A TECHNOLOGY
ASSESSMENT OF
SOLAR ENERGY SYSTEMS

NATIONAL IMPLICATIONS OF SOLAR FUTURES

A **TASE** PROJECT REPORT

November 1981

U.S. Department of Energy
Assistant Secretary, Environmental Protection,
Safety, and Emergency Preparedness
Office of Environmental Programs

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Prepared by:

Argonne National Laboratory
Brookhaven National Laboratory
Lawrence Berkeley Laboratory
Los Alamos National Laboratory
Oak Ridge National Laboratory
Pacific Northwest Laboratory
The Mitre Corporation

U.S. Department of Energy
Assistant Secretary, Environmental Protection,
Safety, and Emergency Preparedness
Office of Environmental Programs
Washington, D.C. 20585

Preface

The U.S. Department of Energy, Office of Environmental Programs is conducting a project entitled a Technology Assessment of Solar Energy (TASE) systems, to evaluate the range of potential environmental, community and economic consequences of rapid, large-scale commercialization of solar technologies. The goal of this project is to identify and evaluate both the positive and negative effects of solar technology deployment. The project can provide a basis for avoiding potential problems and for grasping opportunities during the transition to significant levels of solar energy in the U.S.

Solar energy is generally considered a benign energy source. However, this source includes a wide variety of diverse technologies such as biomass combustion, gasification and liquefaction, photovoltaic cells, wind energy, and others. Therefore, a systematic analysis of both solar and biomass technology deployment, biomass resource use, and the associated expansion of solar system manufacturing is required to reduce generalities to concrete terms. In particular, the rate of growth required to meet earlier Federal policy goals for solar energy raises a number of issues.

The manufacture and installation of solar energy systems, including biomass, on a scale sufficient to meet significant national estimates for solar energy by the year 2000 implies large shifts in the economy as new solar industries evolve and expand.

Massive solar development will force a major increase in the use of those raw materials needed to make solar system components. Along with this increased resource consumption and production will come associated pollution. In addition, rapid solar energy development may mean significant secondary or unplanned changes in institutions as the nation moves toward greater use of solar energy systems.

Objectives of the TASE Project

The project is designed to achieve two overall objectives:

1. Comprehensively examine the environmental, community and economic impacts resulting from widespread development and utilization of solar energy technologies, emphasizing regional differences and
2. On a national basis, determine the relationship between alternate solar development options and existing environmental, resource and economic issues.

It is hoped that within the framework of these objectives, the findings of the project will help the Federal, State and local governments define an environmentally acceptable solar energy future.

This report presents the findings from studies conducted by six DOE National Laboratories and the MITRE Corporation aimed at meeting the first objective. The report analyzes and compares two potential solar energy futures for the U.S. in the year 2000 in the context of high overall national energy growth.

Throughout the document, scenarios and views of energy/economic and institutional futures are presented. These should be viewed as illustrations for exploring potential impacts of policy implementation strategies, not as predictions of a likely future.

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Executive Summary

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BACKGROUND

This report analyzes and compares two potential solar energy futures for the U.S. in the year 2000, in the context of high overall national energy growth (118 quads) which is compatible with the upper range of National Energy Plan. Both solar scenarios are derived from the Federal Domestic Policy Review of Solar Energy (DPR).

One scenario is a low solar growth scenario, wherein solar and biomass technologies contribute the equivalent of 6 quads or 5 percent to total national energy supply. This is termed the Business As Usual or BAU case and assumes minimum federal incentives for solar energy.

The other scenario is a high solar growth scenario wherein solar and biomass technologies contribute the equivalent of 14.2 quads or 12 percent of total national energy supply. This is termed the Maximum Practical Growth or MPG case and assumes maximum federal incentives for solar energy.

This section presents the results and synthesis of several studies which analyzed and compared the environmental and socioeconomic implications of these potential futures at national, regional and community levels. Detailed discussions of the project itself, the construction of the scenarios and each analysis contributing to the study are contained in subsequent sections of the report.

MAJOR FINDINGS

On a simple percentage basis, changes in national level pollutant residuals due to solar energy are relatively small compared with national level residuals associated with the economy as a whole. However, that fact does *not* lead to the conclusion that the environmental, resource and economic impacts of solar and biomass energy are negligible and hence do not require attention in formulating national energy and environmental policies and programs.

In fact, if a maximum practical effort to deploy solar and biomass energy systems in the U.S. is undertaken over the next twenty years using economic incentives alone, *a variety of significant environmental and socioeconomic effects can occur;* some of these are detrimental while others are beneficial in character.

This conclusion is derived from the following ten major findings of the study which are based on a comparison of the MPG and BAU scenarios:

POTENTIAL PROBLEMS

1. *Small, biomass combustion units can lead to significant increases (10-30%) in particulate air emissions nationally.*

Particulate air emissions from small biomass combustion sources could equal more than one-half the national particulate emissions from utility and industrial coal use. Such emission levels would result chiefly from wood combustion in the industrial and residential sectors and from crop residue combustion in the agricultural sector.

Emphasis on alternate technology such as biogasification or on particulate emission controls would significantly reduce this problem in the industrial sector. Attention to wood stoves is indicated due to their disproportionately high particulate emissions.

2. *Indiscriminate collection of agricultural residues for use in biomass systems can lead to significant increases (up to 18%) in erosion in a number of midwestern and western states.*

Erosion due to crop resiude collection is sensitive to the type of crop residue collected, the soil type, and level of cultivation of the land where such collection might occur. In the high solar case, barley and wheat residues account for 80% of the biomass residue energy used, but result in only 10% of the erosion.

Emphasis on selected crop residues and on selected agricultural areas could markedly reduce this potential erosion and sedimentation problem.

3. *Relatively less-polluting solar technologies can require over twenty times the capital investment of the more polluting biomass technologies.*

Finished materials (metals, concrete, glass, etc.) requirements and hence capital costs are significantly greater for solar technologies than for biomass technologies. Of the total $750 billion in capital required in the MPG for solar and biomass between 1980 and 2000, biomass systems require only 4% of the capital ($30 billion) to provide 40% of the total biomass/solar energy contribution in the year 2000.

Shifting a relatively modest fraction of the total solar/biomass capital requirement to pollution control equipment can result in major reductions in biomass related pollution without significantly reducing the solar/biomass energy contribution.

4. *Manufacturing or indirect pollution "hot spots" can occur near and after 2000 where industrial growth occurs for materials intensive solar technologies.*

There is a wide range of indirect pollution emission rates among the solar technologies on a per unit energy installed basis. They are all greater than the corresponding indirect rates for biomass and conventional systems. Silicon photovoltaics appears to have by far the greatest such indirect emission rate. The significance of the indirect pollution impacts will depend on the *growth rates* of the most materials intensive solar technologies, the geographical concentration of their manufacturing facilities, and how modern those facilities are. Indirect pollution will also grow as the national solar siting pattern penetrates areas of lesser insolation and wind regime.

The installation of modern steel, copper, etc. processing technology in the U.S. in advance of the rapid solar growth of the 1990's would minimize indirect pollution problems in industrial growth areas. Importation of finished products would also mitigate this problem, but with less favorable balance-of-payment implications.

5. *With the exception of passive solar designs, solar systems have much greater finished materials requirements than biomass and conventional systems.*

Some solar systems are much more materials intensive than others, for example, solar thermal power systems for utilities and photovoltaic utility systems are highest; dispersed wind systems are more materials intensive per unit energy than central wind systems. Any solar system material that will be in short supply or whose price would increase dramatically during the 1990's will tend to undermine the nation's ability to realize the solar scenario. Copper in particular, appears to be such a problem in view of current supply trends and its use in most solar systems.

A long range materials policy as well as the development of solar system material substitutes should be a basic underpinning of a major federal solar incentive program.

POTENTIAL BENEFITS

1. *Sulfur dioxide and nitrogen oxide emissions from the utility and industrial sectors could be reduced by solar and biomass systems by 5% and 6%, respectively.*

These reductions are due chiefly to the displacement of new coal combustion facilities in the utility and industrial sectors. Sulfur dioxide reductions are due to such displacements by biomass and solar systems. Nitrogen oxide reductions are due primarily to displacement by solar technologies. Greater displacements of older coal combustion facilities and less of gas and nuclear units would further reduce such emissions.

2. *Water pollution associated with coal mining and conventional power plants would be reduced in various locales.*

Effluents associated with the mining of up to 185 million short tons of coal per annum could be eliminated by 2000. In addition the effluents from the equivalent of up to 65 coal fired and 35 nuclear power plants could be eliminated in the same period. Actual effluent levels would depend on locales where displacement occurs.

3. *Water resource requirements for solar systems are minimal.*

Water requirements for solar systems are largely discretionary and are subject to flexible management. Some local benefits are possible where conventional systems with mandatory water requirements have been displaced. If silvicultural energy forms had been included in the scenarios, regional water use would be a significant concern.

4. *Decentralized solar systems need not lead to urban sprawl in non-metropolitan residential communities.*

If complete planning for small scale solar systems takes place *at the local level,* physical impacts, such as elimination of tree cover or disruption of community character, can be minimized. In all but the most dense commercial downtown sector, non-metropllitan conities can meet on site energy demands consistent with the high solar scenario.

5. *Average annual employment associated with the energy sector would increase in the high solar case with the greatest new requirements in certain engineering fields.*

While both skilled and unskilled labor requirements would increase, the greatest relative increases would occur in the area of engineering skills. A major federal solar incentives program would logically require increased output from educational institutions in these skills beginning in the late 1980's and early 1990's.

These major findings result from eight analytical studies described in subsequent chapters of the report. Each of these analyses is summarized in the following section.

RESULTS

1. *Air Pollution: Maximum pratical solar and biomass energy growth can lead to some reductions in sulfur dioxide and nitrogen oxides air emissions, but to significant increases in particulate emissions.*

In general, the high solar case results in significant increases and decreases in energy related criteria pollutant emissions; moderate regional decrease in SO_2 and NO_x; significant increases in biomass related particulate emissions in certain regions and subregions; minor changes from nonenergy related criteria polluants associated with manufacturing solar on a national basis; essentially no influence on long-range transport of energy related pollutants.

Sulfur dioxide and nitrogen oxide emissions can be reduced by 5 and 6 percent, respectively. These lower emissions are due to an estimated reduction in output from coal-fired plants in the year 2000 due to energy demands met by solar and biomass systems. Nationally, particulate emissions from biomass combustion could equal one-half of those from coal combustion even though the energy supplied by coal would be more than five times greater than that provided by biomass. Particulate emissions were estimated to increase by nearly 30 percent in the high solar case if uncontrolled biomass combustion systems increased. Seventy-five percent control on small industrial systems would reduce this figure to 10%. The greatest increase in particulate loading occurs in the Southeast. More stringent controls on biomass combustion systems or the use of biomass resources to produce liquid or gaseous fuels would reduce the projected particulate emissions load significantly.

The consequences of these changes in emissions, as projected by long range transport trajectory models, are to slightly improve sulfate air quality over most of the U.S. at a cost in slightly increased fine particulate concentrations. This would result in a small net improvement for these pollutants in most locations by the year 2000. These changes are in addition to an underlying temporal trend of improving air quality in the Northeast and deteriorating air quality in the South-central U.S.

The direct solar energy technologies result in minimal direct and indirect air polution impacts. The photovoltaic technology examined as a part of the TASE Project produces significantly larger amounts of air pollutants per dollar investment than the technologies it displaces. Thus, it appears that photovoltaics system production could produce more SO_2 pollution than would the conventional coal combustion systems displaced by photovoltaics. However, the small quanity of energy derived from photovoltaics in both scenarios does not influence overall national air pollution results.

Small scale, low cost decentralized biomass combustion produces significantly greater amounts of air pollution than do larger biomass combustion facilities in supplying the same amount of energy because the smaller facilities are unregulated and uncontrolled.

The biomass technologies require only 4 pe rcent of the total solar/biomass capital investment to contribute 40 percent of the total solar/biomass energy supply. Thus the cost of controlling biomass industrial air pollution would not be significant compared to the overall solar/biomass capital requirements. However, if relatively small, low cost uncontrolled biomass combustion technologies dominate the biomass share (40 percent) of the overall solar/biomass energy supply in the year 2000, they would result in very high proportion of the total solar/biomass pollution.

2. *Water Pollution: Local water quality could be degraded in certain agricultural areas; however, certain locales could benefit slightly providing toxic fluids from solar systems are properly disposed.*

Overall, the high solar case causes relatively minor increases and decreases in water pollution across the nation; some significant increases in erosion occur in agricultural states; some potential local benefits and penalties associated with reduction of conventional waste disposal requirements and increased solar working fluid use also occur.

While some lessening in water pollution due to reduced coal mining and power plant wastes could be expected, biomass residue harvesting could significantly exacerbate existing erosion and water pollution problems in certain midwestern and western agricultural regions. In certain land resource areas the average relative increases in erosion from present levels to levels in the high solar case are as large as 18%. On average, in the senarios, corn, soybeans, sorghum and sugar cane residues result in the greatest erosion but this can be highly dependent on local land type.

Residue collection and increased cropping could increase sediment and nutrient and pesticide loading in surface waters as a result of erosion on agricultural lands. This increase in erosion engendered by the high solar scenario would be felt primarily in the Northern and Central Plains states and in certain areas of California and Washington. Because of the availability of agricultural areas with acceptable erosion rates, the significant impacts of erosion rates on water quality could possibly be minimized by management of residue collection patterns and limiting collection to certain agricultural land resource areas. Oat, wheat and barley residues cause the least erosion in the scenarios but this is highly dependent on land type.

The use of biomass residues such as municipal wastes, sludge and feedlot manures for energy production can result in two potential benefits: reduced discharge of oxygen demanding wastes to streams and reduce landfill requirements.

Potentially significant public health and safety problems can result from recharging and disposal of various heat transfer and storage fluids used in central solar thermal systems and in other direct solar systems. These fluids include Therminol 66, Dow A, and toluene, known toxic substances. Responsible maintenance and toxic waste disposal procedures are required to eliminate pathways to the public.

Manufacturing of solar cells could produce significant quantities of toxic solids and liquid wastes in certain locales. The public would generally not be exposed to such products as silicon dust, phosphine gas, and hydrogen chloride, if proper housekeeping procedures are observed.

3. *Indirect Pollution: Because the scenario year occurs early in an extrapolated solar transition, indirect pollution is not estimated to be highly significant.*

However, solar *growth rates* required to achieve the high solar case, if projected into the 21st century, could make indirect pollution a siginificant problem in industrial areas in that period. The significance of indirect impacts in general will be dependent on the *growth rates* of the most materials intensive solar technologies.

The indirect residuals from the solar technologies vary, in general, with the level of investment and those technologies, but they are generally insensitive to the precise set of industries stimulated by that investment. This generalization seems to hold well for all criteria air pollutants and solid waste, but not water pollutants and for all technologies except photovoltaics.

The indirect emissions from solar systems are considerably greater than those from biomass systems or conventional energy systems. There is a wide range of indirect pollution, particularly air pollution among the direct solar technologies on a per unit energy basis. Photovoltaic systems cause by far the greatest indirect pollution per unit energy output.

Because significant growth in direct solar systems begins only by the mid-1990's, toward the end of the century it is possible that maximum growth for solar technologies may engender emerging pollution "hot spots" associated with rapid growth in certain primary materials industries such as copper, aluminum and steel.

4. *Water Resources: Water availability will be largely unaffected by the increased use of solar and biomass technologies, especially in the East.*

A slight water savings can result from displacing conventional technologies and associated mandatory cooling water requirements with solar energy, particularly in the East. This savings is on the order of tenth's of a percent of total projected water consumption in 2000.

Solar collectors can periodically consume large quantities of wash water from municipal water supply systems. Thus, the potential does exist for certain localized impacts where concentrations of solar collectors are projected to be sited, particularly in the West. However, these wash requirements are largely discretionary and hence to some extent controllable.

Large, intensively cultivated biomass farms (not included in the scenarios) would have drastically increased regional water requirements.

5. *Land Resources: Impacts on the physical layout and character of nonmetropolitan communities can be minimized only by comprehensive local energy planning.*

In all but the most dense land-use sectors (commercial business district), communities can meet significantly more on-site energy demand than required by the scenario with minimal physical impact on the community. In the residential sector, urban sprawl is not required.

Local government action can have substantial influence on the contribution of small scale solar technologies. This contribution from small technologies will vary widely depending on insolation and community character.

Municipal biomass processes could reduce requirement for land needed for municipal sewage waste disposal.

In rural areas, erosion is the primary land use impact and this would result from agricultural biomass collection.

6. *Material Resource Impacts: Certain key materials including steel, copper, aluminum, and concrete are likely to be in short supply, based on current projections of resource availability.*

The requirement for the above key materials and finished products increases significantly between scenarios. In the high solar case, the solar technologies characterized would require the equivalent of 7 percent of national steel production, 16 percent of copper production, 8 percent of aluminum production, 16 percent of concrete production and 8.5 percent of glass production based on 1974 U.S. production figures.

The U.S. industrial capacity needed to produce some of these materials is presently declining. This would increase in U.S. reliance on foreign sources of supply. This could in turn influence the cost to produce the solar technologies and inhibit the rate of growth to some degree.

Increasing the U.S. industrial capacity to produce the required materials has associated with it some positive socioeconomic impacts, but potentially negative environmental effects, unless modern production technology is used or significant imports of finished products occur.

The use of wood for biomass system fuel could have a significant impact on ecosystems and on prices of fibre related products, but this issue was not addressed quantitatively in the present analysis.

7. *Economic Resource Implications: Most solar energy technologies will require considerably more capital investment than will be required for the conventional energy technologies for which they are substituted.*

The large amounts of capital investment required in the high solar case to produce and deploy direct solar technologies are likely to have dampening effect on other areas of the economy over the period 1980 to 2000.

Most solar energy technologies are capital and labor intensive. The total investment in solar energy activities increases by $350 billion between 1980 and 2000 for the high solar scenario which embodies Federal incentives for solar energy. This is approximately a 25 percent increase over the low solar case. The investment in solar technologies increases while investments in nuclear, coal and gas industries decline.

This is due to the fact that solar technologies are significantly more capital intensive than biomass and conventional energy sources. The operational expenses of solar technologies are considerably less than biomass and conventional technologies because of the latter's fuel requirements, but in the aggregate, the associated financial benefits would not arise until well into the next century.

The distribution of investment requirements indicates that solar space heating has the largest requirement, followed by wind systems, medium temperature industrial process heat, and central receivers.

In all time periods, a dollar spent for solar materials and equipment results in less indirect employment than does a dollar spent in the energy industry as a whole. However, the distribution of the additional energy related investments have a more significant impact at the local level than comparable investments in conventional energy sources.

8. *Employment and Skills Implications: Net direct employment gains may be as high as three million employee years between the low and high solar case.*

Solar related employment shows minor increases compared to total national employment, but can be potentially significant as the rate of growth of solar energy accelerates in the late 1990's; significant increases can occur in certain skilled labor categories with corresponding decreases in other labor categories.

The high solar scenario would require significantly more direct on-site labor in the energy sector than would the low solar scenario. The cumulative net employment gain in the energy sector from the high solar scenario would be almost 3 million direct, on-site employee-years over the scenario's 1980 to 2000 time period. While cumulative conventional powerplant construction, operation, and maintenance employment would total some 500,000 employee years less in the high solar scenario and fuel system employment some 300,000 employee-years less, solar electric facilities would require about 900,000 more on-site employee-years, biomass systems about 750,000 more, and Solar Heating and Cooling of Buildings (SHACOB) and Solar Industrial Process Heat (IPH) systems some 2,100,000 more employee-years than in the low solar scenario. The annual net difference would reach about 300,000 direct employee-years in the 1996 to 2000 period when the market penetration of solar systems is at its peak.

The average community or county could experience significantly greater energy employment opportunities under the high solar scenario.

The requirements for both skilled and unskilled labor could increase substantially in the high solar case. Skills such as carpentry and pipefitting could be required in increasing numbers, while the need for boilermakers and linemen could decrease. In the engineering disciplines more chemical, civil, and mechanical engineers could be needed, whereas fewer petroleum, geological, nuclear, and mining engineering could be needed. The average annual employment for civil and mechanical engineers could double and could increase fivefold for chemical engineers in the high solar case.

Indirect employment in industries associated with supplying goods and services for solar energy construction is nearly three times larger in the high solar case than in the low solar case.

CONCLUSIONS

Given Federal economic incentives alone as the method to accelerate development and deployment of solar and biomass energy technologies, detrimental effects would not be minimized nor would potential benefits be maximized. This is due to the fact that certain community factors, regional and subregional pollution levels, economic factors and materials resources are sensitively dependent on: (a) the solar technology and biomass resource/technology mix and deployment pattern, (b) the primary fuels and conventional technologies displaced, and (c) the types, levels and rates of materials consumed in constructing solar systems and in fueling biomass systems.

A key feature of the maximum national effort is that most of the solar and biomass energy contribution occurs only after the early 1990s. If environmental problems are to be avoided or mitigated and potential environmental benefits are to be realized during that time period, three key elements could be incorporated into solar and biomass commercialization strategies and into national and regional environmental protection policies.

First, relatively small, lower cost solar and biomass technologies which are not subject to environmental regulations should not proliferate in number to the point where uncontrolled emissions or waste become significant regional or local problems.

Second, within the limits of economic feasibility and conventional energy available, older facilities could be displaced by solar and biomass technologies to minimize pollution from all conventional sources.

Third, because solar technologies are materials intensive and biomass technologies are fuel intensive (wood, grain residue, etc.), care must be taken at a national level to: (a) avoid proliferation of those technologies or systems which depend on materials which are projected to be within short supply domestically within 10 to 20 years, or use resources that are critical or irreplaceable in other segments of the economy (this would avoid shortages and price increases); and (b) control indirect pollution from manufacturing of solar energy systems at a number of primary industrial " hot spots." The growth of such situations could be sudden near the turn of the century as a feature of the rapid solar growth rate inherent in meeting the maximum practical national estimate.

Incorporation of these three key elements into national and regional planning can provide a basis for avoiding some undesirable side-effects of solar and biomass energy and for making intelligent trade-offs.

To date, the TASE study has demonstrated that both enviromental benefits and penalties can result from a national solar strategy based only on economic incentives. The final effort of the TASE study will examine specific technological alternatives consistent with national solar estimates. These alternatives can minimize some of the potential environmental, resource and economic problems identified in this report.

Chapter 1

Project Overview

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CHAPTER 1

PROJECT OVERVIEW

Introduction

In fiscal year 1979, the Office of the Assistant Secretary for Environment* of the Department of Energy undertook a Technology Assessment of Solar Energy (TASE) systems to evaluate the implications of solar technology deployment in the U.S. The specific objectives of TASE are (1) to examine the environmental, economic, and community effects of widespread development and use of solar and biomass technologies from 1980 to 2000; and (2) to determine, on a national basis, the relationship between alternate solar and biomass development options and existing environmental resource and economic issues.

Phase I

TASE is being conducted in three phases. Phase I was completed in fiscal 1980. During this phase thirty-eight model solar energy systems were characterized in terms of their resource requirements; pollutant residuals; and capital, operating, and maintenance costs. It also specified detailed energy scenarios and investigated the impact of solar-based energy systems on the community and its physical structure. The community level studies are divided into three task areas: (1) *community impact analysis*, (2) *threshold impact analysis* and (3) *solar city end-state analysis*. The overall purpose of the studies is to investigate the impacts of various solar-based energy systems on the community environment and its physical and institutional structure. Further, the studies identify issues and constraints to local and regional deployment of decentralized solar technologies. The integration of these studies has been coordinated by Lawrence Berkeley Laboratory. Each of these studies was designed and conducted, for the most part, by outside investigators. The community impact analysis was carried out by a research team from the University of California, Berkeley and resulted in a report, "Community-Level Environmental Impacts of Decentralized Solar Technologies." The threshold impact analysis conducted by a team from SRI, International (formerly Stanford Research Institute) was issued as a report, "Community Impediments to Implementation of Solar Energy." The end-state analysis was undertaken by the Urban Innovations Group of the University of California, Los Angeles. Its final report was entitled "Three Solar Urban Futures."

Several general conclusions emerge from the individual community-level studies. Even though each task area used a different study methodology and format, the results provide some generalized trends that should enrich the overall TASE analysis. The conclusions are related to the scenario and study assumptions and should be viewed as illustrations of potential opportunities and impacts but not as projections of a likely urban future.

The first general conclusion is that a community can meet the on-site energy demands assumed by the scenario in all but the most dense land-use sectors (e.g., central business district). In the residential sector, however, this may require removal of 15 to 35 percent of the tree canopy. Further, it may be required that greater than 80 percent of the total area in the industrial sector and about 50 percent of the available commercial parking area be covered with solar collections.

Secondly, decentralized solar technologies can produce substantially greater amounts of on-site energy supply than was prescribed by the scenario. Greater solar development can be realized by using "shared neighborhood systems" and by employing passive design in all new buildings. As evidenced in the hypothetical "solar city" (Future 3), a community may become energy self-sufficient if 650 acres of photovoltaic arrays are added in the commercial sector and 2800 acres of on-site collect ors are augmented in the industrial sector.

A third conclusion is that various institutional impediments can cause delays in achieving acceptance of solar technologies within the community structure. Most important among those barriers are the acceptance and adoption of solar systems by residential and commercial building industries, the legal issues of solar access, easements and use of public lands for solar technology installations, and the aesthetic concerns of the public and planning agencies. In order to meet the levels of on-site solar collection that are described in this study, these impediments must be removed.

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*Presently Assistant Secretary for Environmental Protection, Safety & Emergency Preparedness.

A fourth general conclusion is that passively designed buildings in future residential, commercial and industrial sectors need not look different from existing versions that consume up to 25 times more energy. However, the overall appearance of a community with a high level of solar development (e.g., large collector areas, tree removal, etc.), may be quite different based on current urban design and aesthetic criteria.

Finally, there are great opportunities for implementing decentralized solar technologies within a community. The implementation, however, will require the integration of urban and energy planning at the local level in order to avoid potential aesthetic, institutional and land use impacts.

