapor may be released when water is brought to surface.	Air quality degradation. Health hazards	Monitor radioactive and toxic releases. Collect and store substances as necessary.
Also, possible release of radioactive materials (e.g., radon products).	Long-term hazards from low-level radiation.	Use closed-cycle systems.
Release of heat. Local warming.	Microclimatic changes are possible.	
DIRECT IMPACT ON WILDLIFE AND FLORA		
Disruption of natural habitats due to presence of the facility. Barriers to movement. Introduction of new noise source.	Changes in habitat and migration patterns. Possible loss of some species.	Avoid sites that disturb critical habitats.

GEOTHERMAL ENERGY

Environmental Stress	Consequences	Mitigation
DIRECT IMPACT ON WILDLIFE AND FLORA (continued)		
Cutting and clearing for construction and roads.	Destruction of plants.	
OTHER STRESSES		
Physical presence of the facility in previously natural settings.	Altered view of landscape. May be aesthetically unpleasing.	Avoid using prime landscapes and recreational areas.
Hot, high-pressure fluids in the work environment.	Potential hazard to workers.	Promote awareness of safety problems and precautions.
Construction materials and chemicals are used to build and maintain the facility.	Competition for materials. Pollution and non-renewable energy use are associated with the manufacture of materials.	Minimize use of substances in short supply. Use renewable energy sources.

GEOTHERMAL ENERGY
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*Discusses environmental side effects

SUMMARY AND PRELIMINARY EVALUATION

The summary tables found in this section of the interim report represent the evaluation of the data accumulated at this stage of the project. The side effects that appear to pose the highest risks fall into the following categories:

* Increased demand for construction materials, chemicals, and nonrenewable energy.
* Increased numbers of human accidents associated with particular energy systems.
* Problems associated with water and land use.
* Air pollution.
* Other high-risk side effects on natural biota.

For each renewable, those specific side effects judged to be the most significant are listed in the summary table 6. Ongoing work in the SERES project is aimed at further investigation of these side effects -- including the quantification of the effects where possible. Modification of the evaluations and rankings will be made as more data and calculations become available.

Finally, and most importantly, the search for possible solutions to the problems arising from the various side effects is a major objective of the ongoing work. The mitigating actions proposed at this point are summarized in Table 7, and the renewables for which these actions are most necessary are indicated. Further mitigating actions will be investigated as the project proceeds.

Table 6.

SUMMARY OF HIGH-RISK SIDE EFFECTS

ENERGY SOURCE	MATERIALS USE	ACCIDENTS AND ILLNESS	WATER USE	LAND USE	AIR POLLUTION	OTHER SIDE EFFECTS
BIOMASS	Increased use of chemicals to make fertilizers. Materials are needed for construction of conversion facilities.	Accident rates are high for workers in agriculture and logging	Demand for water would increase. Runoff of soil and chemicals could be large.	Pressure would significantly increase to convert cropland and protected lands. Erosion rates could increase if proper land management is not followed.	Emissions from boilers and stills could be significant--especially if using nonrenewable fuels. Local pollution from wood burning. Wind erosion.	Potential loss of some critical natural habitats. Possible loss of some wildlife and plant species.
LARGE-SCALE PHOTOVOLTAIC AND STEC	Further demand on some constituents of photovoltaic cells that are in short supply. Increased use of concrete, steel, etc. in the construction of collector farms.	High accident rates for construction of large, tall towers. Worker exposure to toxics in manufacture and installation of cells and working fluid system.	Increased water use if conversion system has water cooling. Improper disposal of cleaning fluids, working fluids, and used cells could contaminate water supplies.	Land areas are required for collector farms.		Military applications of SPS. Bird and insect kills could result from improper siting in flight paths. Disruption of natural habitats. Possible local climate changes.
HYDROPOWER				Prime natural areas might be flooded for reservoirs.		Radical disruptions of habitats by new reservoirs. Loss of natural free-flowing rivers

Table 6.

SUMMARY OF HIGH-RISK SIDE EFFECTS

ENERGY SOURCE	MATERIALS USE	ACCIDENTS AND ILLNESS	WATER USE	LAND USE	AIR POLLUTION	OTHER SIDE EFFECTS
WIND ENERGY	Increased use of metals and concrete for construction of WEC systems.	Hazards from working on tall structures.		Some land required for WEC system arrays and possibly for new transmission lines (multiple uses of land are possible though).		WEC arrays may be visually unpleasin Noise may be disturbing. Possible radio and TV interference.
GEOTHERMAL ENERGY		Hazards from hot, high-pressure fluids.	Chemicals may get into groundwater --especially, geopressured brine systems.	Possible geologic effects. Might lead to subsidence or earthquakes--especially for geopressured brines.	Possible emissions of significant quantities of toxic substances. Some radioactive substances would be released.	Possible disruptio of scenic areas.
OTEC			Possible release of chemicals and waste products into water.	Some coastal areas would be used for support facilities.	Possible release of CO_2 from deep ocean water brought to the surface.	Disruption of loca marine ecosystem.
RESIDENTIAL PHOTOVOLTAIC	Increased demand for scarce materials needed for manufacture of photovoltaic cells.	Fire hazards and overheating of rooftop collectors. Release of toxics in fires and other accidents.	Possible contamination from disposal of used cells and working fluids.			

Table 6.