Phase II

Phase II of the TASE Project builds on the results of Phase I. The objectives of Phase II are to analyze the environmental, resource and economic effects of two solar deployment scenarios. The two scenarios were derived from the Federal Domestic Policy Review of Solar Energy (DPR). A low-growth scenario (6 quads of primary fuel displaced in the year 2000) is based on the DPR "Business as Usual" scenario; a high-growth scenario (14.2 quads of primary fuel displaced in the year 2000) is based on the DPR "Maximum Practical Growth." TASE is based on a National Energy Plan (NEP) II scenario which projects a total maximum U.S. energy supply of 118 quads compared to DPR's maximum projected 114 quads. The details of the scenario comparison can be found in Chapter 2.

The third DPR scenario postulating a 20 percent share for solar and hydropower for the year 2000, with a projected total energy supply of 95 quads, is not discussed in this interim report.

The TASE Project is being administered by the Department of Energy's Office of Environmental Programs, Technology Assessments Division. The effort is being supported by a team of six DOE National Laboratories and the MITRE Corporation. The six DOE National Laboratories are:

- Argonne National Laboratory
- Brookhaven National Laboratory
- Lawrence Berkeley Laboratory
- Los Alamos Scientific Laboratory
- Oak Ridge National Laboratory
- Pacific Northwest Laboratory

This report, integrated by The MITRE Corporation, is based on contributions from each of the DOE National Laboratories. Their respective study areas are indicated in Table 1.1.

Approach

Phase II is essentially a comparative study of the quantities of the resources and the environemtnal pollutants projected under each scenario. The study focuses on the difference between the low and high growth solar scenarios. Analysts from each of the participating DOE National Laboratories and from The MITRE Corporation assessed the environmental and socioeconomic implications of solar deployment at the national, regional, and subregional levels. These analysts used the Strategic Environmental Assessment System (SEAS) model, a large energy/economic/environmental simulation model. Regional and subregional assessments were made using DOE National Laboratory simulation models. The basic comparison accounts for both direct effects associated with normal operations of solar systems, and indirect effects associated with system manufacture and installation.

Distinguishing between the direct and indirect effects of solar energy is important: for some technologies, such as photovoltaics, the indirect effects of solar deployment may be more significant than the direct. Unlike many solar studies in the past, this evaluation considered the entire U.S. economy projected for the year 2000.

Solar influences are evaluated according to their effect on air and water quality, water and land use, toxic and hazardous wastes disposal, the national economy, and employment. The study also establishes a framework for examining institutional issues and impacts.

Throughout the TASE "Base Comparison" analysis, project analysts searched for the causal relationships underlying observed trends. For example, if emissions projections for a given pollutant are seen to increase under the TASE 14 scenario, project analysts studied the two sceanrios to determine which specific solar technologies and/or supporting industries were

TABLE 1.1
Program Responsibilities

TECHNOLOGY ASSESSMENT DIVISION	Project definition, planning and management
MITRE	Data coordination and integration Materials resources Scenario development Waste disposal impacts Executive summary coordination
ARGONNE NATIONAL LABORATORY	Employment-technology specific Air quality Water quality
BROOKHAVEN NATIONAL LABORATORY	Long range transport of sulfates
LAWRENCE BERKELEY LABORATORY	National economics and employment skills categories Socioeconomics Urban land use
LOS ALAMOS SCIENTIFIC LABORATORY	Indirect impacts Rural land use Western water use
OAK RIDGE NATIONAL LABORATORY	Eastern water use
PACIFIC NORTHWEST LABORATORY	Long range transport of fine particulates

causing the increase. Conversely, where emissions projections are seen to decline under the TASE 14 scenario, analysts compared scenarios to discover the emissions sources which were being displaced as the result of high solar penetration. In this way, TASE addresses both the positive and the negative aspects of solar deployment and provides a framework to judge potential trade-offs.

Project Guidelines

At the start of Phase II, four basic guidelines were laid down for TASE Project simulation and analyses.

- Assess the impacts of solar development as defined in the Domestic Policy Review (DPR), a cabinet-level review of the supply potential of solar energy conducted by a federal task force and published in August 1978. That review postulated three development scenarios, of which two are examined in this report: the low case (6 quads of primary fuel displacement by the year 2000), and the high case (14.2 quads of primary fuel displacement by the year 2000).
- Use the SEAS model for national residuals calculations and as a screening device to identify regional and subregional residual distribution.
- The FOSSIL 2 Model which was used to generate NEP II would be used as a basis for detailed development and analysis of the nonsolar energy sectors and of other elements of the economy in the year 2000.
- Conduct the anaylses using the solar technology characterizations described in the TASE Phase II Workplan. These characterizations include thirty-eight model solar systems which were developed by the DOE National Laboratories and The MITRE Corporation in terms of materials requirements, energy output, capital cost, and environmental characteristics. Table 1.2 identifies the model systems.
- Consider the results of existing solar energy studies.

These assumptions resulted in the following major features of the scenarios which were analyzed and compared.

- Use of the FOSSIL 2 Model resulted in a projected national supply of 118 quads[2] of energy, of which solar would contribute 5 percent and 12 percent respectively.
- FOSSIL 2 included certain asumptions regarding the anticipated world price of oil, economic growth, and levels of national energy supply: national energy supply projections of 118 quads and a world oil price of $35 a barrel ($1978) in the year 2000, and an economic growth rate of greater than 3 percent. These projections result in solar systems contributing a lesser portion to national energy supply than might now be expected from extrapolating 1980 oil prices. More recent projections now estimate national energy supply at somewhere between 95 and 105 quads, with a corresponding growth rate of less than 3 percent. The implications of solar energy's contribution to a lower total national supply will be explored in the next phase of the TASE project. On this basis, it is emphasized that this interim report addresses the likely upper limits of a spectrum of possible U.S. energy futures.
- Retrofit solar systems were not characterized during TASE Phase I and thus the scenarios implied that solar would displace conventional nonrenewable energy systems expected to be built in the 1980-2000 time frame. This largely has the effect of solar systems displacing energy generated by new coal-fired facilities (that would have been built to more stringent air quality standards) and by nuclear power plants. Because little, if any, new oil-fired consumption would occur in this time frame, solar systems had little impact on reducing the pollution from combustion of oil or on reducing oil imports. Alcohol from biomass and alcohol use in the transportation sector is not considered in this report.

Other specific assumptions are identified in particular chapters of this report and in detail in the individual DOE National Laboratory and MITRE TASE reports.

In addition to the explicit assumptions made for the TASE Project, there are assumptions implicit in the DPR solar energy scenarios which the TASE Project is designed to assess.

The DPR Base Case, on which the TASE 6 solar scenario is based, assumed that:

- the National Energy Act would be implemented
- federal support for solar energy research, development, and demonstration will continue to exceed $500 million per year (1978 dollars)
- federal efforts will continue "to identify and overcome institutional barriers to solar energy"
- a specific solar energy technology mix will supply 6 quadrillion Btu's of primary fuel equivalent in 2000 (not including hydropower)

*The DPR Maximum Practical Case,*on which the TASE 14 scenario is based, assumed that:

- federal solar commercialization policies and programs will be more aggressive than in the base case

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1 quad = quadrillion BTUs of energy (10^{15} BTUs) in fossil fuel equivalents (FFE).

[2] From FOSSIL 2 Model, EIA: Basis of NEP II. This includes coal export, unconventional gas production, aggressive synfuels production and growth in nuclear capacity during 1980-2000.

TABLE 1.2
The Source of TASE Characterization Data

Data Source(Nat'l Lab.) *Model System*	*ORNL*	*LASL*	*LBL*	*ANL*	*MITRE*
A.1 Residential Heating (Active)		●			
A.2 Residential Heating and Cooling (Active)		●			
A.3 Residential Heating (Passive)		●			
A.4 Commercial Heating (Passive)		●			
A.5 Domestic Hot Water (Active)		●			
A.6 Commercial Hot Water (Active)		●			
A.7 Residential Wood Stoves					●
A.8 Residential Photovoltaic Conversion		●			
A.9 Commercial Photovolaic Conversion					●
A.10 Residential/Commercial Wind Energy Conversion		●			
B.1 Low-Temperature Industrial Process Heat		●			
B.2 Medium-Temperature Industrial Process Heat		●			
B.3 Industrial-Scale Solar Total Energy System					●
B.4 Incineration of Municipal Solid Waste			●		
B.5 Direct Combustion of Agricultural and Wood Residues				●	
B.6 Direct Combustion of Paper Wastes with Coal			●		
B.7 Furfural from Corn Residues (Acid Hydrolysis)				●	
B.8 Low-Btu Gas from Manure (Anaerobic Digestion)				●	
B.9 Low-Btu Gas from Municipal Sludge (Anaerobic Digestion)				●	
B.10 Low-Btu Gas from Municipal Solid Waste (Pyrolysis)			●		
B.11 Low-Btu Gas from Wood (Pyrolysis:850 Tons/Day Input)	●				
B.12 Low-Btu Gas from Wood (Pyrolysis:3400 Tons/Day Input)				●	
B.13 Medium-Btu Gas from Manure (Pyrolysis)				●	
B.14 Medium-Btu Gas from Corn Residues (Pyrolysis)				●	
B.15 Medium-Btu Fuel Gas from Wheat Residues (Pyrolysis)				●	
B.16 Ethanol from Corn (Enzymatic Hydrolysis/Fermentation)				●	
B.17 Ethanol from Corn Residues (Acid Hydrolysis/Fermentation)				●	
B.18 Ethanol from Wheat Straw (Enzymatic Hydrolysis/Fermentation)				●	
B.19 Ethanol from Wood (Acid Hydrolysis/Fermentation)				●	
B.20 Ethanol from Molasses (Fermentation)				●	
B.21 Methanol from Wood (Pyrolysis/Shift Conversion)				●	
B.22 Refuse-Derived Fuel Pellets from Municipal Solid Waste			●		
C.1 Agricultural Wood Stoves	●				
C.2 Solar Total Energy System			●		
D.1 Solar Thermal Power Generation (Central Receiver)					●
D.2 Utility-Scale Photovoltaic Conversion					●
D.3 Ocean Thermal Energy Conversion					●
D.4 Utility-Scale Wind Energy Conversion		●			

- the rate of solar deployment will be less sensitive to energy price than to federal policy initiatives
- a specific solar energy technology mix will supply 14.2 quadrillion Btu's of primary fuel equivalent in 2000 (not including hydropower)

The Basis for the Technology Assessment of Solar Energy Project

The TASE Project examines whether rapid solar deployment in the United States will produce significant changes in the environment and in the economy. A technology assessment of solar energy is needed to identify where these effects are likely, and to suggest development stragtegies which avoid or minimize undesirable effects.

To accomplish this purpose, TASE has identified the mechanisms by which solar effects may be produced, and has examined the cause-and-effect relationships to isolate key parameters which control the magnitude and extent of the effects.

Environmental Factors

TASE has identified at least three ways that increased use of solar technologies may produce environmental effects:

- by displacing conventional energy sources
- by releasing pollutants and using land and water resources during the normal operation and maintenance of solar systems (direct effects)
- by releasing pollutants and using land and water resources during the manufacture and installation of solar systems (indirect effects)

The environmental effects of the above factors have been defined in a series of issues involving ambient air quality, water quality, and land and water use in relation to the improvement or degradation of the environment under two alternative solar scenarios.

Economic Factors

The TASE Project focuses on two economic factors which can be affected by the different solar scenarios:

- the structure of solar-related capital investments
- changes in the distribution of capital investments in energy-related industries

The economic effects produced by these two generic factors are examined in terms of the relationship between increasing levels of solar deployment and the distribution of jobs by occupation and income level, materials resource requirements, and the creation of small business opportunities.

Institutional and Community Factors

The use of renewable energy resources and systems could influence institutions, infrastructures, and even the physical shape of urban centers—and these effects must be considered for a comprehensive, balanced assessment of solar technology. This TASE report focused on residential, industrial and rural land uses.

Chapter 2

The Scenarios

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CHAPTER 2

THE SCENARIOS

Introduction

This section presents an overview of the scenarios used by the TASE Project team to assess the implications of solar deployment. Included in this section are summaries of national energy supply productions and the role of solar systems in contributing to the national energy supply mix. All discussions are in FFE supplied or displaced. To examine the environmental and economic implications of solar technology deployment, the TASE Project postulated two solar deployment scenarios, a TASE low solar growth case (6 quads of primary fuel displacement) and a TASE high solar growth case (14.2 quads of primary fuel displacement). Figure 2.1 illustrates the production of energy by resource type through the year 2000 for these two scenarios. These scenarios are analogous to the Domestic Policy Review (DPR) of Solar Energy "Business as Usual" and "Maximum Practical" growth cases.

Figure 2.2 illustrates the accelerated rate of growth of the generic solar and biomass technologies evaluated in TASE. The estimated total primary energy demand in the year 2000 is estimated to be 118 quads (FFE). Figure 2.2 identifies the estimated contributions for the generic categories of solar energy between 1980 and 2000. For example, industrial solar thermal is expected to displace 2.1 quads of energy, primarily coal and gas in the industrial sector by the year 2000. The solar technologies that make up this category are expected to grow at different rates between the period 1980–85, 1985–90, and 1990–2000. Low temperature I PH systems are projected to be brought on line at a rate of 19.4 percent per year, while medium temperature systems grow at a rate of 9.2 percent per year (1990–2000). Overall solar is introduced at a rate of 3.2 percent per year through 1985; from 1985 to 1990 the rate of growth is 5.6 percent per year; and between 1990 and 2000 the growth rate is 6.6 percent per year in the low solar case. Only 15 per cent of the solar and biomass resources are used in central utility applications: the bulk of these contributions is from wind systems. In the high case, solar comes on line at an accelerated rate. Between 1975 and 1985, the growth rate is 6.2 percent per year; 1985 and 1990, 10 percent per year; and 1990 and 2000, 10.5 percent per year. In both the low and high case, the industrial, residential, and commercial sectors gain most during this rapid growth period. The major difference in growth in supply between the two cases is the increase in the utility share of solar supply. Approximately one-third of the energy coming on line between 1990 and 2000 in the high case is for utility applications.

The national energy mix in the year 2000 for each TASE scenario is shown in Figure 2.3. In the TASE low case, the 6 quads of solar supply represent 5 percent of the total supply. Coal, natural gas, nuclear and oil account for 35, 15, 14 and 27 percent of the total, respectively. In the high case, solar accounts for 12 percent of the total supply. The nonrenewable resources of coal, natural gas, and nuclear are reduced to 31, 14, and 12 percent, while oil is reduced only slightly as a result of this increase in solar penetration. This shift in the components of national energy supply causes a decrease in the number of large-scale conventional supply facilities and an increase in the number of small-scale solar and biomass systems. For example, the annual generation from 100 power plants would no longer be needed in the high case (two-thirds would have been provided by coal fired and one-third nuclear).

The high solar scenario approximately doubles the energy output from solar industrial process heat systems (especially biomass gas), nearly triples energy from residential/commercial solar and wind, and almost quadruples electricity generation from solar. This 8.2 quads increase displaces about 4.6 quads of fuel for conventional electric plants (41 percent nuclear, 59 percent coal), about 2.8 quads of industrial energy (44 percent coal, 56 percent oil and gas), and about 0.8 quads of residential/commercial oil and gas use.

Implications of Project Assumptions

The assumptions implicit within the TASE scenarios must be high-lighted at this point, since the study findings are influenced by them.

First, the FOSSIL2 scenario assumed a world oil price of $35 (in 1978 dollars) per barrel for oil in the year 2000, for both the low and high solar cases. The FOSSIL2 included an aggressive synfuels program and continued nuclear growth. Along with these assump-

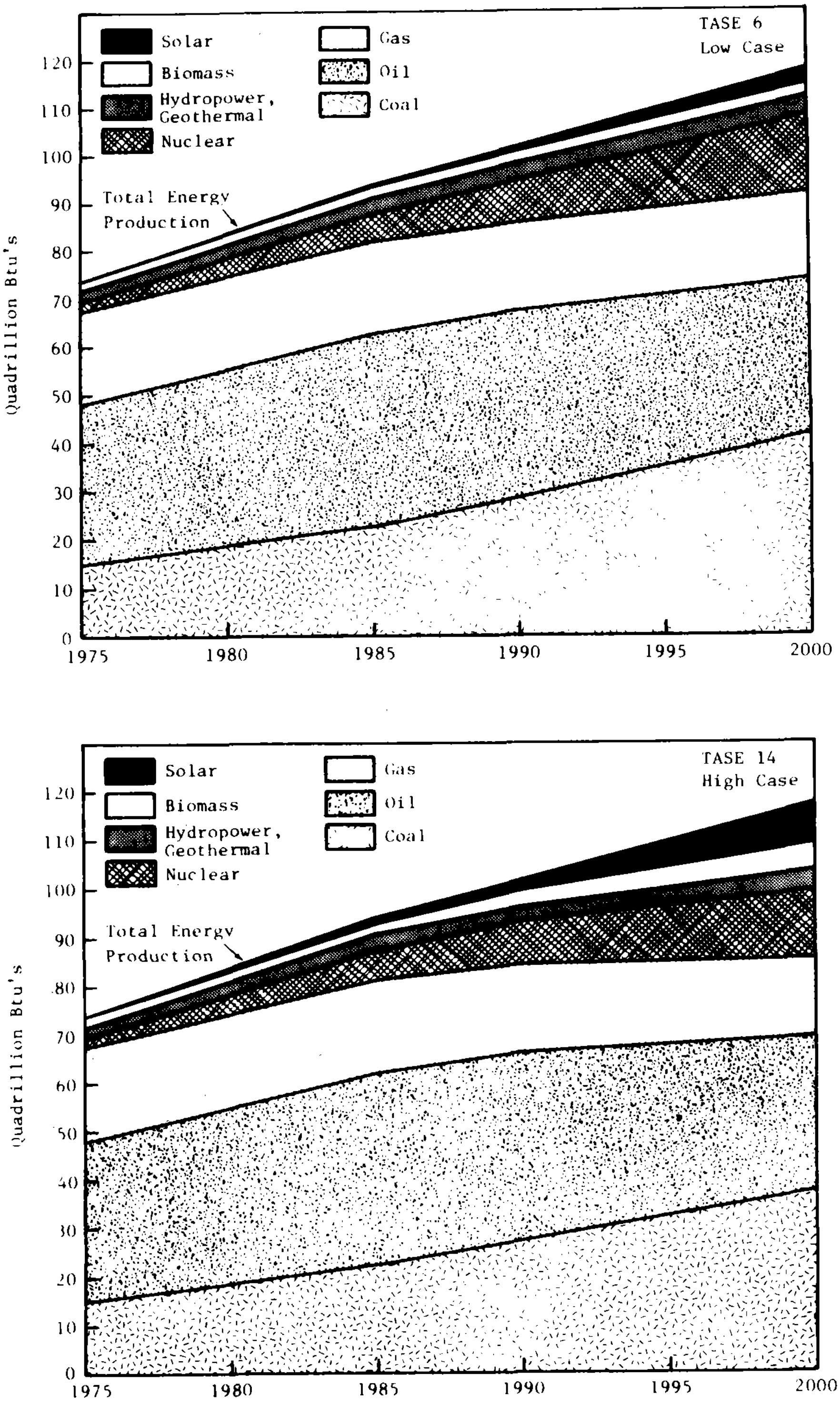


Figure 2.1
Production of Energy By Type

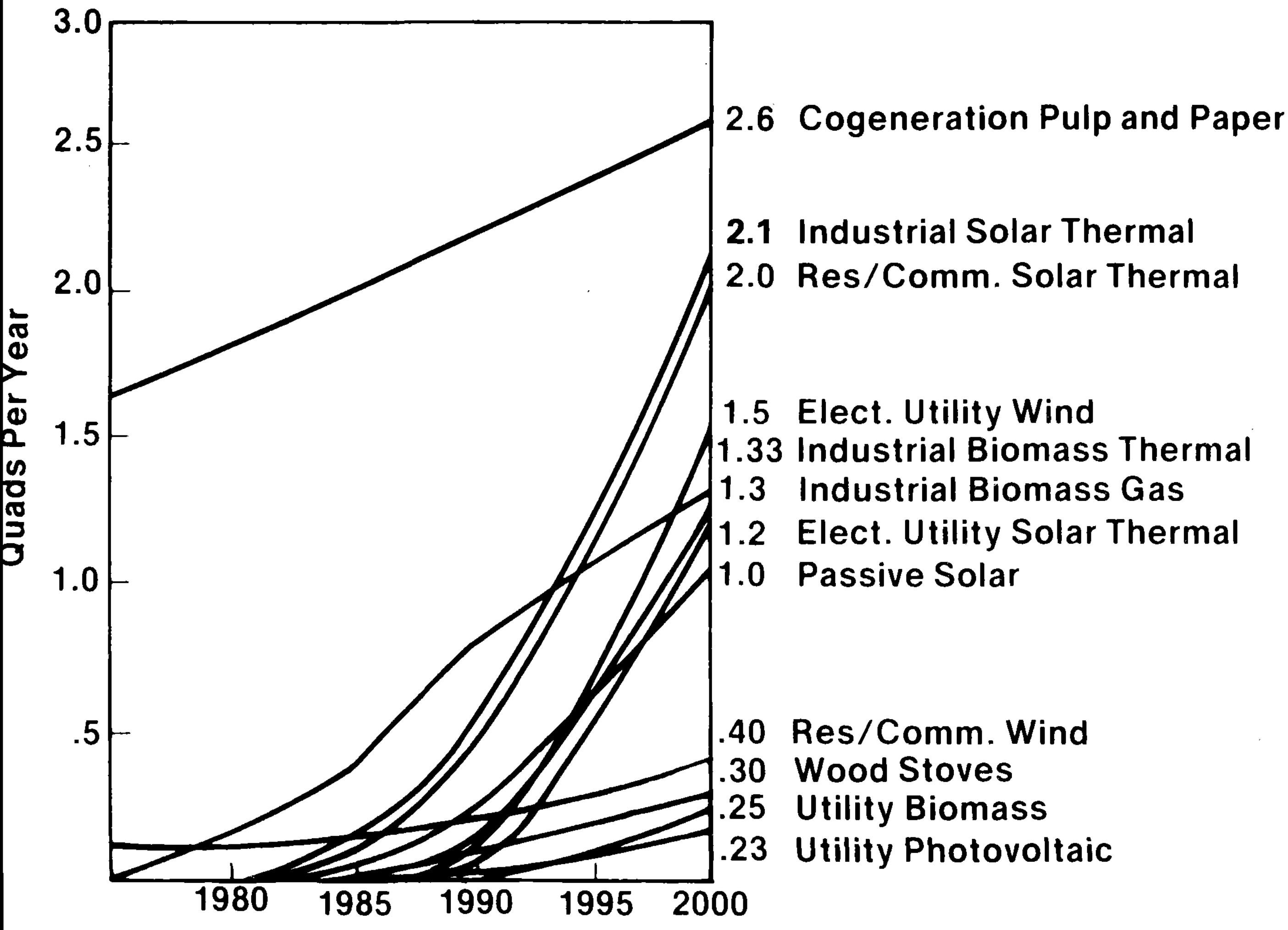


Figure 2.2
Growth of Major Solar Technologies
—TASE High Solar Case

tions, the difference between the high and low solar cases is assumed to be strictly a function of federal incentives and not energy price fluctuations. The FOSSIL2 scenario also assumes that the GNP will grow 3.5 percent annually from 1978 to 1985 and 3.1 percent annually from 1985 to 2000. Prices for all oil will be fully decontrolled after 1981; natural gas will be decontrolled by 1985. The federal policy stated in the National Energy Act of 1978 and the President's April 1979 energy proposals will be followed. The price of oil in 1980 was already $28 (in 1978 dollars) per barrel. This dramatic increase in the price of oil, and a projected U.S. economic growth rate below 3 percent for the 1980s, will tend to cause a lower projection of our national energy supply, probably in the 95 to 105 quad range. A recently released DOE study of low energy projection speculates that energy supply could be in the 50 to 80 quad range.

Second, the scenario implies that solar will displace conventional energy systems projected to be built between 1980 and 2000. The scenario does not imply that these will be early retirements of the older conventional facilities (that is, plants built in the 1950s and early 1960s). The solar facilities brought on line displace the cleaner, nonrenewable plants instead of the facilities built to the less stringent standards of the late 1960s and 1970s. Solar did not, therefore, have as significant an environmental impact as it could have had if displacement of older fossil-fueled facilities had been postulated.

In both the low and high case, biomass plays the major role in solar growth. Biomass accounts for 51 and 40 percent of the solar supply respectively. The biomass systems applications are essentially small-scale facilities. Most of these are residential, agricultural, and industrial combustion facilities. This assumption resulted in the introduction of a large number of small, uncontrolled combustion facilities replacing longer environmentally controlled cleaner facilities.

The further implications of these assumptions will be explored during the next phase of TASE. The comparison reported here essentially represents the upper boundary of a recent series of solar supply projections. The next phase will establish the lower boundary and explore the environmental and socioeconomic consequences of solar and biomass technology contributions to a lower total national energy supply.