SUMMARY OF HIGH-RISK SIDE EFFECTS

ENERGY SOURCE	MATERIALS USE	ACCIDENTS AND ILLNESS	WATER USE	LAND USE	AIR POLLUTION	OTHER SIDE EFFECTS
DIRECT SOLAR HEATING AND COOLING	Construction materials needed (e.g. glass, metals, concrete)	Accidents from handling working fluids for active systems. Glass breakage hazards.	Disposal of working fluids could cause water pollution.	Land area required for storage ponds.		Collectors and solar architecture may be unpleasing to some people.
CONSERVATION	Materials and energy are needed for manufacture of insulation and energy-efficient appliances.	Possible release of toxics from insulation during fire. Possible long-term effects from radon buildup. Greater severity of accidents due to increase in small cars.			Possibility of indoor air pollution if houses are too tight.	

Table 7. Summary of Mitigating Actions That May Be Required for Large-Scale Use of Renewable Energy

MITIGATING ACTION	BIOMASS	EFFICIENCY	DIRECT SOLAR	HYDRO	WIND	PHOTOVOLTAIC	STEC	OTEC	GEOTHERMAL
1. Use energy-efficient equipment and renewable energy in the construction, maintenance, and decommissioning of renewable-energy facilities.	x	x	x		x	x	x	x	x
2. Minimize the use of resources for which the renewable-energy technologies are in competition with critical needs or cause severe economic or employment problems.	x	x	x		x	x	x	x	x
3. Promote awareness of worker and public safety problems that may arise or become worse because of increased use of renewable energy. Publicize precautionary measures and provide safe equipment. Minimize the chances for exposure to toxic chemicals.	x	x	x		x	x	x		x
4. Minimize the use of fresh water supplies and avoid siting in known water-short areas.	x					x	x		
5. Avoid use of critical habitats for energy farms or conversion facility sites.	x			x	x	x	x	x	x
6. Design facilities to be compatible with wildlife habitats and movement patterns.	x			x	x	x	x	x	x
7. No new dam construction; use existing sites.				x					
8. Avoid conversion of prime natural, scenic, and food-crop lands for energy crops or conversion facilities. Look for compatible, multiple uses of any land.	x			x	x	x	x	x	x
9. Use best techniques to minimize erosion.	x								
10. Use proper precautions to avoid contamination of water supplies with soil and chemicals. Choose chemicals for working fluids, maintenance, etc. with environmental risks in mind.	x		x			x	x		x

Table 7, cont.

MITIGATING ACTION	BIOMASS	EFFICIENCY	DIRECT SOLAR	HYDRO	WIND	PHOTOVOLTAIC	STEC	OTEC	GEOTHERMAL
11. Require pollution control technologies. Require or enforce existing local ordinances to reduce air pollution. Monitor pollution levels and modify operations if needed.	x	x						x	x
12. Design facilities to be aesthetically pleasing and free of noise disturbance.			x		x	x	x		x
13. Avoid electromagnetic interference with communications systems.					x				
14. Monitor side effects that could contribute to climate or weather changes.	x					x	x	x	x
15. Promote awareness of potential military applications.						x			

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This section contains a selected bibliography of recent references. While some key references on technical aspects are included, this compilation is primarily devoted to references covering the environmental aspects of renewable energy sources.

Table 8 below is a summary of references of special interest. As indicated, several references each contained discussions of more than one renewable energy source. A few recent bibliographies are also given in the table. Finally, sources of continually updated information are listed.

Table 8

References in which more than one renewable energy source is covered	(81 Ros), (81 Pla), (81 CON), (80 EIA), (80 EIH), (80 Hol), (80 Ken), (80 LBV), (79 Hol), (79 Inh), (79 Law), (79 Smi), (79 Sor), (79 Win), (78 Har), (78 Inh), (78 Poo), (77 Til)
Bibliographies	(81 DOE), (81 MITR), (80 Bio), in (80 CON), in (80 EIH), in (80 Hol), in (80 Law), (80 War), (79 Hoy)
Sources of updated information	Environment Information Center, Inc. - Energy Information Abstracts Energy Information Administration - Monthly Energy Review

Table 9 Addresses of Organizations Cited in the Bibliography

The Bioenergy Council	1625 Eye St., N.W. Washington, D.C. 20006
Center for Energy and Environmental Studies	Princeton University Princeton, N.J. 08544
Citizens' Energy Project	1110 6th St., N.W. Washington, D.C. 20001
Energy and Resources Group	University of California Berkeley, CA 94720
Energy Information Center, Inc.	292 Madison Ave. New York, NY 10017
Energy Information Administration (EIA)	12th St. & Pennsylvania Ave., N.W. Washington, D.C. 20461
International Solar Energy Society-American Section (ISES-AS)	R.I.A.T., U.S. Highway 190 W Killeen, TX 76541
MITRE Corp.	1820 Dolley Madison Blvd. McLean, VA 22102
National Bureau of Standards (NBS)	Rte. 270 Gaithersburg, MD 20234
National Technical Information Service (NTIS)	5285 Port Royal Road Springfield, VA 22161
Office of Technology Assessment (OTA)	17th St. & Pennsylvania Ave., N.W. Washington, D.C. 20500
Scientists' Institute for Public Information (SIPI)	355 Lexington Ave. New York, NY 10017
Solar Energy Research Institute (SERI)	1536 Cole Blvd. Golden, CO 80401
Worldwatch Institute	1776 Massachusetts Ave., N.W. Washington, D.C. 20036

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