Comparison of TASE to Other Energy Scenarios

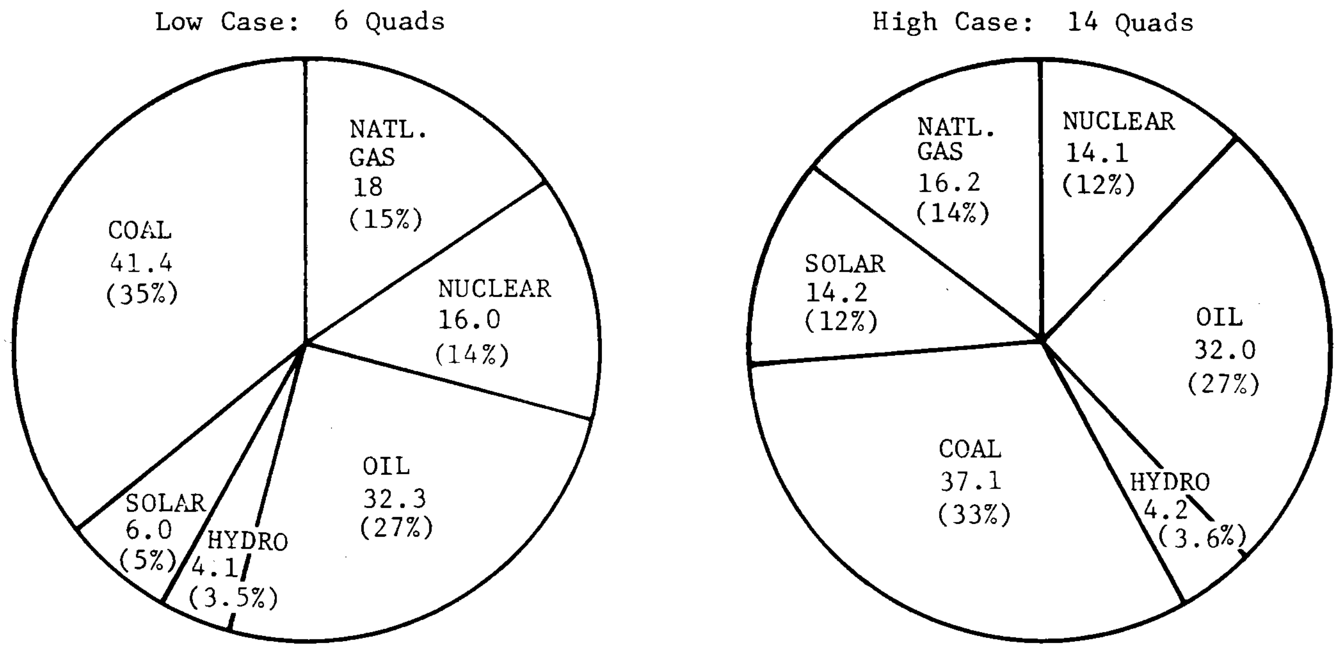
A number of studies have been published which analyze the potential development of solar energy in the United States over the next twenty years or more. This section presents some basic data on future U.S. total energy supply and the solar contribution from five studies typical of recent analyses. The reports were authored by the Council on Environmental Quality (CEQ), the Solar Resource Group of the Committee on Nuclear and Alternative Energy Systems (CONAES), the Stanford Research Institute (SRI), the Energy Project at the Harvard Business School, and The MITRE Corporation. These energy supply data present the best available estimates of future energy supply, based on a variety of assumptions about trends in the economy, in technology, and in government policy. Most of the studies present more than one possible energy future: supply totals are changed by altering the underlying assumptions. Some major differences are apparent between these studies and TASE. The following discussion analyzes what variations in the basic assumptions of the studies caused these differences.

Figures 2.4 through 2.8 present the estimates of total energy supply in the year 2000, and the contribution of conventional energy sources within that total. (A breakdown by conventional fuel type was not contained in the CEQ, CONAES, or Harvard studies.) The CONAES cases and two of the SRI cases show higher total demand estimates than assumed in TASE. Since the CONAES, SRI, CEQ, Harvard, and MITRE studies were completed during the period 1977 to 1979, they reflect the recognition of different links between U.S. energy consumption and economic growth over the long term.

The earlier studies assumed that continued economic strength meant continued high energy consumption: for example, SRI's low demand case assumed a smaller economic growth rate than the other two cases. Equally important, the SRI low demand case assumes much higher energy prices than in the high demand cases. The SRI reference and solar emphasis cases assume that imported oil prices will rise to only $21 per barrel by 2020, and that a domestic policy of minimizing energy prices will continue.

The mix of conventional fuels within the overall demand for SRI's reference and solar cases shows only one major difference from the estimates in more recent studies: that is, the contribution of nuclear energy, which is estimated by SRI to be twice as much as in the TASE cases. The SRI study does point out that certain obstacles must be overcome before nuclear power could supply 30 or more quads by 2000. However, the increased complexity and severity of the obstacles which have required more conservative estimates about nuclear's contribution by 2000 could not have been foreseen in 1977.

Figure 2.9 presents the total solar contribution by major generic solar technology estimated by each of the studies. Looking first at the low solar and base cases, the total solar contribution figures are in the same range—with one exception. The CONAES low solar scenario total of 0.1 quad is much lower than any of the other estimates because the CONAES study assumed that no government policy would assist the entry of solar energy into the market. The other studies all assume some level of government incentives, as ex-



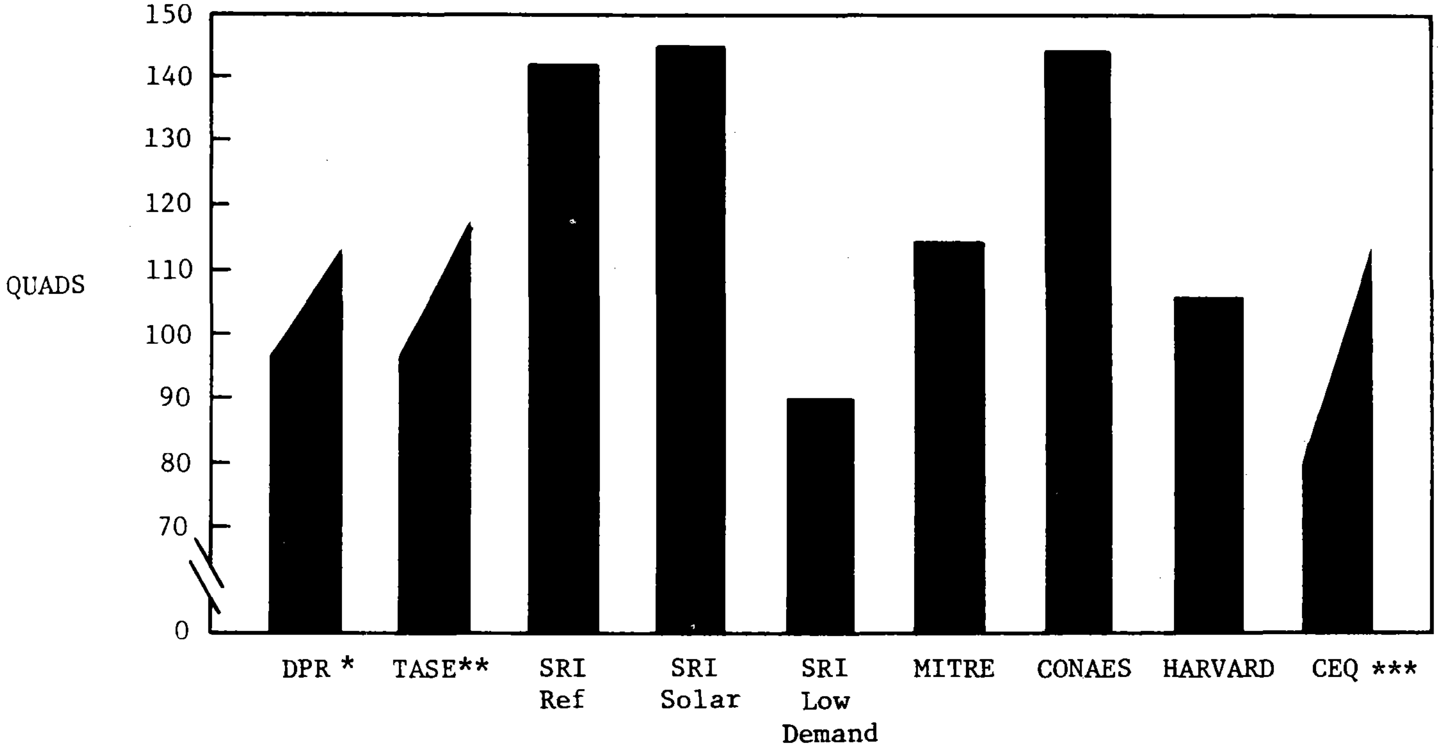
Low Case: 6 Quads

High Case: 14 Quads

The diagram illustrates national energy supply in the year 2000 by fuel type, assuming a "low" solar growth scenario and a high solar scenario. The total energy supply for the year 2000 is 118 quads for each case.

Figure 2.3

National Energy Mix in The Year 2000 (in Quads)
(% Contribution by Fuel Type)



* A range of potential supply (95-114 quads) was given.

** A range of potential supply (95-118 quads) was given.

*** A range of potential supply (80-114 quads) was given.

Figure 2.4
Total Energy Supply in Year 2000

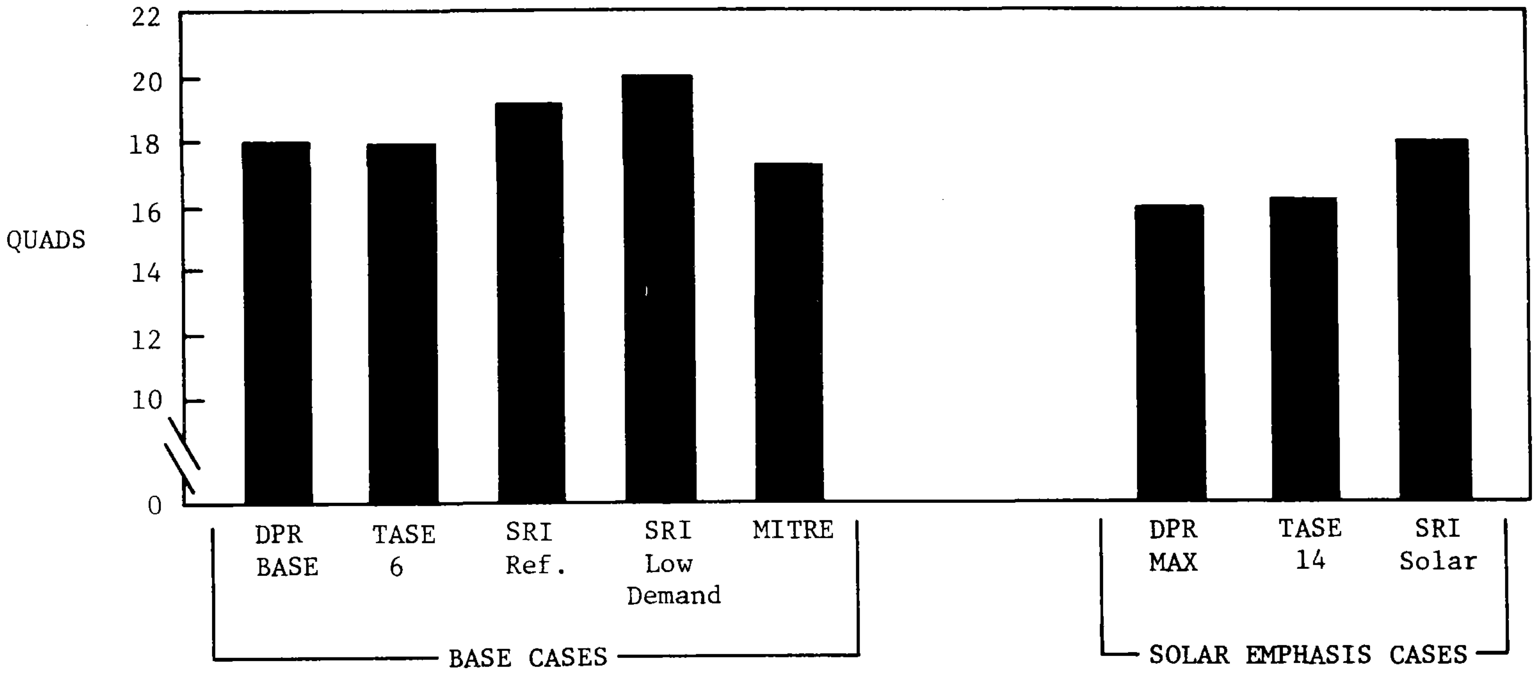


Figure 2.5
Gas Supply in Year 2000

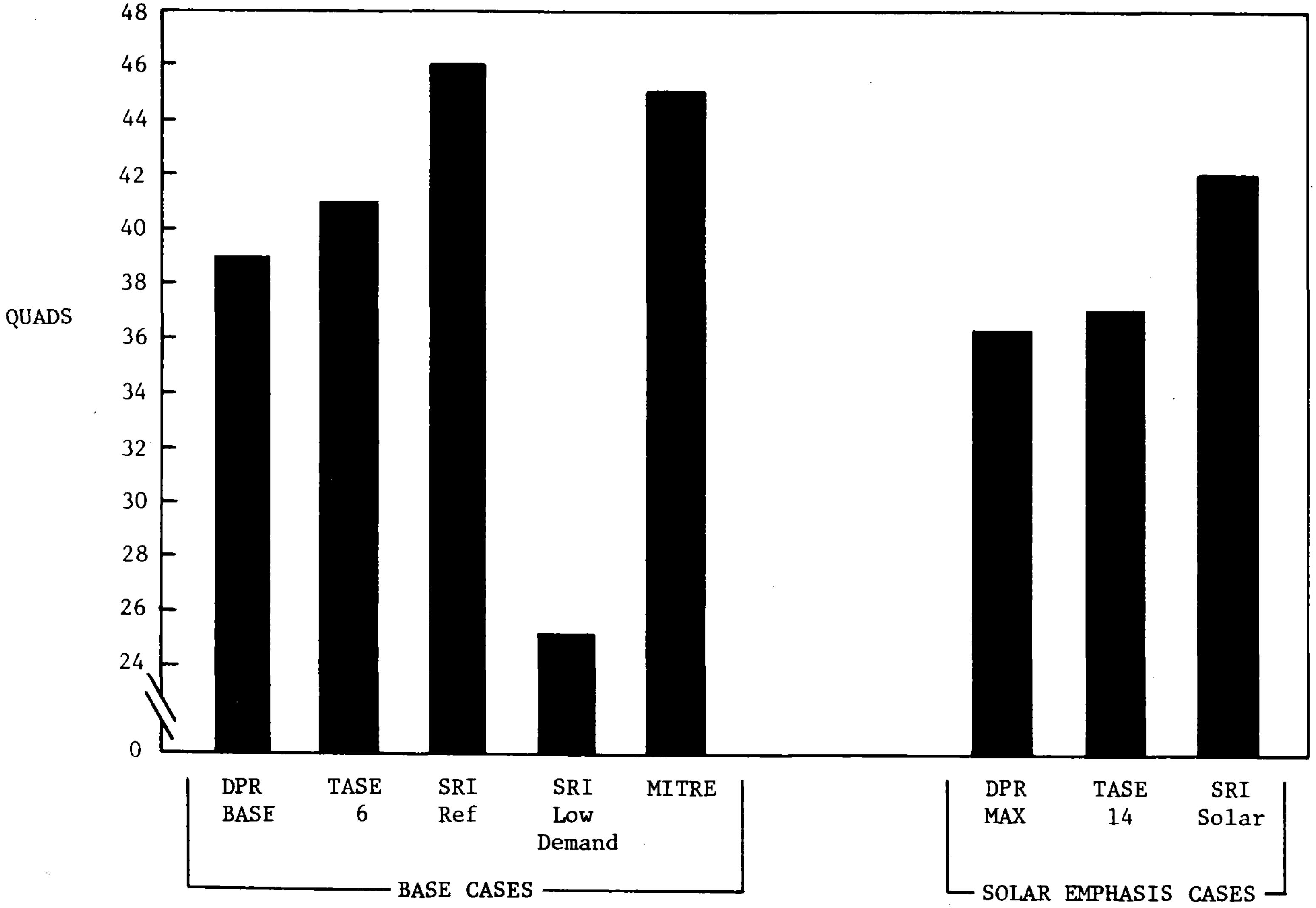


Figure 2.6
Coal Supply in Year 2000

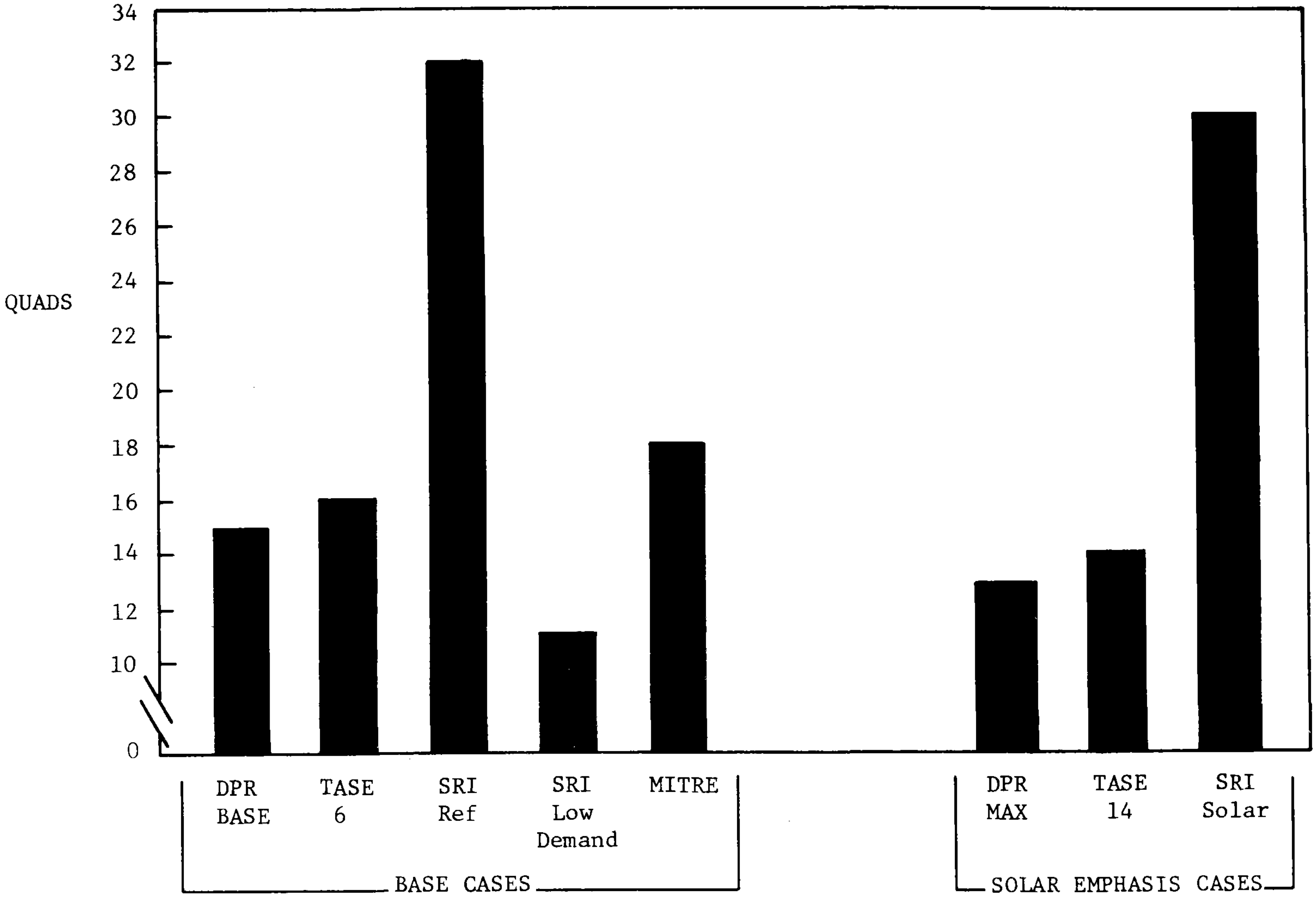


Figure 2.7
Nuclear Supply in Year 2000

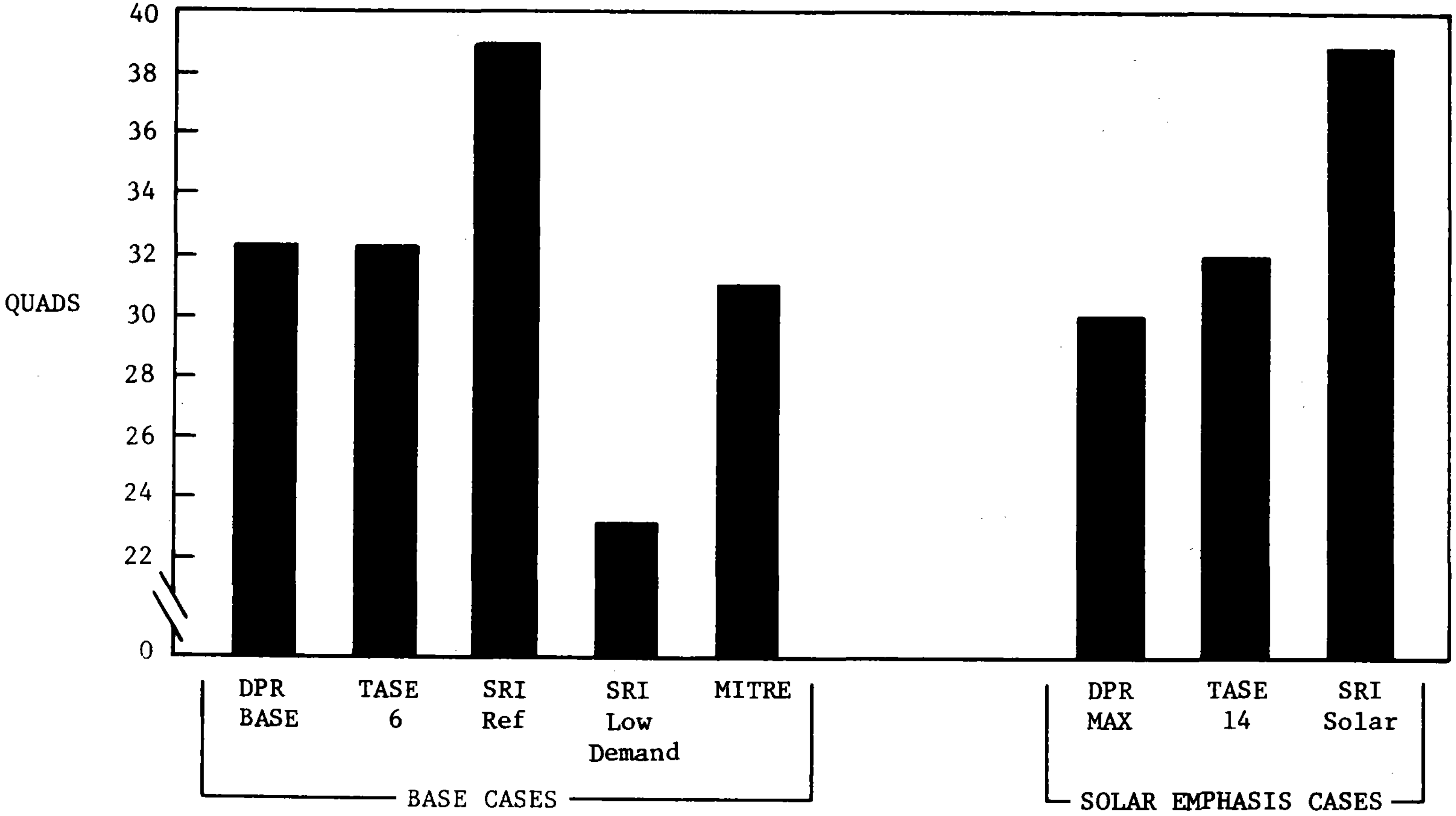
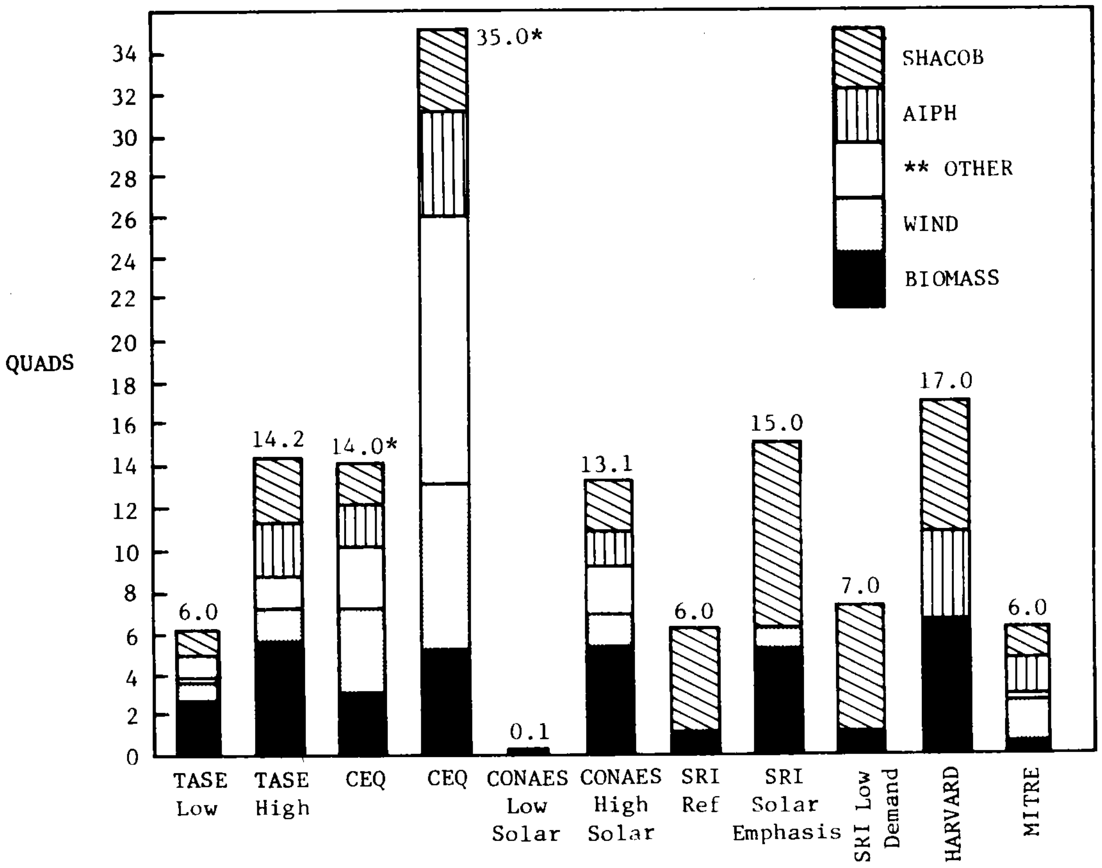


Figure 2.8
Oil Supply in Year 2000



* CEQ gave a range of the potential impact of solar, the number given represent the low and high limits of that range.

** Included solar thermal, photovoltaics, and OTEC.

Figure 2.9
Scenario Comparison of Solar Technology Mixes Used in Solar Scenarios by Various Studies

pressed in the National Energy Plan for the TASE and MITRE cases, and the ERDA National Energy Research and Development Plan for the earlier SRI study. In addition, although both CONAES and SRI assumed lower prices for conventional fuels than the later studies, CONAES assumed in its low solar case that all energy costs except natural gas would remain constant in 1975 dollars.

Although most of the base cases estimate approximately the same total solar contribution, there are some major differences among them on how much each type of solar technology will contribute to that total. The SRI reference case, unlike TASE and MITRE, has 5 of the total 6 quads supplied by hot water, heating, and cooling technologies. The other quad would be supplied by biomass conversion. Again, SRI's assumption of a continuing U.S. policy to minimize conventional fuel costs explains the noncompetitiveness of the more expensive solar electric technologies. Also, SRI did not include wind systems as a part of their analysis. The SRI study concludes, however, that "when alternatives to solar fuels are expensive, such as areas where natural gas is not available, solar energy is likely to dominate the space heating market for new construction as soon as the year 2000.

Comparing the TASE 6 and MITRE cases, the most significant difference is found between the TASE estimate of 3.1 quads versus MITRE's 0.4 quads fuel displaced by biomass conversion technologies. This discrepancy is easily explained by the different assumptions behind these estimates. The MITRE study considered only the potential contribution of wood biomass, because of limitations on their data base at the time of the study. The TASE biomass estimate, however, also includes the potential contributions from crop residues and urban and animal wastes.

Among the total solar estimates, CEQ's 14 to 35 quads is higher than any of the other totals. However, looking at the low range of CEQ's estimates for the specific technologies, only two stand out as significantly higher than the TASE numbers: wind and OTEC technologies. CEQ based their estimates on an analysis of the results of a number of other solar studies. The studies chosen for analysis by CEQ all seem to have taken the most optimistic view of the rate of technological development and the removal of barriers to solar implementation, and so predict high potential solar market penetration. The study on wind technologies on which CEQ based its estimate, for example, concluded that under conditions of "rapid implementation" 5 to 10 quads of conventional fuel could be displaced by wind energy in 2000. This would mean going beyond the aggressive government solar policy within the traditional limits of government intervention assumed in the TASE 14 cases.

The CONAES high solar case estimates for each technology generally fall within the same range as TASE. The SRI solar emphasis and Harvard studies both have the major part of their total solar contribution coming from residential and commercial hot water, heating, and cooling systems, and biomass conversion. However, the reasons behind these two estimates are different. The SRI study, as in the reference case, assumed a lower price for conventional fuels compared to more recent studies, which explains the lack of market penetration by solar electric technologies. To increase the solar contribution in the solar emphasis case, SRI assumed solar heating and biomass costs 50 percent lower than in the reference case, but this still resulted in an estimate of only 1 quad from all solar electric technologies. Also, as mentioned earlier, wind technologies were not included in SRI's analysis.

The Energy Project at the Havard Business School estimates a similar emphasis among the solar technologies, but for very different reasons. The Harvard study concludes that the most significant contribution from solar energy over the next twenty years can be made from the widespread use of on-site solar technologies; that is, decentralized solar applications such as commercial space heating and cooling and water heating, agricultural/industrial process heat, and small scale biomass conversion technologies, rather than from centralized solar technologies such as power towers, ocean thermal energy conversion, and solar power space satellites. Economic problems are not seen mainly as a matter of continuing to lower the price of on-site solar technologies, but as a need to educate the consumer to the true cost of fossil fuels and the true savings from solar as a type of tax-free income.

The solar emphasis cases all assumed, to one degree or another, a more active government role in promoting solar technologies. A strong program for conservation was also assumed to be part of the energy future by 2000.

TASE Solar Contributions in the Year 2000

The specific implications of the TASE solar deployment scenarios are described below, by generic solar technology.

Solar Systems for Residential and Commercial Heating, Cooling and Hot Water

- By 2000, 100 million dwelling units will be in place, 45 million of which will be contructed between now and 2000.
- Nearly 10 million residential/commercial active heating systems will be installed in the high solar case.
- Approximately 2.7 million residential/commercial active heating and cooling systems will be in place in the high solar case.
- In the high solar case, 25 million hot water systems will be installed.

- Almost 11 million passive solar-designed buildings will be constructed in the high solar case.
- Nearly 2 million wood stoves will also be used for space heating and hot water in the high solar case.

Solar Systems for Agricultural and Industrial Process Heat

Solar Process Heat Systems

- Almost 2 million industrial process heat systems are required in the high solar case, or more than double the number required by the low solar case.
- In the base case, low-temperature solar systems are expected to amount to 0.2 quad. The medium and high temperature systems would provide 0.7 quads.
- In the maximum practical case, space heating, hot water heating, preheating, hot air, and steam generating could contribute up to 1.7 quads.

Biomass Process Heat and Fuels

- In the base case, up to 3.1 quads of biomass could be supplied principally from forest residues, with lesser amounts from crop residues, urban sewage, and animal wastes.
- Under the maximum practical case, 5.5 quads of energy could be obtained, of which 1.5 to 2 quads would be available from crop residues, urban and animal wastes.

Solar Systems for Electric Supply

Utility Sector

- In the base case, approximately 0.1 quad of energy could be displaced by solar thermal electric facilities, principally installed in the Southwest.
- In the maximum practical case, nearly 1.25 quads of fuel could be displaced by solar thermal electric systems.
- In the base case, approximately 0.6 quads of primary fuel displacement would be expected using wind energy systems.
- In the maximum practical case, nearly 1.5 quads of wind energy systems are anticipated to be in place.
- In the base case, photovoltaics are expected to displace approximately 0.1 quads of primary fuels.
- In the maximum practical case, up to 0.2 quad of energy can be displaced by photovoltaics.
- No OTEC is envisioned for the base case.
- In the maximum practical case, approximately 0.1 quad of primary fuel displacement could be displaced by OTEC.

Residential and Commercial Sector

- In the base case, wind and photovoltaics displace less than 0.1 quad of primary fuels.
- In the maximum practical case, wind and photovoltaics combine to displace nearly 0.5 quads of primary fuels.

Table 2.1 illustrates the postulated contribution of each of the solar technologies and system estimates to the national energy supply mix.

Figures 2.10 and 2.11 illustrate how the solar and biomass component of the scenarios are allocated by technology and economic sector.

Scenario Development

At the start of Phase II of the TASE Project, DOE management stipulated four basic guidelines to be followed in conducting TASE Project simulations and analyses (see Chapter 1).

Two project requirements influenced the development of the TASE scenarios. The first was that the TASE Project would use the DPR as the point of departure for the solar portion of the TASE Project. The second was that the TASE Project would use SEAS for calculating national level residuals and as a screening device for identifying regional and subregional residual distributions. Because the DPR did not provide sufficient data to drive the SEAS model, the TASE project team reviewed a number of existing energy data bases and selected the one that most closely approximated the solar component of the DPR. The data base was FOSSIL2, a model developed by the Energy Information Administration (EIA). FOSSIL2 had been used in evaluating the National Energy Plan and included a 6 quad solar scenario. Because the differences between the nonsolar elements of the DPR and FOSSIL2 were traceable, it was selected to provide a basis from which TASE analysis could be conducted. The steps taken to integrate the solar component of the DPR scenario with FOSSIL2 are shown in Figure 2.12

Supply Trend Data Added to the DPR

Supply trend data for conventional energy sources were obtained by integrating the DPR solar development projections with the FOSSIL2 National Energy Model. FOSSIL2 is operated by the Office of the Assistant Secretary for Policy and Evaluation in DOE. It was originally developed to study the environemntal implications of the Department's National Energy Plan. The model simulates several energy futures based on different energy, economic, and policy assumptions. The energy supply levels for 2000 in the FOSSIL2 High World Oil Price scenario closely match the DPR Solar Base Case projections. Table 2.2 compares the percentage contribution of each fuel type to the supply for the DPR and FOSSIL2 scenarios. The absolute differ-

Table 2.1
TASE Solar Energy and System Estimates
Year 2000 Comparison

	14.2 Q		*6.0 Q*			
Technology	*10^{12} Btu (FFE)*	*Number of Scaled Systems*	*10^{12} Btu (FFE)*	*Number of Scaled Systems*	*10^{12} Btu (FFE)*	*Number of Scaled Systems*
E. U. Wind	1,484.5	37,696	601.5	15,189	883.0	22,506
E. U. PV	232.3	110	99.4	48	132.9	62
E. U. Solar Thermal	1,242.7	326	99.4	24	1,143.3	302
E. U.—Total	2,959.5		800.3		2,159.2	
RDF	251.4	22	89.5	7	161.9	15
IPH—TES	617.2	9,375	308.4	4,719	308.8	4,656
IPH—Low T.	226.1	1,851,300	113.2	929,540	112.9	921,760
IPH—Med T.	1,222.5	5,229	611.1	2,612	611.4	2,617
IPH— Total	2,065.8		1,032.7		1,033.1	
Incinerator	247.1	202	89.8	75	157.3	127
Direct Combustion	1,085.7	6,495	101.9	609	983.8	5,886
Cogen. P+P	2,599.7	444	2,311.9	398	287.8	46
P. H.— Total	3,932.5		2,503.6		1,428.9	
A. D.— Sludge	32.0	62	32.0	62	0.0	0
PYR.— MSW	74.9	3	20.0	1	54.9	2
A. D.— Manure	66.9	446	66.9	446	0.0	0
PYR.— Ag. Res.	327.8	2,801	99.9	856	227.9	1,945
PRY.—Wood	699.6	178	0.0	0	699.6	178
Gas— Total	1,201.2		218.8		1,036.9	
Industrial— Total	7,199.5		3,755.1		3,444.4	
Act. Heating	959.3	10,350,620	416.2	4,498,006	543.1	5,852,554
Act. H + Cool.	330.8	2,752,601	142.0	1,184,474	188.8	1,568,127
Passive H+C	999.9	10,736,504	200.0	2,232,591	799.9	8,503,913
Hot Water	709.9	25,183,985	341.0	12,096,032	368.9	13,087,953
R/C Wind	418.2	1,556,373	53.2	202,581	365.0	1,353,792
R/C PV	51.7	373,287	33.9	245,775	17.8	126,512
Wood Stoves	229.9	1,893,000	200.0	1,270,000	99.9	623,000
R/C—Total	3,769.7 14.18		1,326.5 5.98		2,383.4	

TABLE 2.2
Comparison of DPR and FOSSIL2 Scenarios

	DPR		*FOSSIL2*	
In Shares (%)* *Fuel*	*Base*	*Maximum Practical Case*	*Base*	*Maximum Practical Case*
Case				
Oil	28	26	27	26
Natural Gas	16	14	15	14
Coal	34	32	36	33
Nuclear	13	11	13	12
Hydro/Geothermal	3	4	3	3
Solar/Biomass	5	12	5	12
	100.0	100.0	100.0	100.0

*May not add to 100% due to rounding.

ence in energy supply between DPR and FOSSIL2 scenarios is attributable to a more aggressive synfuels and unconventional gas development inherent in FOSSIL2.

Disaggregation of National-level Data

The FOSSIL2 model, like the DPR, only provides national energy forecasts. Two processes were used to develop regional and subregional information for solar and conventional energy supplies.

National data on conventional fuel supplies were regionalized by integrating FOSSIL2 data with the Midrange Energy Forecasting System (MEFS), a model also used by the Energy Information Administration. MEFS forecasts energy consumption and generation

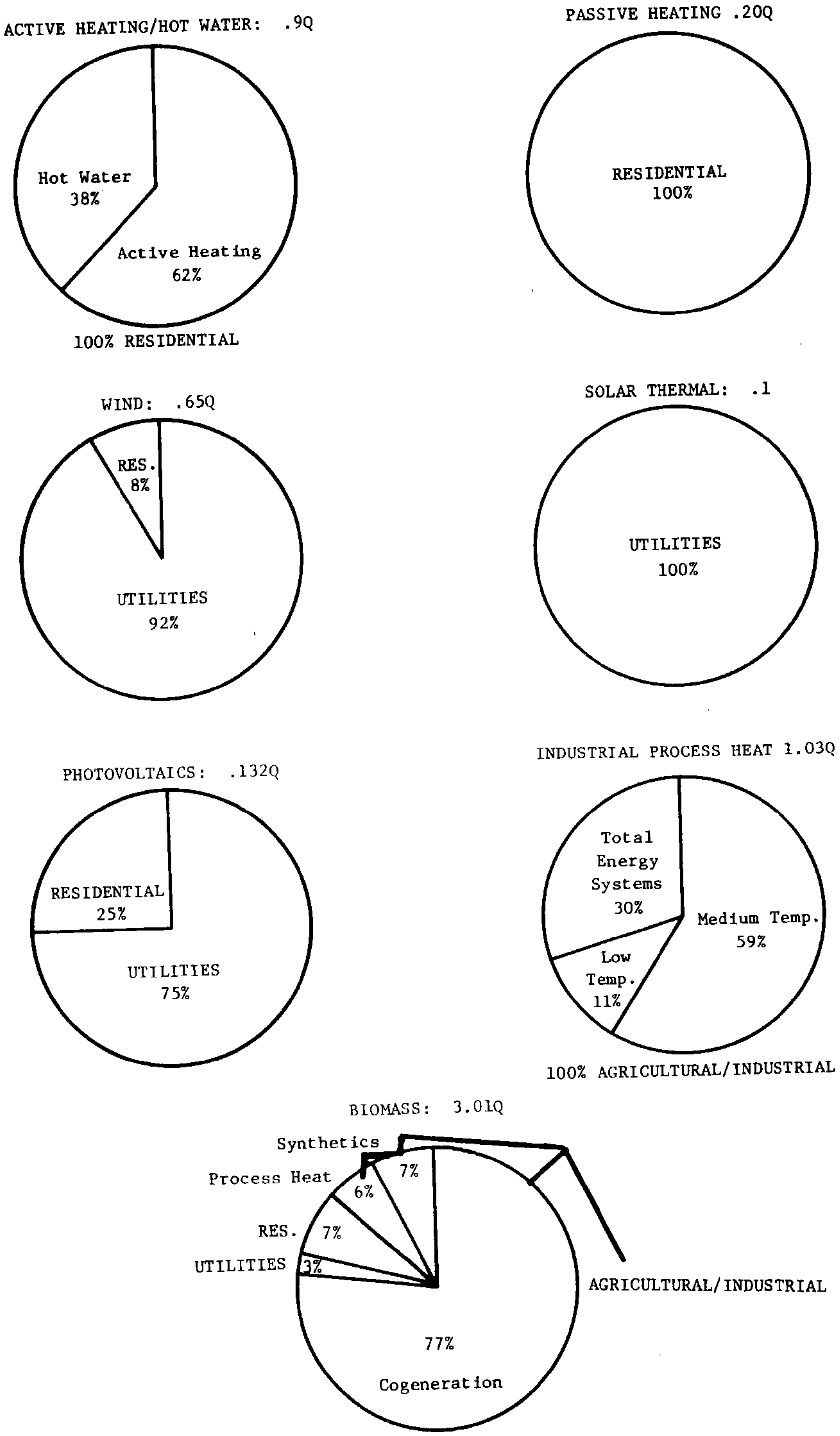


Figure 2.10
TECHNOLOGY SHARES BY ECONOMIC SECTOR
TASE 6

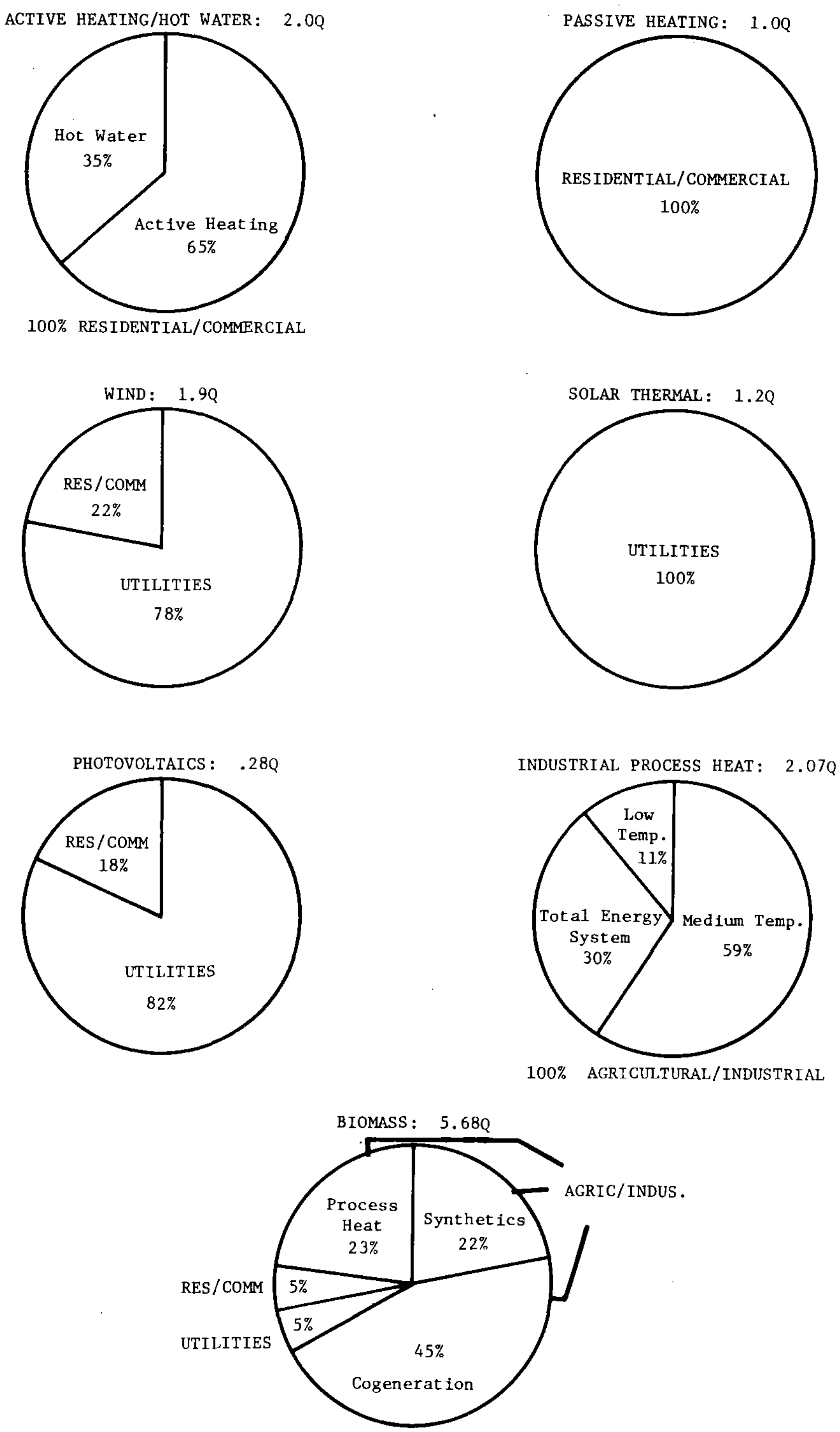


Figure 2.11
TECHNOLOGY SHARES BY ECONOMIC SECTOR
TASE 14

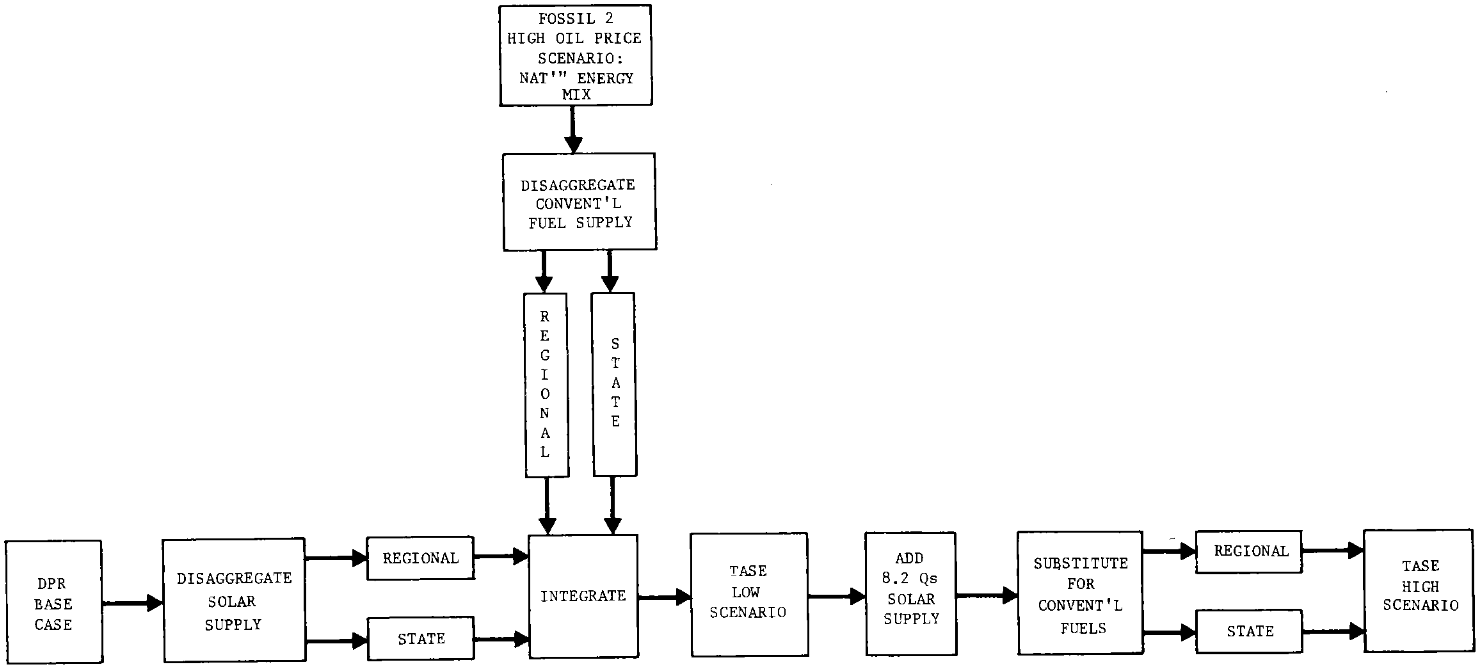


Figure 2.12
Overview of TASE Scenario Development

by ten federal regions. The regionalization process involved correlating regional fuel use by economic sector with total national fuel use for the same sector.

The DPR national level solar data was disaggregated using input from two sources (Figure 2.13). First, based on the projected levels of commercialization reflected in the SPURR[3] studies, technology "shares" were developed to determine the contribution from each solar technology within the SHACOB, AIPH, and solar electric solar components.

Second, energy supply data for SHACOB, AIPH, and solar electric systems had to be disaggregated geographically. This was done in several steps starting with a regional breakdown, again based on commercialization data developed using SPURR. In this case, regional shares were developed to reflect how the total solar contribution from the various systems was spread out over the entire country. The levels of market penetration by the different solar systems in the various federal regions were determined by SPURR based on the following input data:

- —size of the potential market
- —solar technology costs and expected cost reductions over time (experience curve)
- —competing technologies costs
- —regional fuel prices
- —mix of competing fuels
- —regional climate data
- —suitability (orientation of existing buildings, land availability, etc.)
- —energy load profiles
- —market lags reflecting initial resistance to new technologies

The regional data were then used to develop the state-level data. Siting criteria, based on factors such as population, land use and levels of industralization, were applied to locate the various systems.

The disaggregation of biomass energy supply by country was based on biomass resource availability. ANL, MITRE, and ORNL used their own methods to site specific biomass systems within counties in all regions. Figures 2.14 and 2.15 and Table 2.3 illustrate the TASE geographic distribution of solar and biomass technologies by technology.

The size of each pie chart is proportional to the total solar contribution of that region for each case. For example, in TASE 6 the largest contribution is in region 4, the smallest in region 7 (the pie in region 4 is approximately 6 times larger than region 7's pie). No attempt should be made to correlate pie size between figures.

---

[3] System for Projecting Utilization of Renewable Resources, The Mitre Corporations.

TABLE 2.3
Comparison of Solar Shares by Federal Region

Region	*TASE 6*	*TASE 14*
1	5	6
2	5	6
3	8	7
4	27	25
5	13	14
6	17	16
7	2	5
8	4	4
9	9	9
10	10	8
	100	100

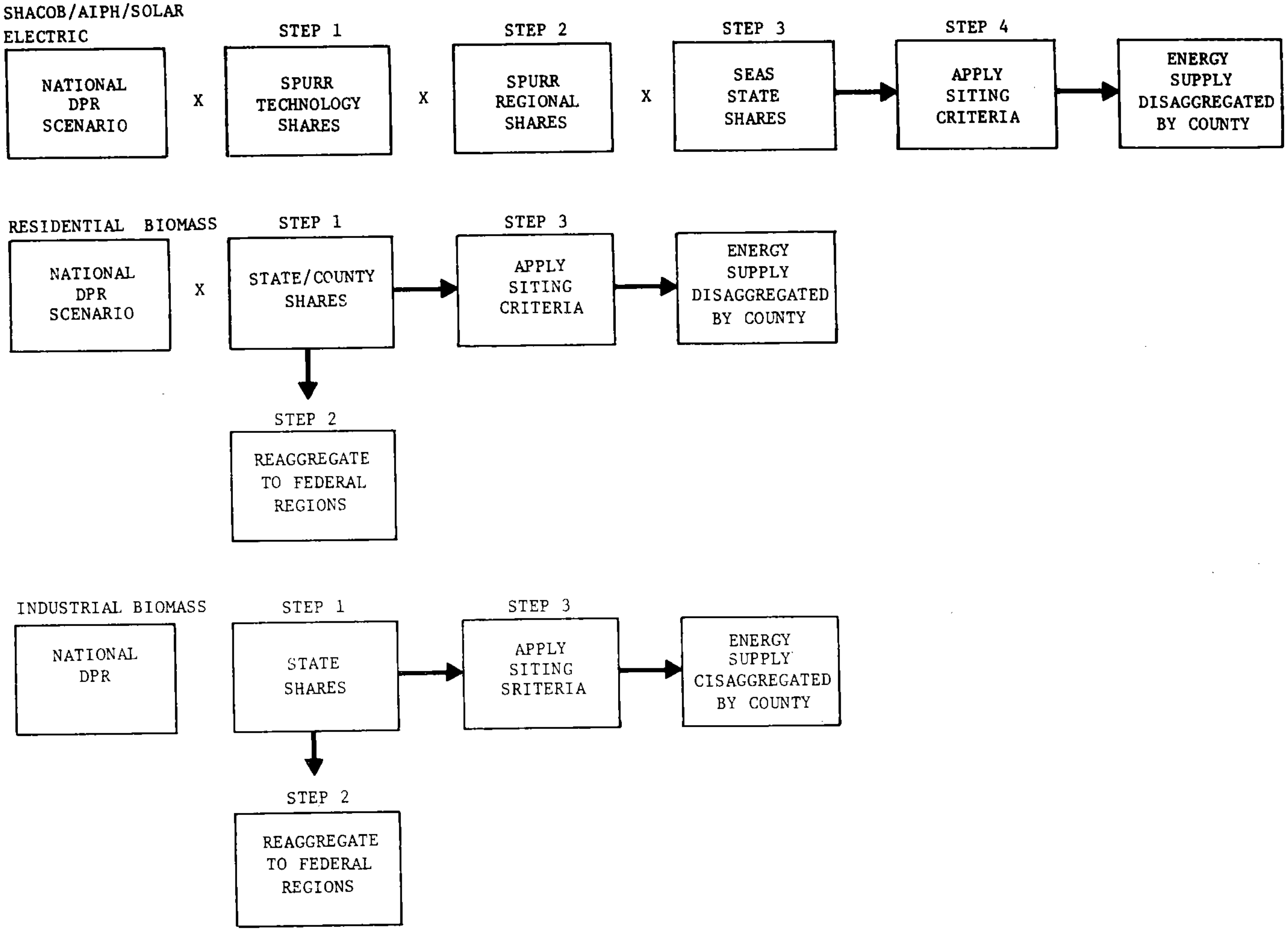


Figure 2.13
The TASE Disaggregation Methodology

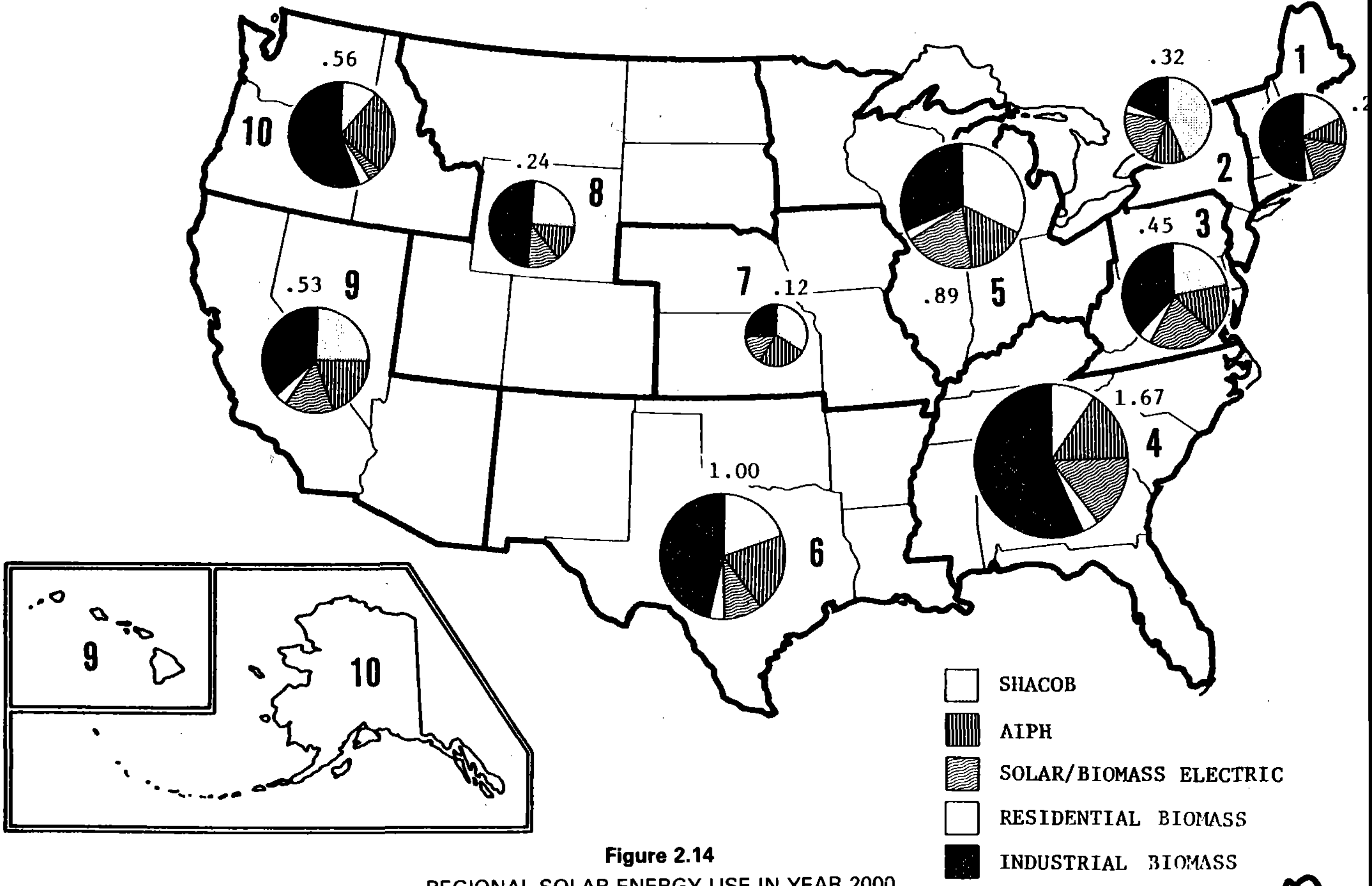


Figure 2.14
REGIONAL SOLAR ENERGY USE IN YEAR 2000
TASE 6

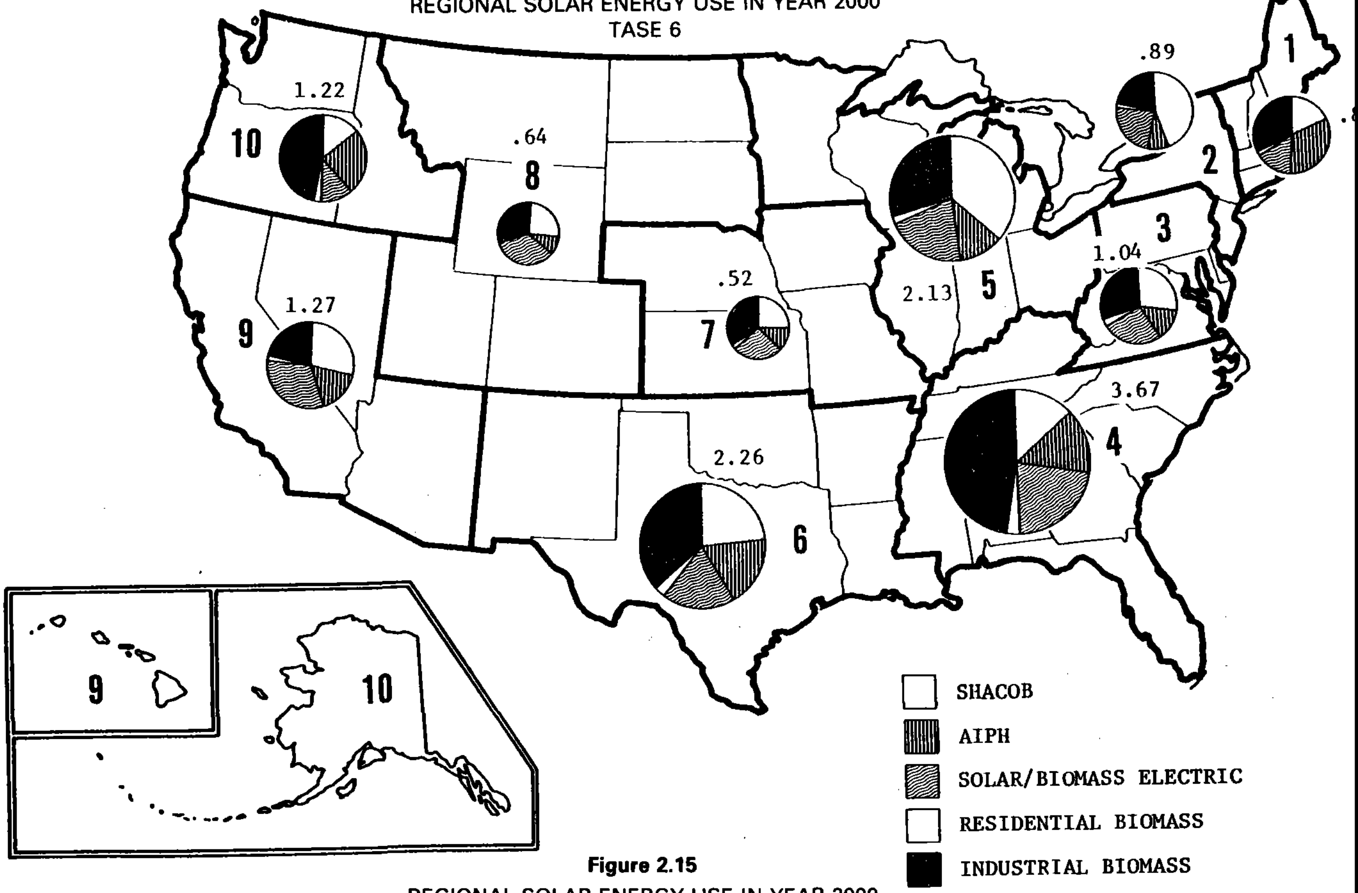


Figure 2.15
REGIONAL SOLAR ENERGY USE IN YEAR 2000
TASE 14

Chapter 3

Air Quality Analysis

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CHAPTER 3

AIR QUALITY ANALYSIS

Introduction

The primary objective of the air quality analysis was to assess the potential for both benefits and damages to future ambient air quality as other energy technologies were displaced by increased solar energy. This assessment was undertaken from two perspectives: (1) by comparing the relative emissions from individual solar technologies with those from the conventional technologies which the solar technologies would replace, and (2) by analyzing the difference in cumulative effects for the high and low scenarios in the year 2000. By focusing on the difference rather than absolute values for the senarios, the significance of the nonsolar features of the total senario are minimized (e.g., the total energy consumption in the year 2000 is a secondary issue in this study). No attempt was made to adjust the technology mix or siting patterns of scenarios to maximize the benefits to air quality. However, the following discussion can be expected to be useful in directing solar implementation strategies to mitigate current or potential air quality problems from biomass technologies.

Summary and Conclusions

The solar scenarios used in this study were developed primarily on the basis of resource availability and market potential as expressed by the DPR. Air quality improvement or other environmental objectives played only a minor role in the scenario development. As a result, the scenarios do not explicitly demonstrate the maximum air quality benefits (or damages) which solar technologies could yield. However, the air quality analysis of the scenarios does give an understanding of the various trade-offs associated with alternative regional and national levels and mixes of solar technologies. As such, this analysis can be useful in implementing both solar strategies with more explicit environmental objectives and long term air quality strategies based on varying the regional energy mix.

The following is a brief overview of major conclusions derived from the study.

- Total suspended particulate emission levels can be expected to decline from 1975 to 2000 as new, less polluting technologies including direct solar are introduced, and as existing facilities come into compliance with emission limitations of state implementation plans (SIPs).
- This trend of decreasing particulate levels will be partially offset if future energy patterns include high levels of uncontrolled direct biomass combustion technologies.
- In a majority of U.S. regions, there is an increase in fine particulate ambient concentration related to the increased emissions for the high solar scenario, but the increase is slight (0.5$\mu g/m^3$ AQCR average in the winter).
- Solar technologies contribute only minimally to SO_2 emissions, and the net effect of solar is to reduce SO_2 emissions by displacing fossil technologies.
- For the scenarios used in this study, the SO_2 emission reduction from the introduction of solar is not large enough to offset the 1975-2000 increase from much greater coal use.
- The fuel substitution assumptions used in this scenario resulted in the savings of 257 million MW-hrs of coal-fired electrical generation, corresponding to a decrease in SO_2 emissions of about 0.7×10^6 tons/yr at the national level.
- The high solar scenario results in small improvements in airborne sulfate ($<1\ \mu g/m^3$), relative to the low solar scenario. The areas of greatest benefit are the Southern Appalachians and NE Ohio/NW Pennsylvania.
- NO_x emissions are of the same general magnitude for biomass and fossil fuel technologies, and thus a benefit to NO_x emission levels is derived primarily through use of the direct solar technologies (e.g., SHACOB, solar electric).
- A reduction of 1.1×10^6 tons of nitrogen oxide emissions in 2000 will occur due to a reduction of large utilities and industrial boilers in the high solar case. Air quality will continue to deteriorate due to a projected overall increase of 5.6×10^6 tons of NO_x over 1975 levels.
- Extensive use of uncontrolled biomass combustion may threaten ambient TSP standards in some locations. In this event, future industrial growth may be curtailed.

- Particulate emissions from wood stoves will triple from 1975 to 2000 in the high solar scenario. This will have relatively low air quality impact in rural and densely populated areas where wood is scarce, but could significantly increase TSP levels in suburban areas and smaller rural towns in valleys where emissions could be trapped during winter inversions.
- A possible improvement in visibility between the scenarios could be expected, due to elimination of plume blight and reduced haze from decreased new coal-fired electric power plants in certian areas (remote from biomass combustion).
- Combining the trends for sulfates and primary fine particulates gives an estimate of the total fine particulate air concentration. Improvements in sulfate air concentrations due to the increased use of solar technologies are greater than the increases in primary fine particulate air concentrations. Consequently, their combined effect causes overall improvements (<1.0 $\mu g/m^3$), except for slight increases (<0.3 $\mu g/m^3$) in air concentrations in central Florida/Georgia, western Iowa/Minnesota, and Texas.

Three major areas of concern are addressed in this chapter; they are:

- National and regional emission levels
- Long-range pollutant transport
- Local air quality impacts

Chapter Organization

The section on national and regional emission levels provides an overview of the effects of increased dependence on solar energy in 2000. Three pollutants that have been the focus of past and current regulatory activities are considered: particulate matter, sulfur dioxide (SO_2), and nitrogen oxides (NO_x). There are certain species of particulate matter having special concerns. Polycyclic organic matter (POM) and other hazardous organic compounds are emitted from wood combustion and crop residue could comprise a significant health hazard. Suspended sulfates are both emitted directly from oil and coal firing, as well as forming in the atmosphere from SO_2. The section on long range pollutant transport analyzes the impact of these emission differences on interregionally transported SO_2 sulfates, and fine particulates, which are of prime concern related to health effects and visibility. The local air quality section discusses the near-field impacts from the regulatory perspective.

These sections focus on the trade-off in direct residuals from the operation of solar versus conventional fossil fuel technologies. An additional area of concern in comparing these technologies is the effect of differences in indirect emissions associated with manufacturing energy system components, including raw material extraction and processing. Further effects of indirect emission impacts may be associated with changes in economic activity caused by greater capital requirements of certain solar technologies. Detailed discussion of these indirect effects is reserved for Chapter 6. However, the evaluation of sulfur dioxide and sulfates related to long-range transport of SO_x does include preliminary estimates of indirect emission differences. For the year 2000, the high solar scenario has a 0.8 percent increase in SO_2 emissions over the low solar scenario from these indirect emissions, compared to a 4.7 percent decrease in direct energy-related emissions. These small national indirect emission effects are thus only significant in local areas. Similar indirect emission estimates were not available to evaluate particulates and nitrogen oxides.

Emission Levels

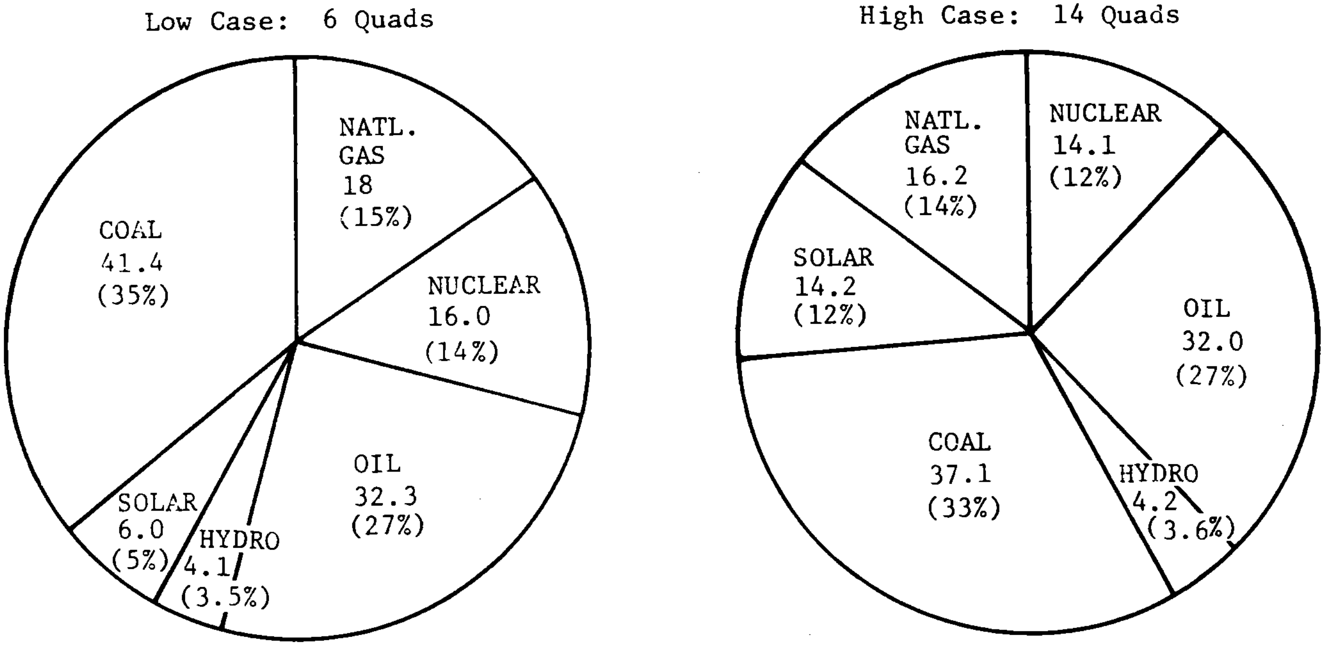
The major aspects of the energy scenarios that relate to the air quality analysis are summarized in Figure 3.1. (The scenarios are described in more detail in Chapter 2.)

Total Suspended Particulates

Estimates of national levels of particulate emissions by fuel type for 1975 and the two scenarios in 2000 are summarized in Figure 3.2.

An overall decrease in emissions was estimated between 1975 and 2000 in the low solar scenario, primarily because of projected reductions in emissions from existing coal-fired utility plants, and a smaller decrease because of reduced oil consumption. In both scenarios this decrease in emissions from existing facilities is largest (34 to 45 percent) in the 1975 to 1985 growth period. The decrease is followed by smaller increases back to the indicated levels, as new fossil and biomass facilities are introduced. In comparing the 2000 low and high scenarios, biomass utilization is a major contributor to an overall greater estimate of national particulate emissions for the high solar scenario. Biomass emissions are only partially offset by a decrease in the number of new coal-fired utility plants and industrial boilers between the two scenarios, because of the projected low emission levels of the newer coal facilities. These features and others are illustrated in more detail in Figure 3.3.

Figure 3.3 illustrates the importance of the industrial biomass direct combustion emissions in the overall emission projections (with a 75 percent emission control assumed). A somewhat pessimistic assumption of uncontrolled particulate emissions was also considered for data shown in Figures 3.2 and 3.3 for this technology. Dispersed biomass fuel resources lead to potentially small average facility sizes, which are more difficult and costly to control. By assuming the 75 percent control level for the industrial biomass combus-



Low Case: 6 Quads

High Case: 14 Quads

The diagram illustrates national energy supply in the year 2000 by fuel type, assuming a "low" solar growth scenario and a high solar scenario. The total energy supply for the year 2000 is 118 quads for each case.

Figure 3.1

National Energy Mix in the Year 2000 (in Quads)
(% Contribution by Fuel Type)

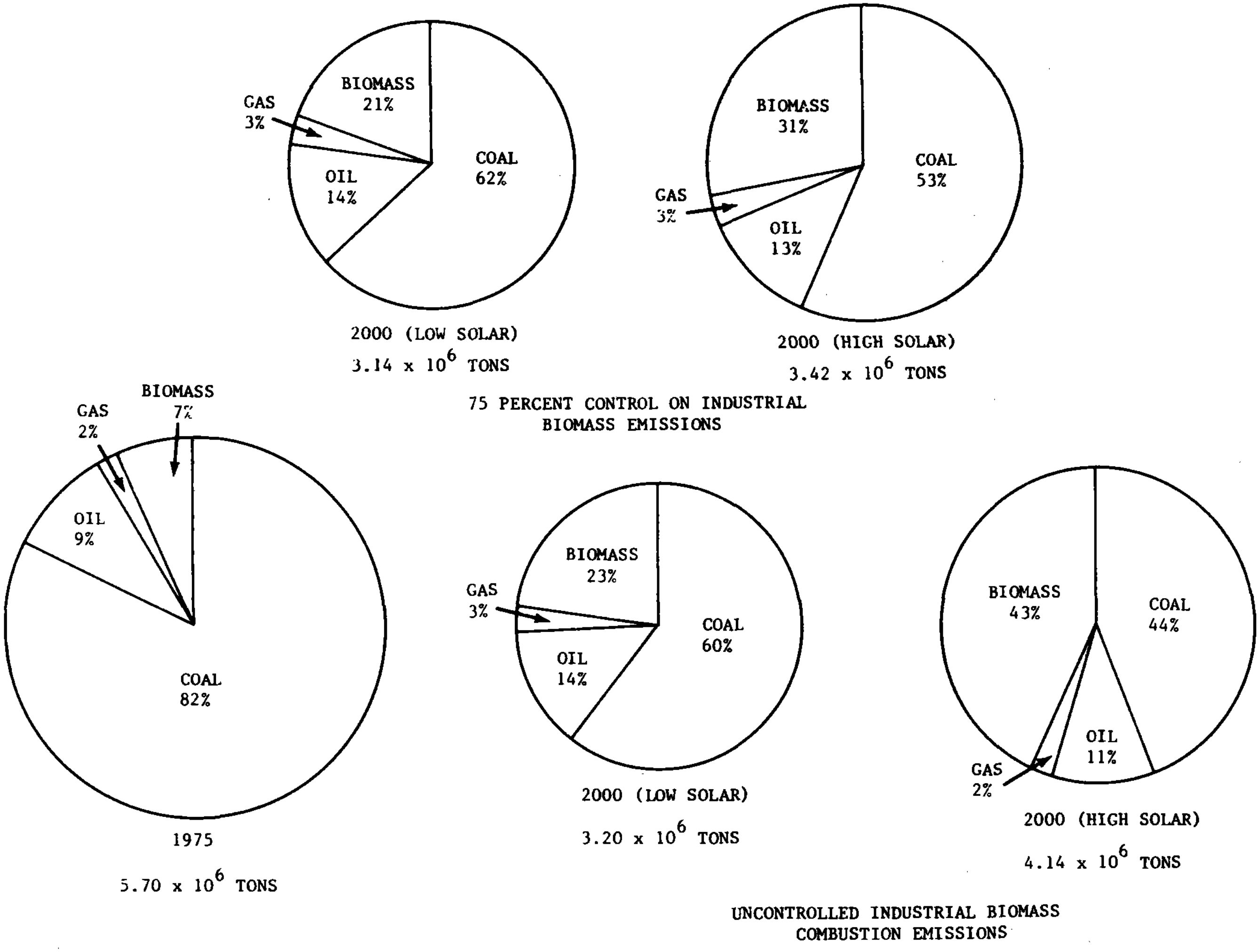


Figure 3.2

National Particulate Emissions by Fuel Type for 1975
and for 2000 Low and High Solar Scenarios

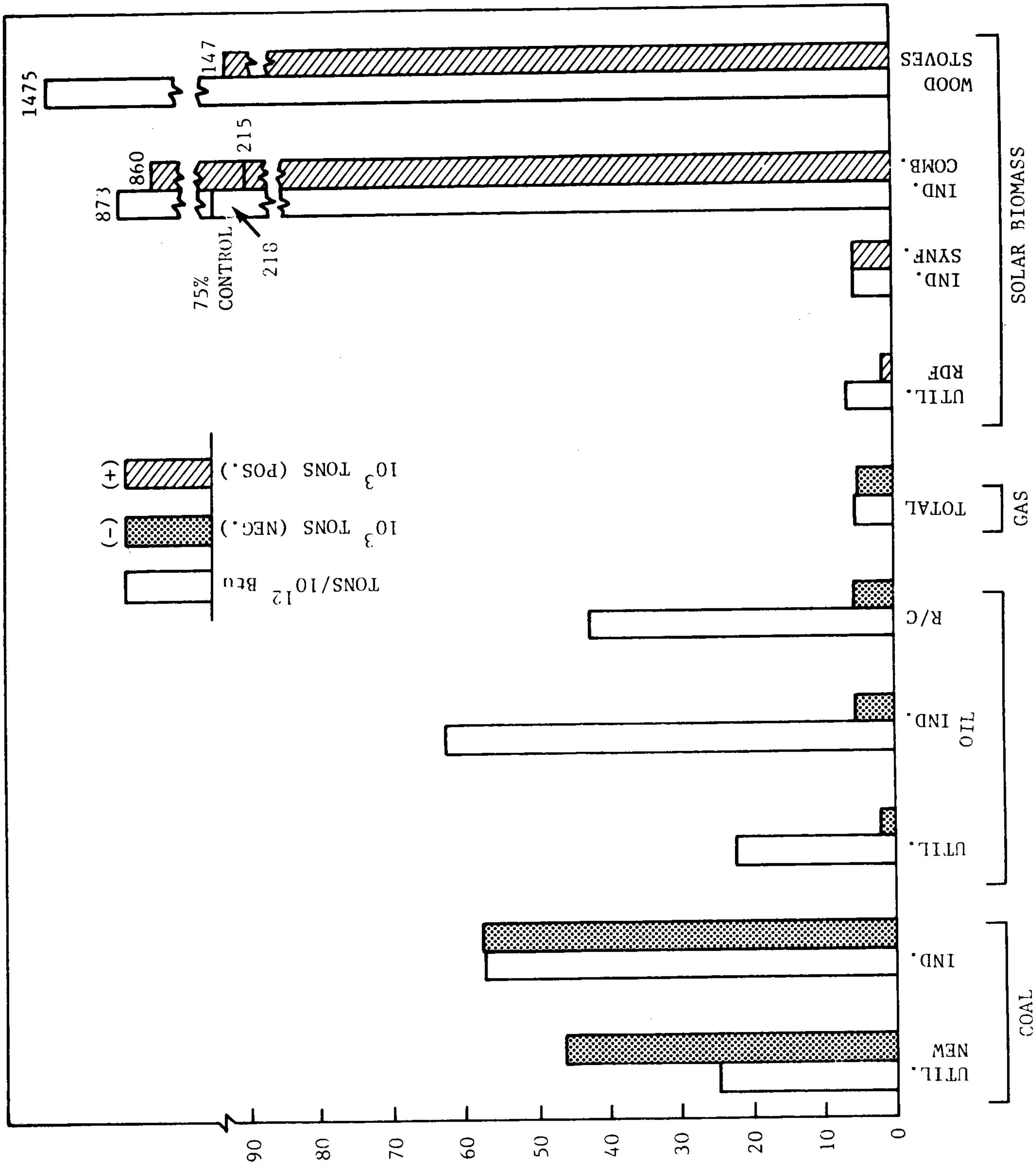


Figure 3.3

Particulate Emission Rates and Differences in Year 2000 National Emissions (High Solar Case Minus Low Solar Case) By Fuel Type and Energy Sector tion, the difference in emissions level is reduced by 0.66 × 10^6 tons between the low and high solar scenario in 2000.

For the other major contributor to biomass particulate emissions—wood stoves— technological improvements may also reduce emission rates below those projected. However, difficulties in regulating small residential units may dictate alternate approaches to energy-related use of the wood resources if further emission reductions are deemed necessary.

For comparison, for the 2000 low-solar scenario, the remaining nonenergy national particulate emissions were projected as 7.14 × 10^6 tons, or 2.2 times the energy emissions.

Sulfur Dioxide

The estimated level of national SO_2 energy sector emissions (Figure 3.4) indicates a 14 percent increase (from 25.9 to 29.7 × 10^6 tons) from 1975 to 2000 for the low solar scenario. This increase is primarily due to substantial increases in coal use for both industries and utilities, which are only partially offset by tighter emission controls in existing plants. In comparing the year 2000 high and low solar scenarios for individual energy sectors (Figure 3.5), displacing the coal facilities with solar technologies reduces emissions substantially, but not to the levels estimated for 1975. A more effective strategy to reduce SO_2 emissions would be to displace existing, more polluting coal utility plants with solar energy rather than with new facilities, as was assumed in the scenario. The estimated nonenergy SO_2 emissions for the year 2000 low solar scenario are 3.06 × 10^6 tons or one-tenth of the energy-related SO_2 emissions.

Nitrogen Oxides

For nitrogen oxides there is a smaller difference in emission rates between existing and projected new facilities than is the case for particulates and SO_2, and thus the projected 2000 national emissions (Figure 3.6) more directly reflect the increase in energy production over the 1975 levels. Also, the biomass technologies contribute substantially to NO_x emissions (Figure 3.7), although generally at lower levels than the coal facilities for the technologies assumed in the scenarios. The major NO_x emission reduction for the high solar scenario is through displacement of the conventional technologies with direct solar technologies (e.g., solar electric, wind, SHACOB, etc.). For 2000 in the low solar scenario, estimated NO_x nonenergy emissions (including transportation) are 6.54 × 10^6 tons, compared to 16.9 × 10^6 tons for direct energy emissions or four-tenths of the energy-related NO_x emissions.

Regional Emissions

A further perspective on the range of influences and trade-offs in air quality from solar technology implementation can be obtained by considering relativ differences in various U.S. regions. The regional chang in emissions between the year 2000 high and low sola scenarios, illustrated in Figure 3.8, reflect not only th relative proportion of solar and fossil fuel technologie but also the mix of technologies within these genera categories.

Regions with the largest difference in solar energ between the year 2000 high and low solar scenario ar Regions 4, 5, 6, and 9. The change in emissions i Figure 3.8 reflects these general magnitudes. Regio 4 also has the greatest percentage of its solar energ derived from biomass sources (43 percent) and this produces the large increase in particulate emissions fo that region between the high and low solar scenarios.

For Regions 4, 5, and 6, a substantial proportio of solar supply displaces coal, which causes a larg decrease in SO_2 emissions. This decrease is relativel small for Region 6, because the coal displaced is primarily in the utility sector, which has a lower projecte emission rate than coal use in the industrial sector. larger proportion of industrial coal is displaced by th solar increment in Regions 4 and 5. Solar also displace a substantial portion of natural gas use in Region 6 which has only minimal air emissions benefit, excep for NO_x emissions. This, in part, explains the relativel large ratio of NO_x to SO_2 reduction in Region 6, compared to Region 4. Also, the Region 4 solar incremen includes a large fraction of biomass synfuel conversio which has a relatively large NO_x emission rate according to the technology characterization used in the analysis (see Figurge 3.7).

In Region 9, emissions of SO_2 and NO_x are reduce through solar substitution without the trade-off of large increase in particulates. This feature of the scenario in Region 9 is the result of relying more on nonpolluting direct solar technologies (solar electric, SHACOB, etc.) instead of biomass.

Long-Range Pollutant Transport Impacts

Long Range Transport Sulfur Dioxide and Sulfates

Long-Range SO_x Transport Model

Concentrations of sulfur dioxide and sulfate in th contiguous U.S. have been calculated using the AIRSOX long-range transport model (Meyers, et al.). Fro each emission source, wind trajectories have been calculated using the observed upper air winds of Januar and July 1974. These two months represent typica winters and summers. Chemical conversion of SO_2 t sulfates (SO_4), vertical and horizontal diffusion, an dry and wet deposition of SO_2 and SO_4 are also simulated in the model. The values of the model paramete that describe these processes are shown in Table 3.1 and were selected based on comparisons between mode predictions and observed concentrations for 1974.

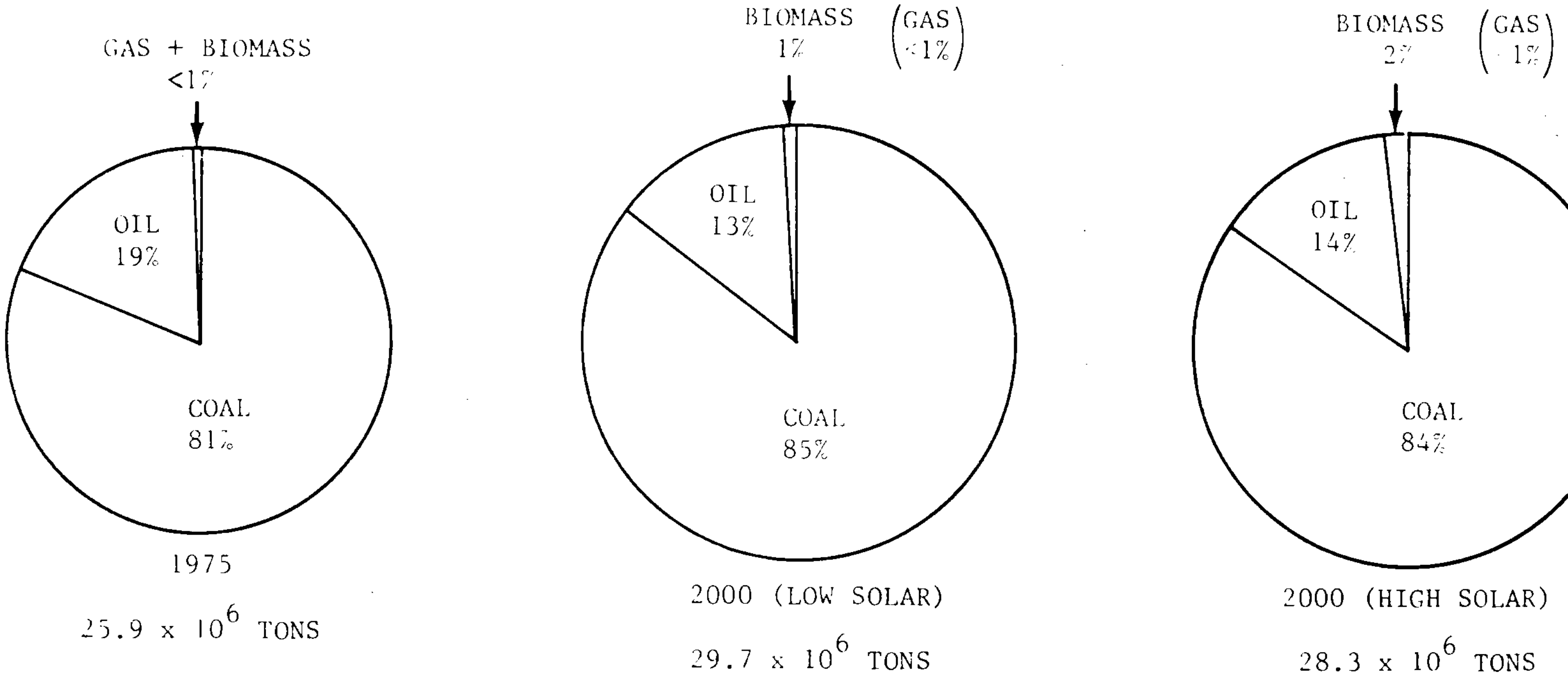


Figure 3.4

National Sulfur Dioxide Emissions by Fuel Type for 1975 and 2000 Low and High Solar Scenario

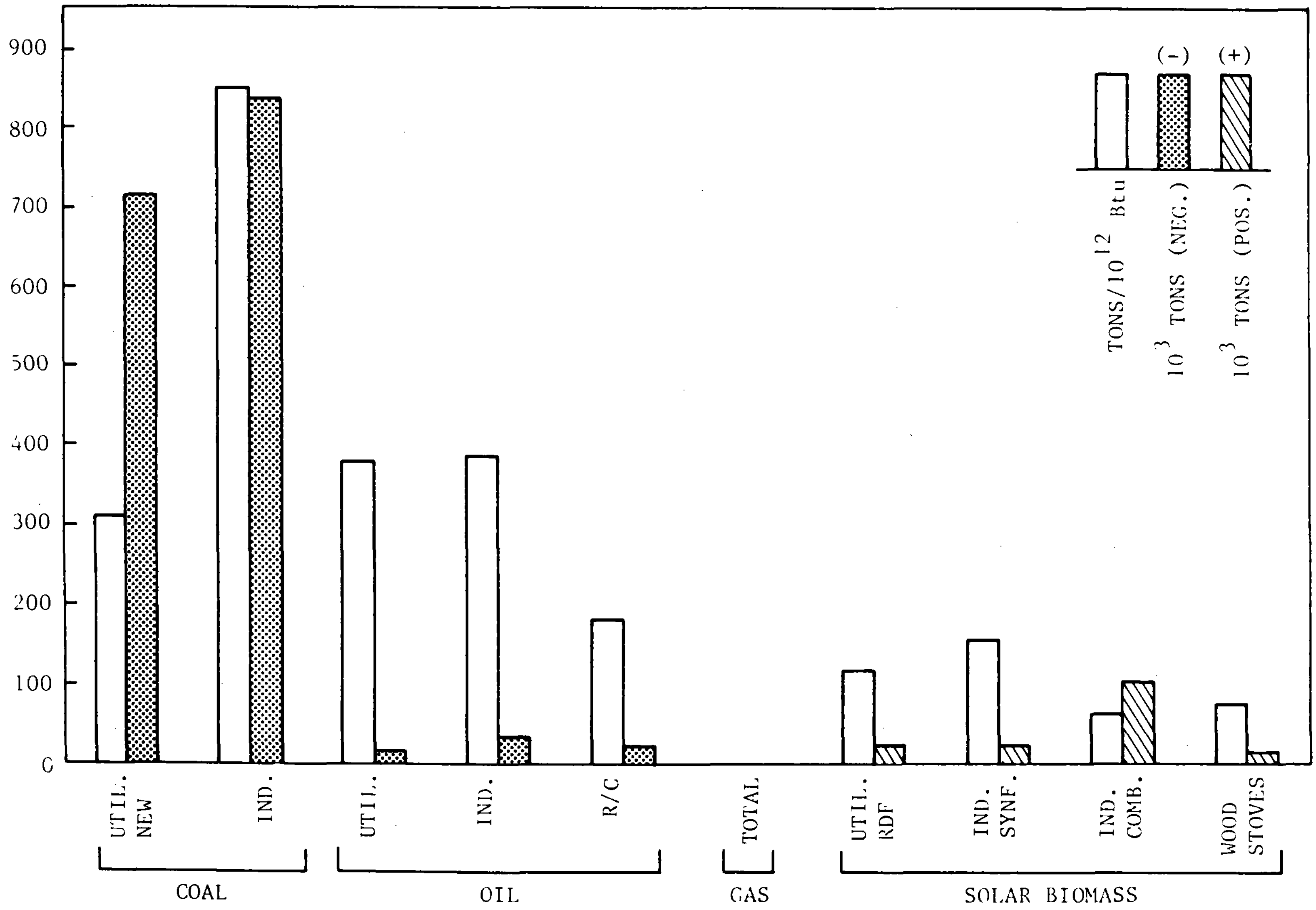


Figure 3.5

Sulfur Dioxide Emissions Rates and Differences in Year 2000 National Emissions (High Solar Case Minus Low Solar Case) By Fuel Type and Energy Sectors

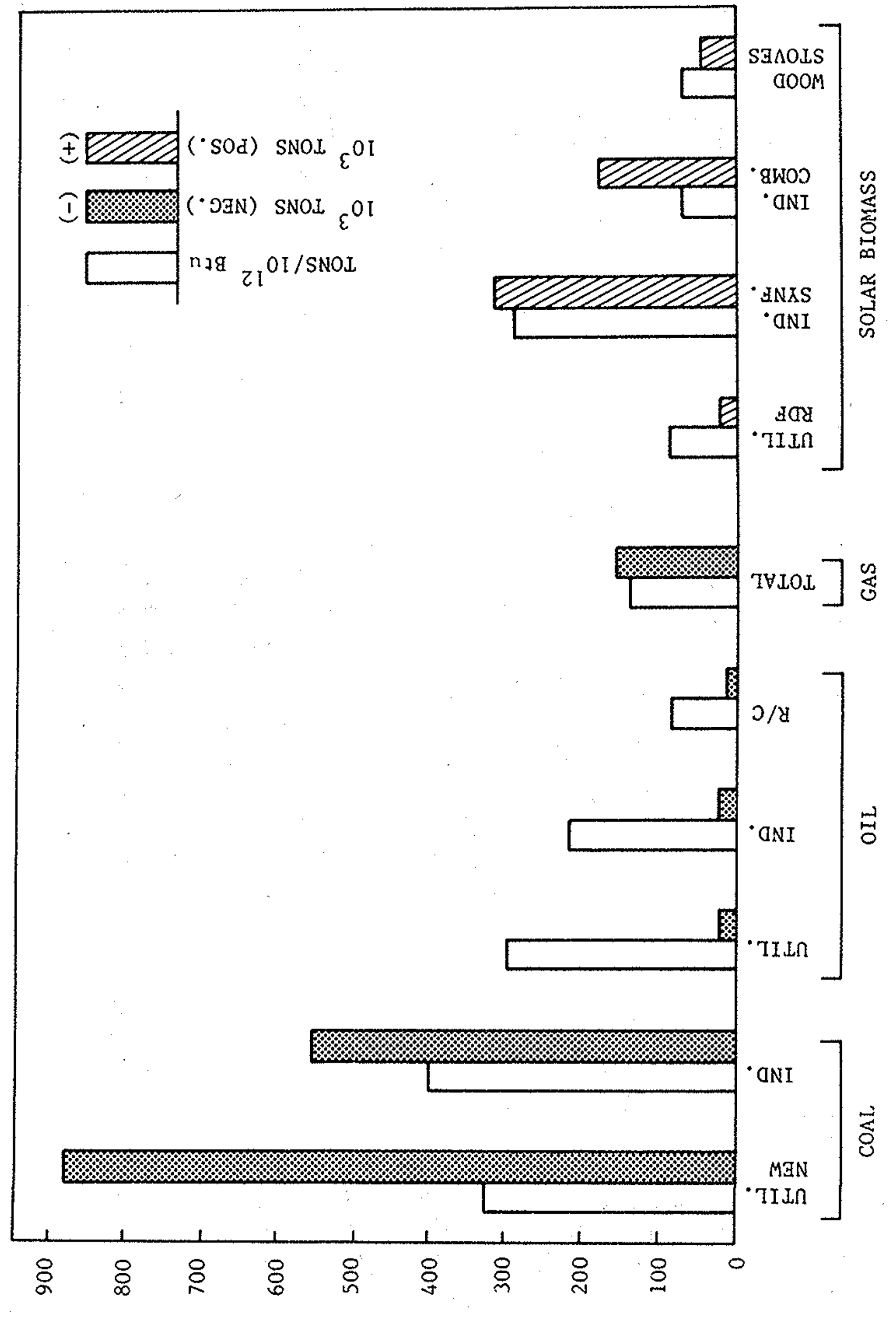


Figure 3.7
Nitrogen Oxide Emission Rates and Differences in Year 2000
National Emission (High Solar Case Minus Low Solar Case) By Fuel Type and Energy Sectors

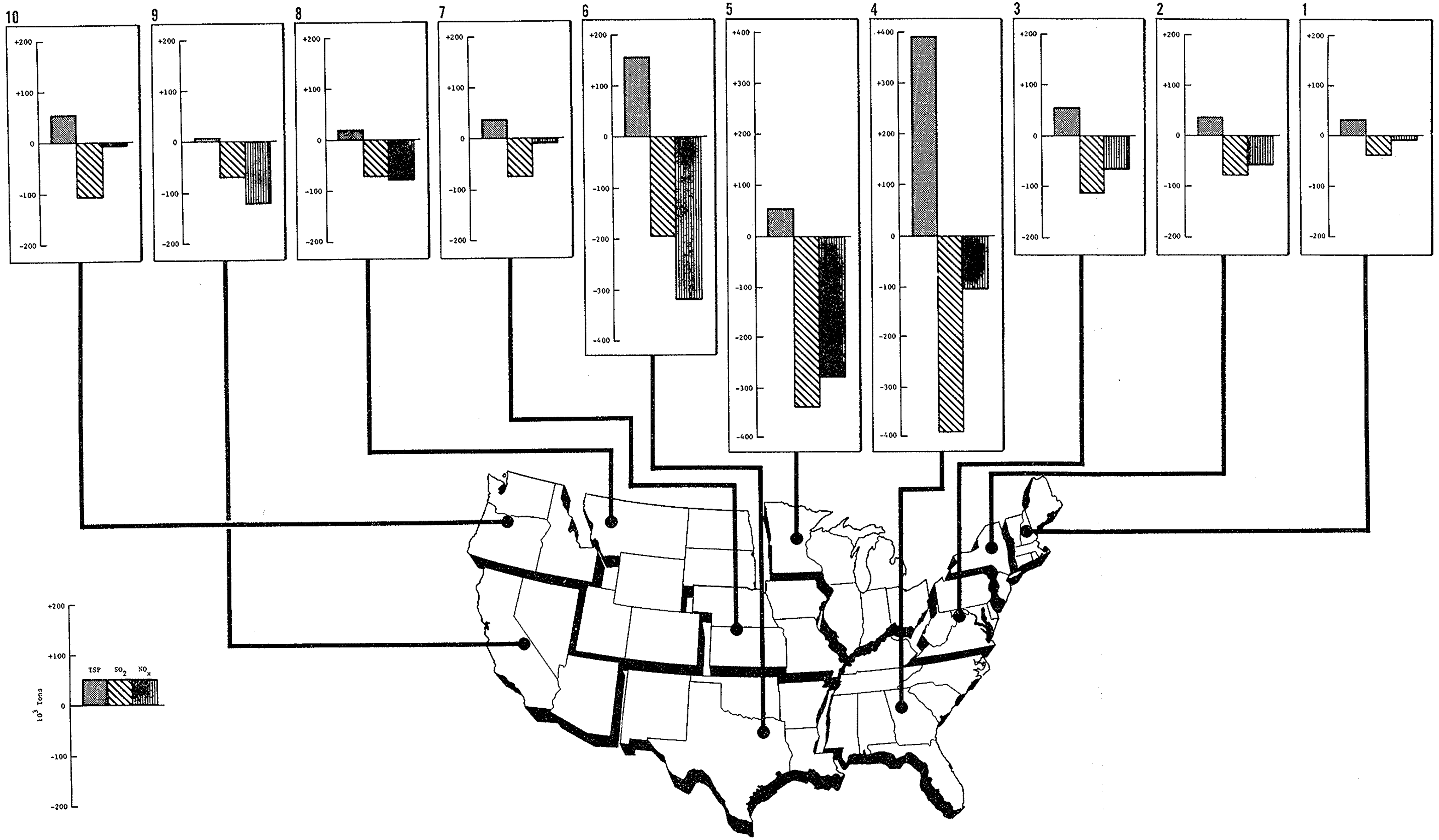
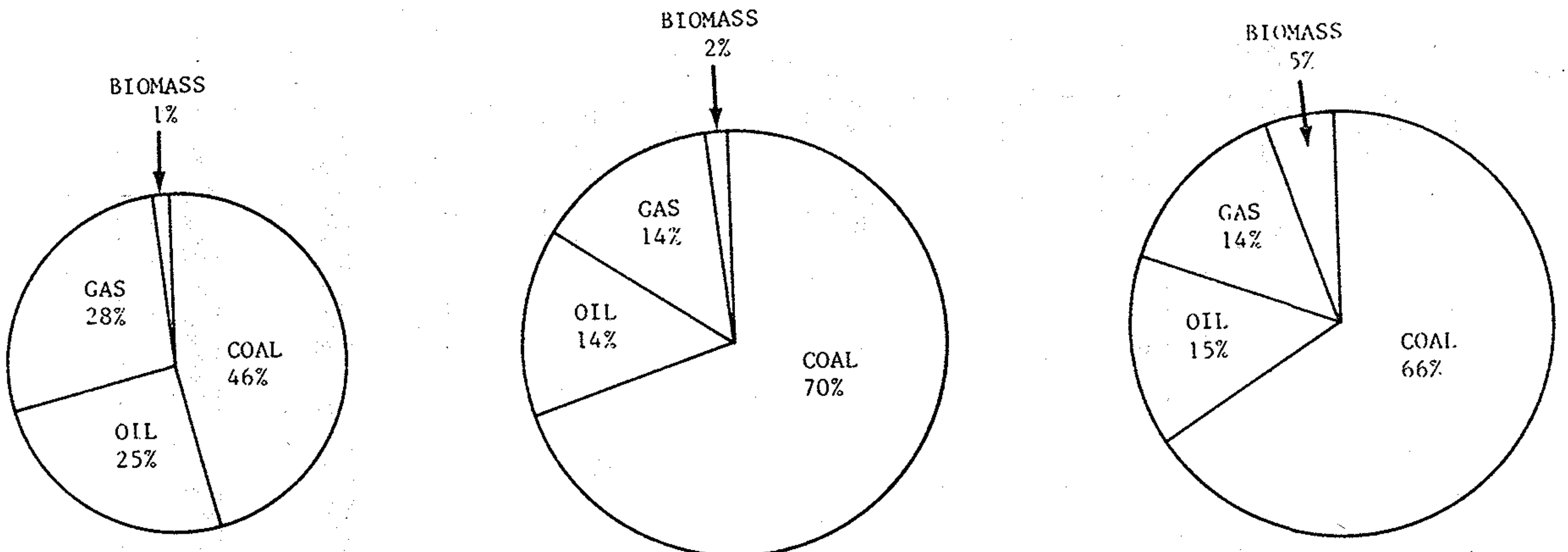


Figure 3.8
Regional Emission Particulates, Sulfur
Oxides, Nitrogen Oxides in Year 2000—High Solar Case Minus Low Solar Case



1975
10.7 x 10^6 TONS

2000 (LOW SOLAR)
16.9 x 10^6 TONS

2000 (HIGH SOLAR)
15.8 x 10^6 TONS

Figure 3.6
National Nitrogen Oxides Emissions by Fuel Type for 1975 and 2000 Low and High Solar Scenarios

Table 3.1.
AIRSOX Model Parameters

Parameter	*Value*
1. Effective release height (height of stabilized plume after plume rise)	
power plants and nonferrous smelters	200 meters
industrial and other point sources	100 meters
area sources	20 meters
2. Amount of $SO_4^=$ in stack effluent	2% of emitted SO_2 (by mole)
3. Meteorology and precipitation data	July 1974 or January 1974
4. Mixing layer height	1000 meters above terrain (July) 600 meters (January)
5. Atmospheric stability	neutral
6. Number of vertical levels	12 (July) 8 (January)
7. Conversion rate of SO_2 to $SO_4^=$	0.57%/hour (July) 0.49%/hour (January)
8. Dry deposition velocity	
for SO_2	3.4 cm/sec (July) 2.5 cm/sec (January)
for $SO_4^=$	0.23 cm/sec
9. Wet removal rate	
for SO_2	0.216 P
for $SO_4^=$	0.007 P P = rainfall (mm/hour)
10. Grid resolution, approximate	32 × 32 km

The AIRSOX model output consists of SO_2 and SO_4 concentrations displayed on a grid, with a nominal resolution of 32 km. These grid fields were used to create transfer matrices which were used in the subsequent analysis. The transfer matrices are arrays of coefficients which relate emissions of SO_2 in each air quality control region (AQCR) to ground level concentrations of SO_2 and SO_4 in all other AQCRs. Separate transfer matrices were calculated for July and January for three pollutant release heights which represented utility, industrial, and area sources. Two methods of averaging air concentrations over an AQCR were also calculated.

- *area weighted*—the estimated average concentration over the AQCR land area.
- *population weighted*—the estimated average concentration weighted by the population distribution within the AQCR. Population estimates were for 1975, regardless of the year for which concentration estimates were made.

Space Heating Emissions

Since domestic space heating is an important use for certain solar energy technologies, special attention was given to these sources, which are characterized as area sources. It was postulated that the pollutant emissions from such sources are proportonal to the ambient temperature difference, given as degree-days, and that these emissions would be negligible in the summer (July). This approach neglects water-heating emissions, which tend to be more constant year-round. To represent the geographic variability of space heating demands, an algorithm was developed based on thirty-year weather averages from the *Climatic Atlas of the United States*. This algorithm gives the fraction of annual heat load (emission) that occurs in January, as a function of latitude:

$$\frac{\text{Jan °D}}{\text{Annual °D}} = 22.84 + 0.111\ \text{Lat}—0.826$$

(Meyers, et al.)

The change in total annual heat load or emissions with latitude is included in the basic emission data given by the SEAS model. Using the above relation January emissions are derived by multiplying annual emissions by Jan °D/Annual °D, which is a factor of about.18, on the average (2.2 times the average month). Only the area space heating source SO_x emissions (for the residential/commercial sector) were multiplied by this factor for winter.

Primary Sulfate Emissions

Although the bulk of ambient sulfate is formed from ambient sulfur dioxide in the atmosphere, sulfates emitted directly from stacks can be important near large sources or complexes. Such "primary" sulfate emissions are difficult to quantify reliably; the AIRSOX model assumes that 2 percent by mole (3 percent by weight) of the sulfur emissions are in the form of sulfate, for all sources. This factor accounts for nearly half of the ambient sulfate within the same AQCR as the emission source, on average, decreasing to about 20 percent at receptors more remote from the source.

The 2 percent figure was derived in part from stack emissions tests on oil-fired power plants (Deitz, et al.), which can be quite variable in this regard, depending on metal content in the oil, combustion conditions, and particulate control equipment. Recent tests on commercial boilers in New York City firing low sulfur residual oil showed a much higher proportion of sulfate emissions (Homolya). Although coal-fired plants appear to emit less primary sulfate than oil-fired plants, wet scrubbers can also have an effect. Since these devices are more effective in removing SO_2 than sulfuric acid mist, for example, the fraction of SO_4 in the stack exhaust can often exceed the 2 percent average figure used in these calculations. These trends should be considered when assessing the ambient concentration estimates provided by AIRSOX.

Scenario Comparison Results

Although the primary emphasis of this analysis is the incremental difference between the high and low solar scenarios in the year 2000, it is necessary to analyze the baseline trends, both geographically and temporally, in order to place the solar increments in proper perspective. This is especially true given the biases and limitations of the model used to simulate ambient air quality. Only population-weighted averages are given here.

The sulfate air concentration patterns for January and July 1975 are quite similar, except that the influence of space heating is seen in January in the eastern part of the country where oil is the predominant fuel, and concentrations are somewhat higher in the West in July. In comparing these estimates to actual ambient measurements it is necessary to use annual averages, since the biweekly sampling schedule used at most stations does not permit statistically reliable estimates for shorter periods.

The predicted annual average has been taken as the arithmetic average of January and July, although this average is likely to be an overestimate. In addition, the measured values are known to be biased upward due to the measuring technique. These factors should be kept in mind in reviewing these results.

Table 3.2 compares the measured and predicted sulfate data on a more detailed basis for some large metropolitan areas in each federal region. The measurements are (unweighted) averages of the available data for the appropriate AQCR. Three years' data are shown to give some idea of their variability. The pre-

Table 3.2
Ambient Sulfate Measurements and Predictions
(μg/m³ annual arithmetic average)

	Locations	*Measurements*			*Predictions*	*T6*	*T14*
		1974	*1975*	*1976*	*1975*	*2000*	*2000*
R I	Boston	14.	—	8.5	9.	9.	9.
R II	New York	11.	11.	11.	11.	11.	11.
R III	Philadelphia	14.	13.	13.	13.	12.	12.
	Baltimore	11.	13.	10.	16.	15.	15.
	Pittsburgh	15.	13.	14.	28.	24.	24.
R IV	Atlanta	9.	8.	9.	8.	9.	9.
	Miami	6.	5.	5.	1.	1.5	1.
R V	Chicago	14.	14.	10.	13.	13.	13.
	Cincinnati	12.	13.	11.	17.	17.	17.
	Cleveland	—	—	11.	22.	19.	18.
	Detroit	13.	15.	10.	15.	14.	14.
R VI	Dallas	9.	10.	6.	1.5	7.	6.
	Houston	10.	10.	10.	2.	6.	6.
	New Orleans	12.	10.	10.	2.	4.	4.
R VII	St. Louis	14.	16.	9.	14.	19.	18.
	Kansas City	7.	9.	9.	3.	6.	6.
R VIII	Denver	—	4.	3.	2.	2.	2.
	Salt Lake City	—	6.	—	1.5	1.5	1.5
R IX	Los Angeles	13.	13.	9.	3.	4.	4.
	San Francisco	5.	4.	4.	1.	1.	1.
R X	Seattle	—	6.	6.	2.	1.5	1.5

ictions use 1974 meteorology and 1975 emissions, hich in general are quite similar to 1976 emissions, r the large SO_2 sources. According to the Federal nergy Regulatory Commission, 1976 emissions are lightly higher. The 1975 predictions compare well ith the range of measured values for the Northeast nd the fringes of the north-central regions. The model nds to overpredict in the central portion of the Mid- est (Ohio, western Pennsylvania), and to underpre- ict substantially along the west coast, the Gulf Coast, nd most of the West.

In comparing data for 2000 versus 1975 (Figures .9 through 3.10), the general observation is one of moothing of the sulfate trends. The dirty areas become leaner and vice versa, although the western and uthern coastal areas remain relatively unchanged. he increased emissions of SO_2 in region 6 are respon- ible for the relatively large SO_4 increases there (2-4 g/m³). Given the apparent large underprediction by e model in this region, such increases could portend latively serious environmental damage, depending n whether one believes the model should be "cali- rated" to reflect the observed values by means of an dditive or a multiplicative factor. Concentrations are lso generally higher in the West, except the area near uthern Arizona/New Mexico, which apparently ben- fits from reduced smelter emissions there (AQCR 12).

Table 3.2 does not facilitate comparison of the two lar scenarios since the differences are so small. More etail is shown in Figures 3.11 and 3.12, which display e differences between scenarios directly for January nd July 2000. The differences between scenarios are en to be generally less than 1 μg/m³. There are a few cations with slight changes in the opposite direction, hich are of no real consequence. The improvements SO_4 concentration appear from the high solar scen- rio for the year 2000 in two general areas, the south- rn Appalachians and NE Ohio/NW Pennsylvania. The anges in the Appalachians could be of some ecolog- al benefit, and the changes in Ohio/Pennsylvania uld possibly have some human health benefit, since e region's air quality is generally not good to begin ith. Although the change between scenarios for the ear 2000 in the energy related national SO_2 emission te is only 4.7 percent, somewhat larger changes in lfates ambient air quality are seen, up to 10 percent some cases. This implies that further local improve- ents could be made if a policy of optimizing solar nergy siting were postulated.

It is of some interest to compare the changes in opulation exposure afforded by the additional 8 quads f solar energy. At the higher concentration levels (as redicted by AIRSOX), between 10 and 20 μg/m³), from to 4 million fewer people are exposed to these con- entration levels in the high solar scenarios as com- ared to the low solar scenario.

Long-Range Transport of Primary Fine Particulates

Fine particulates are that portion of total suspended particulates (TSP) with an aerodynamic equivalent diameter of less than or equal to 2.5 micrometer (μm). These particulates may remain in the atmosphere from a few days to several months, and may be transported up to several thousand kilometers (Price et al.). Due to these long residence times and distant transport characteristics, a long range transport model was used to assess the impact of the increased utilization of solar energy on primary fine particulate air concentrations throughout the United States.

Fine particulates are of environmental concern due to their potential damages to human health and visual air quality. These particulates are of greatest concern from a health standpoint because of their penetration into the gas-exchange region of the respiratory tract. Evidence suggests that some toxic metals such as arsenic, cadmium, nickel, lead, antimony, and selenium tend to be more highly concentrated in this particulate size range (Natusch and Wallace). This is very significant since these small respirable particulates are assumed to contribute to respiratory ailments and to provide a pathway for trace metal body burden increases.

The most important anthropogenic cause of degraded visual air quality is fine particulate matter. Particulates in the size range of 0.1 to 1 are the most efficient light scatterers. Field studies have shown that fine particulate mass dominates particle light scattering (U.S. EPA)

Fine particulates can be emitted directly into the air (primary fines) or can form as a result of atmosphereic gas to particle reactions (secondary fines). At present, ambient air concentrations of fines vary from 15 to 25 percent of TSP levels at Denver, to 40 to 60 percent of TSP levels at Los Angeles and New York (Miller et al.). Of the total fines in these urban areas, 60 to 80 percent can be secondary. This implies a range for primary fine air concentrations of from 3 to 24 percent of TSP levels.

In the United States it is presently estimated that of the nearly 14.5 million tons of particulate matter from anthropogenic sources emitted into the air each year, 33 percent is fine particulates (Lee and Duffield). Of this, 41 percent is from direct energy use (external combustion plus fuel transportation and processing), 38 percent from industrial processing, and 18 percent from transportation.

Due to the uncertainty in estimating the industrial process and transportation total particulate emissions to the year 2000, only the primary fine particulates from the direct energy use sectors were included in this long range transport analysis (approximately 41 percent of the total primary fines in 1975).

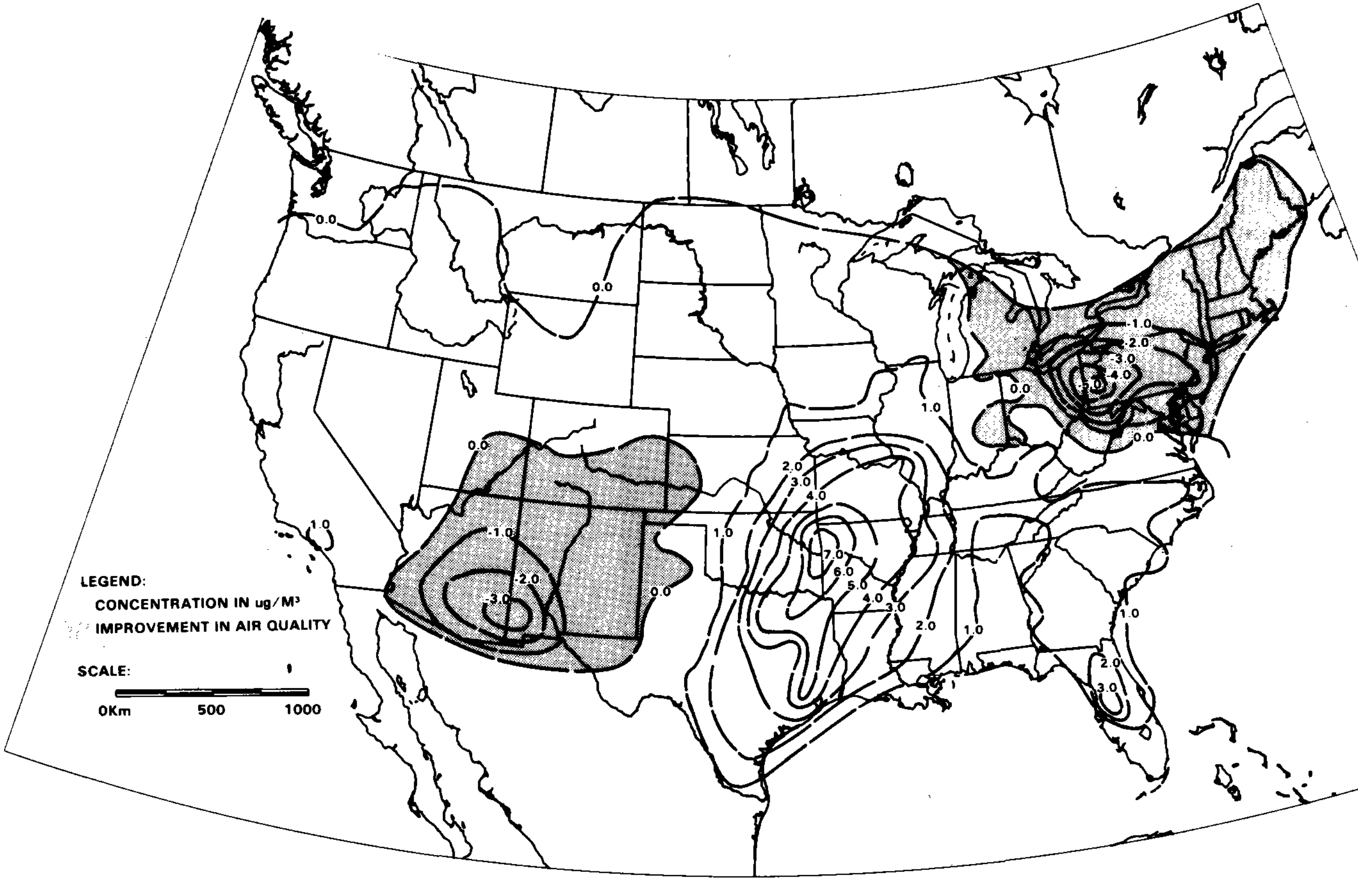


Figure 3.9

SO_4 Concentration, January ($\mu g/m^3$)
Low Solar (2000)—1975

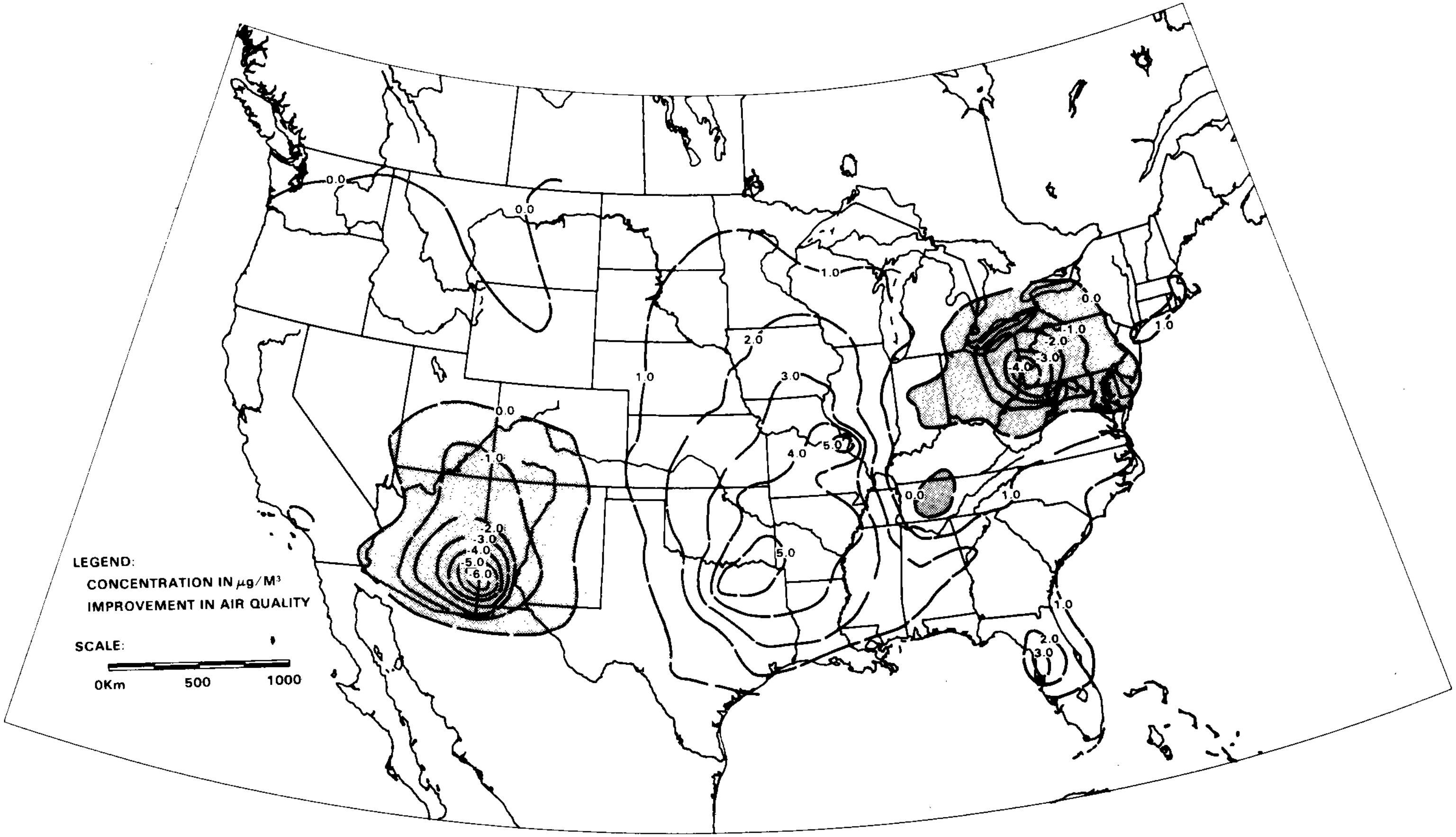


Figure 3.10
SO_4 Concentration, July ($\mu g/m^3$)
Low Solar (2000)—1975

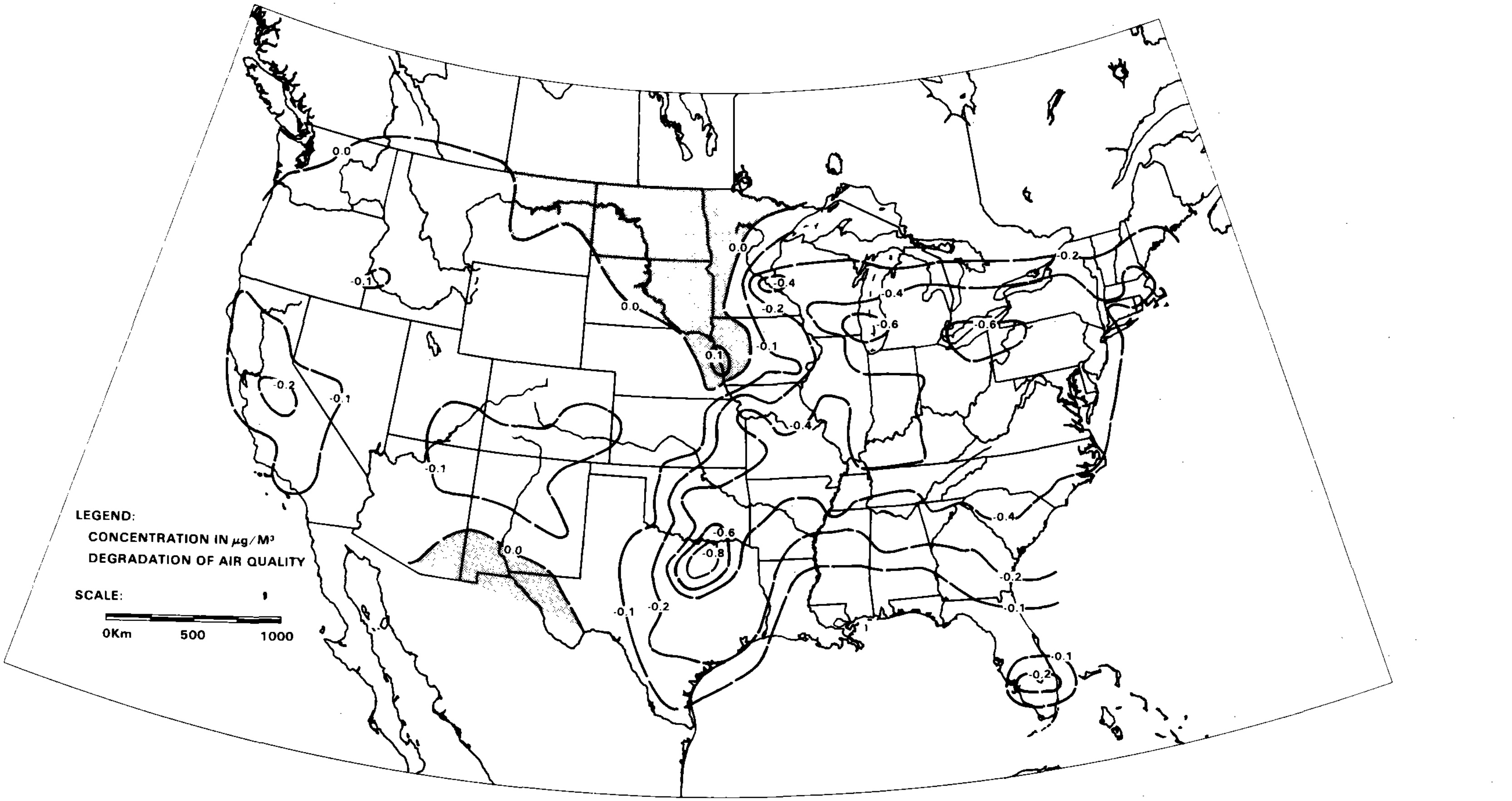


Figure 3.11

SO$_4$ Concentration, January, 2000 (μg/m^3)
(High Solar Case -Low Solar Case)

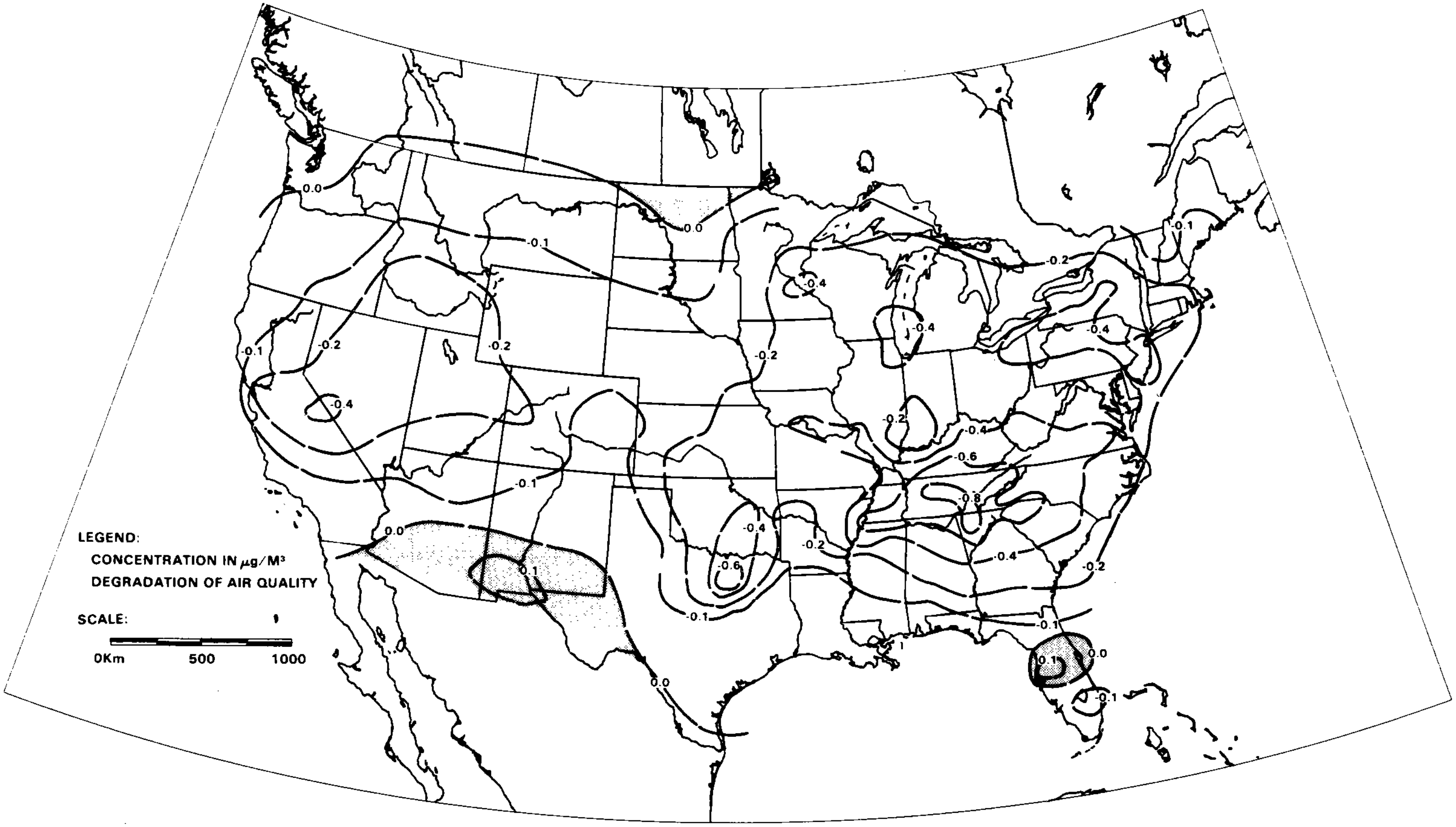


Figure 3.12

SO_4 Concentration, July, 2000 ($\mu g/m^3$)
(High Solar Case —Low Solar Case)

Fine Particulate Emissions

The emissions of fine particulates from the direct energy use sectors were calculated by multiplying the total particulate emission estimates from the SEAS model by the appropriate fine particulate factor listed in Table 3.3. The fine particulate emission levels for each sector were then summed to get a total fines emission estimate for each of the 238 AQCRs within the continental United States. Fine particulate levels at the AQCR level were calculated for 1975 and 2000 low solar and high solar cases.

Of particular significance is the low fraction of fine particulates (0.11) estimated for the Industrial Biomass/Heat sectors (Table 3.3). These sectors are a major contributor to the total suspended particulate emission levels estimated, but this low level for the fine particulate fraction reduces the importance of these sectors in the long-range, fine particulate analysis. It should also be noted (Table 3.3) that a 75 percent control level on industrial biomass combustion is assumed for this analysis, although the implications of this technology being uncontrolled is included in the summary.

Long-Range Particulates Transport Model

Interregional transport (Eadie and Davis) matrices were used to convert fine particulate emissions from each emitting AQCR in to monthly average population weighted air concentrations for each of the 238 receptor AQCRs. The long-range transport model was used to generate these transport matrices by first producing monthly average fine particulate air concentrations from eighty-six unit emission sources located at points on a grid spanning the continental United States. These monthly assessments were interpolated to provide monthly average air concentrations resulting from a 200 meter high unit source at the centroid of each of the 238 AQCRs. The air concentration field from each emitter AQCR was average over each receptor AQCR to produce a population-weighted, average air concentration of fine particulates.

The matrices used for this assessment of solar technologies were generated using meteorological data for January and July 1974 and were used to account for the effect of different meteorologies on fine particulate air concentrations.

Table 3.3
Ratio (j) of Net Fine Particulate Emissions to Net Total Particulate Emissions for Source Categories from SEAS

Source Category	*j*
Oil	
Dist./Extr./Storage	.37
Refining	1.00
Electric Utilities	.90
Res./Com.	.90
Industrial	.90
Gas:	
Process/Dist./Est.	37
Electirc Utilities	90
Res./Com.	90
Process Com.	.90
Industrial	.90
Coal:	
Transp./Proc.	.40
Mining	.40
Electric Utilities, Old	.31
Electric Utilities, New	.80
Res./Com.	.04
Industrial	.04
Synthetic Fuels	.37
Solar:	
Utilities—RDF	.31
Industrial Biomass—Heat:	
Incineration	.11
Combustion (75% Control on Fine Part.)	.11
Cogeneration—Paper & Pulp	.11
Industrial Biomass—Gas:	
Anaer. Dig.—Manure	.90
Pyrolysis—Mun. Waste	.90
Anaer. Dig.—Mun. Sludge	.90
Pyrolysis—Ag. Waste	.90
Res./Com.—Woodstoves	.97

Scenario Comparison Results

Monthly average AQCR fine particulate air concentrations were calculated for 1975, the 2000 low solar case, and the 2000 high solar case. The air concentrations were population weighed and determined using fine particulate emissions from the direct energy use sectors only (see Table 3.3). These emissions constituted approximately 41 percent of the total primary fine particulates on a national basis in 1975.

AQCR emission files were adjusted for season variations in wood stove emissions. It was assumed that no wood stove emissions occurred during the summer, and that the emissions were distributed among the other months using a degree heating day weighting scheme, as given in the section on space heating emissions. The appropriate emission file was then multiplied by the corresponding matrix to get the desired AQCR air concentration fields.

The highest computed 1975 fine particulate air concentrations for both January and July meteorology were found in the corridor bounded by southwestern Pennsylvania to the northeast and Tennessee and western North Carolina to the southwest. The maximum computed value for July was 6.7 μg/m^3 in northeastern Tennessee, and for January was 5.7 g/m^3 in southwestern Pennsylvania. These levels were primarily the result of emissions from coal-fired utilities. For the rest of the region east of the Mississippi River, the fine particulate air concentrations ranged from 1 to 2 μg/m^3. West of the Mississippi, the computed values for both January and July were in general less than 0.5 μg/m^3, except in the Los Angeles area, where a 2.1 μg/m^3 value was calculated.

Comparing the July air concentrations between the two scenarios for the year 2000 shows a very slight improvement projected from increased use of solar energy for over 60 percent of the AQCRs spread throughout the U.S. The improvement was on the order of 0.02 μg/m^3, a statistically insignificant difference. A degradation of fine particulate air concentrations on the same order as the improvement was found for the remaining 40 percent of the AQCRs. Exceptions to the above small levels of change occurred in central California, Dallas/Ft. Worth, south-central Oklahoma, Kansas City, and Minneapolis/St. Paul, where improvements were on the order of 0.2 μg/m^3. The improvement was primarily caused by a decrease in emissions from coal-fired utilities, and to a lesser extent from decreases in oil-fired utilities.

In central Florida degradation was calculated to be about 0.2 μg/m^3. The degradation in fine particulate air concentration in central Florida was primarily the result of increased emissions from biomass-industrial process heat and coal-fired utilities.

Isopleths of the year 2000 scenario difference for January over-lay a United States map in Figure 3.13. Shading denotes the areas of improved air concentration due to increased utilization of solar energy. Very slight improvement (0.05 μg/m^3) is shown for three small areas as a result of decreased emissions from coal-fired utilities. The area of greatest degradation (0.3 to 0.4 μg/m^3) extends from Delaware along the coastal states to Florida. This is almost entirely the result of wood stove emissions. In fact, the projected increase in fine particulate air concentrations throughout the United States for January is, in the most part, the result of wood stove emissions.

Figure 3.14 shows an isopleth plot of the difference in January fine particulate air concentrations between the 2000 low solar projection and the 1975 estimate. Figures 3.13 and 3.14 clearly show that the projected increases in air concentration along the south-eastern seaboard due to increased solar use will be offset by the improvement in air concentration from 1975 to 2000. An exception is central eastern Georgia, in which the 0.4 μg/m^3 increase due to wood stoves will be added to a projected 0.2 μg/m^3 increase from 1975 to 2000. Further inspection of Figure 3.14 shows that the fine particulate air concentration is projected to increase slightly over a large portion of the U.S. from 1975 to 2000. These slight increases are from a combination of increased emissions from coal-fired power plants and wood stoves. The projected 2.0 to 3.0 μg/m^3 improvements in fine particulate air concentration in the southwestern Pennsylvania to eastern Tennessee area are a result of decreased emissions from coal-fired utilities.

To emphasize the limits of this analysis, certain key assumptions and constraints are listed.

- The Strategic Environmental Assessment System (SEAS) model adequately projects the spatial distribution of total particulate emissions given an input scenario.
- The fine particulate factors represent that fraction of total particulate matter which are fine particulates for the aggregated groupings listed in SEAS.
- The fine particulate factors do not change as controls become more efficient.
- Only those particulate emissions from the direct energy use sectors are included (41 percent of total anthropogenic primary fine particulate emissions in 1975).
- The industrial biomass combustion technology has 75 percent total and fine particulate emission controls; other solar technologies have no particulate controls.

In summary, the increased use of solar energy in the year 2000 (high solar minus low solar scenario) will increase primary fine particulate air concentrations during the winter throughout a majority of the United States. These increases will be due almost entirely to residential wood stove emissions. The highest increases (0.3 to 0.4 μg/m^3) are projected to occur from Delaware

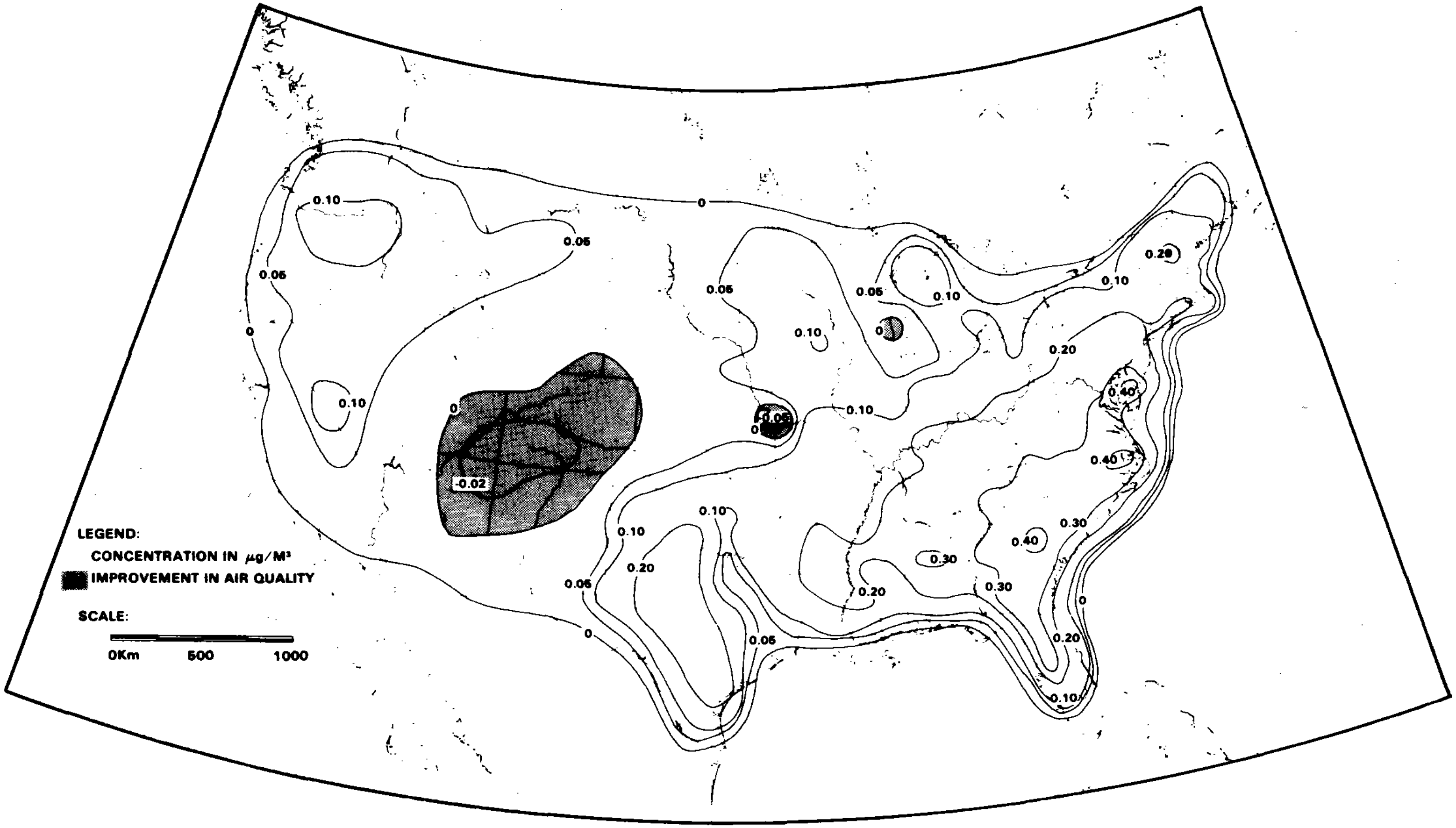


Figure 3.13
Fine Particulate Concentration, January ($\mu g/m^3$)
(High Solar Case-Low Solar Case)

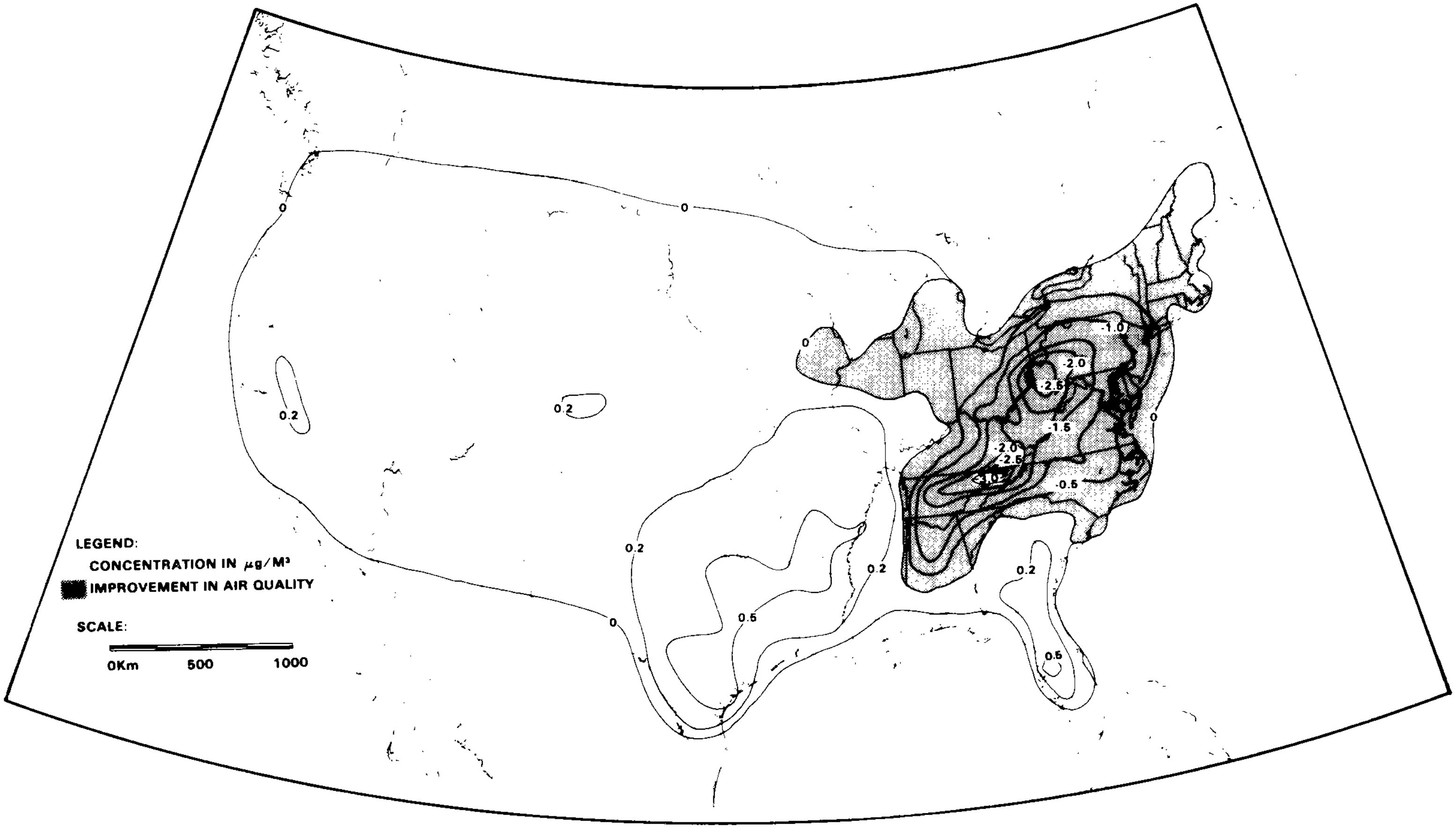


Figure 3.14
Fine Particulate Concentration, January (μg/m²)
(Low Solar Case—1975)

along the coastal states to Florida. Somewhat larger increases (0.4 to 0.5 μg/m^3) in these same states could be expected if industrial biomass direct combustion were to remain uncontrolled. During the summer the changes in primary fine particulate air concentrations are projected to be very slight (± 0.02 μg/m^3) throughout most of the United States.

Influences on Local Air Quality

The concept of local air quality implies site-specific situations depending upon the mix of sources in an area, meterology, topography, local regulatory policy, etc. Bearing this in mind, and without attempting to address specific sites, the major categories of potential local air quality issues associated with high solar use compared to the low solar scenario are discussed below.

Reductions in Conventional Electric Power Generation

The reduction in electric generation by coal and nuclear plants (432.2 × 10^2 MWh) between the high and low solar case are shown in Table 3.4.

Table 3.4
Potential Differences in Central Station Electric Power Generation Between High and Low Solar Scenario in 2000

Fuel	*MWh*
Coal	238.1 × 10^6
Oil	0
Gas	0
Nuclear	185.1 × 10^6

This reduction in coal fired generation corresponds to a savings of 0.7 × 106 tons of SO_2, 0.86 × 106 tons of NO_x, and 0.044 × 106 tons of particulates in the year 2000. If coal-fired rather than nuclear power plants were assumed to be built in the low scenario, an additional savings of 0.5 × 106 tons of SO_2 could be realized.

Table 3.5 indicates that federal regions 4, 5, and 6 would see the greatest benefit in terms of reduced powerplant emissions. Given current trends to site new coal-fired power plants in rural areas, the high solar option will reduce the rate of SO_2 air quality degradation in cleaner area s of the country. As an example, a new 1600 MW coal-fired power plant will cause ground-level concent rations of SO_2 of about 200 μg/m^3 for a 1–3 hour averaging time near the plant.

Regulatory/Growth Implications

Particulate emissions from biomass combustion increase while emissions of SO_2 from utility and industrial boilers decrease. This may prove to be significant in efforts to maintain National Ambient Air Quality Standards (NAAQS) for TSP. As of May 1980, 235 counties in the U.S. were designated to be in nonattainment of NAAQS for TSP. The high solar scenario projects an increase of 0.94 × 106 tons (Figure 3.2) of particulate emissions from new rural power plants. Emissions from large industrial boilers will decrease. However, biomass residential, commercial, and industrial emissions increase with respect to 1975 levels. Thus, TSP standards may be difficult to maintain (or attain) without futher control programs.

Table 3.5
Potential Capacity Displacements by Federal Region

Region	*Capacity (MW)* Coal	*Capacity (MW)* Nuclear	*Total*
1	1400	1000	2400
2	1600	4216	5816
3	3660	1000	4660
4	9394	9713	19107
5	10000	3900	13900
6	8400	3930	12330
7	1375	0	1375
8	3289	330	3619
9	5256	4420	9676
10	800	4000	4800

Modeling studies have estimated that particulate ground-level concentrations of 4–5 μg/m^3 (24-hr average) can be obtained 0.5 to 1.5 km downwind of an area with about 385 wood stoves per square kilometer. This concentration corresponds to the twenty-four-hour significance level specified by EPA for nonattainment areas. A density of about ninety-six stoves/km^2 (250/mi^2) has been suggested as a "safe" density for wood stoves in urbanized areas. The high solar county-level siting scenario for residential wood combustion indicated that only thirty-one counties have sufficient county-wide average particulate emissions to exceed 10 percent of the recommended "safe" density. Three of the potential high wood use counties currenty contain primary nonattainment areas for TSP, six counties are in nonattainment of secondary standards, and two contain PSD Class I areas. A high density of wood stoves could contribute to violations of NAAQS in nonattainment areas. Residential wood combustion has been thought to contribute as much as 100 μg/m^3 of TSP in towns located in valleys.

Wood stove emissions could possibly contribute to the ambient baseline air pollution in developing areas, and possibly reduce the increment available for new industrial expansion. Small wood combustors are not currently regulated. If they are not regulated in the future, it is probable that an increased burden may be placed upon larger industrial point source to offset these wood stove contributions to the TSP air quality in nonattainment areas.

Visibility

Visibility may benefit by increased penetration of solar technologies through reduced emissions from coalfired power plants due to decreased generation demands. Visibility could also be reduced by increased particulate emissions from biomass combustion. Visibility reduced by coal-fired utility plants' plume blights and decreased visual range from haze are expected to be regulated by EPA in PSD Class I areas.

The particulate emissions from wood stoves consist of a large fraction of condensed organic matter in the size range capable of causing haze. This may have some implications for protection of visibility in rural areas if sufficient den sities of wood stoves are in the vincinity. Small sources contributing to the background would not be considered under proposed visibility regulations. Thus, the siting of major new point sources could be more constrained in PSD Class I areas. According to the high solar scenario, approximately 5 to 10 percent of the potential wood stove capacity in the year 2000 could be located in counties with PSD Class I areas. Particulate emissions from these sources would total about 31,500 tons per year.

APPAREL PRODUCTS: 1965 TO 1981

el and clothing donated for charity. Minus sign (–)

1977	1978	1979	1980	1981
2,381	**2,624**	**3,801**	**4,458**	**4,506**
1,857	2,073	3,029	3,457	3,473
378	330	590	642	813
438	426	626	546	335
399	433	678	809	825
39	84	95	106	129
252	406	504	709	694
242	252	329	318	332
109	143	207	327	345
524	551	772	1,001	1,032
5,415	**7,045**	**7,229**	**8,139**	**9,073**
–3,033	**–4,420**	**–3,428**	**–3,681**	**–4,568**

odity by Country, Report FT135, and *U.S. Exports,*

UCTION: 1960 TO 1980

series P 242 and 243]

1974	1975	1976	1977	1978	1979	1980
16.8	13.7	16.2	17.3	17.5	17.0	14.8
2.9	2.5	2.5	3.6	4.7	4.5	3.6
156.6	118.9	132.2	128.8	122.7	125.6	124.0
21.1	13.1	13.8	17.8	16.1	18.3	18.9
18.6	11.5	12.9	16.6	15.0	17.0	17.7
2.5	1.6	.9	1.2	1.1	1.3	1.2
20.4	17.4	19.5	18.2	15.0	14.9	13.8
207.6	153.3	221.3	287.5	99.5	87.2	95.7
				191.0	225.5	261.6
3.4	2.9	3.7	4.0	3.8	3.8	3.6
17.2	18.3	19.7	24.7	25.6	27.5	26.7
190	174	171	193	190	183	179
7.8	9.0	11.7	36.5	32.1	24.9	18.2
18.6	18.3	18.3	18.6	12.4	18.6	19.3
				4.4	5.5	5.9
4.4	4.3	4.9	5.4	5.8	5.6	5.9
20.5	18.4	20.7	19.0	18.9	18.4	16.8
6.3	6.6	6.1	6.6	5.9	4.9	4.4
7.4	7.8	8.4	11.7	11.0	10.7	10.5

ning 1970, includes uniform suits and coats. and woven sport. [5]Beginning 1977, includes

MA-23F, and MA-23G.

960 TO 1981

imes to 1970, series P 260-261, for men's and

1976	1977	1978	1979	1980 [1]	1981 [1]
786.3	**745.7**	**787.7**	**832.9**	**745.1**	**736.6**
422.5	391.1	418.9	398.4	396.9	376.1
1.4	1.3	1.7	2.3	3.2	3.1
3.5	[2]3.7	3.8	4.3	4.7	4.7
355.5	332.0	335.6	320.6	323.5	310.8
128.1	116.8	116.8	103.8	102.5	99.4
155.9	145 0	145.4	145.9	143.1	131.8
15.6	13.2	13.1	13.7	11.3	9.3
21.0	18.3	16.2	13.9	14.2	12.5
24.9	22.7	23.2	22.8	23.6	21.3
10.1	16.0	20 9	20.5	24.3	23 4
369.8	360.0	375.7	443.6	361.0	372.1
47 0	48.3	47.7	53.3	48.5	50.5

1977.

series M31A.

NO. 1413. CHEMICALS AND ALLIED PRODUCTS—VALUE OF SHIPMENTS: 1970 TO 1980

[**In millions of dollars.** "N.e.c." means not elsewhere classified]

PRODUCT	1970	1972	1973	1974	1975	1976	1977	1978	1979	1980
Total [1]	**49,355**	**57,350**	**65,008**	**83,801**	**89,848**	**89,721**	**118,154**	**129,357**	**147,674**	**161,559**
Alkalies and chlorine	666	806	876	1,232	1,673	1,866	1,786	1,746	1,864	2,078
Industrial gases	664	659	721	793	906	1,049	1,199	1,408	1,520	1,563
Cyclic crudes and intermediates	2,014	2,332	2,764	4,141	4,202	5,231	5,514	5,515	7,388	7,732
Inorganic pigments	683	756	893	1,196	964	1,267	1,339	1,381	1,585	1,601
Industrial organic chemicals, n.e.c	6,470	7,466	8,548	12,743	14,098	16,794	19,378	21,214	25,083	27,025
Misc. end-use chems. and chem. prods. exc. urea	4,897	5,900	6,582	9,828	10,901	12,977	2,071	1,851	2,503	2,911
Misc. cyclic and acyclic chemicals and chem. prods							13,425	14,915	17,575	18,888
Industrial inorganic chemicals, n.e.c [1] [2]	4,109	3,003	3,514	4,609	4,675	5,751	6,920	7,977	9,294	10,327
Potassium and sodium compounds	543	503	583	900	910	1,074	1,103	1.206	1,275	1,375
Plastics materials and resins	4,562	4,486	5,678	8,444	7,747	10,455	12,181	13.783	16,964	18,014
Synthetic rubber (vulcanizable elastomers)	1,114	1,289	1,397	1,862	1,820	2,204	2,354	2,826	3,228	3,248
Cellulosic manmade fibers	665	685	744	898	781	814	851	945	1,086	1,156
Organic fibers, noncellulosic	2,468	2,949	3,954	3,867	4,035	4,414	5,472	5,912	6,719	7,147
Biological products	351	495	559	684	788	874	1,068	1,216	1,421	1,599
Medicinals and botanicals	747	794	986	1,467	1,489	1,774	2,206	2,406	2,906	3,158
Pharmaceutical preparations	5,264	6,295	6,841	7,463	8,247	9,217	9,640	10,711	11,539	13,012
Soaps and detergents	2,509	2,852	3,033	3,500	3,963	4,490	5,000	5,551	6,107	7,081
Polishes and sanitation goods	1,306	1,736	1,844	1,980	2,196	2,432	2,669	3,029	3.112	3,359
Specialty cleaning and sanitation products	755	899	937	1,071	1,197	1,316	1,478	1,625	1,880	2,089
Toilet preparations [1]	3,770	4,247	4,573	4,797	5,178	5,883	6,394	6,792	7,510	8,209
Hair preparations (incl shampoos)	1,034	1,065	1,100	1,129	1,306	1,408	1,475	1,466	1,719	2,003
Perfumes, toilet water, colognes	536	677	716	755	918	1,007	1,097	1,250	1,438	1,468
Dentifrices, mouthwashes, gargles, etc	468	485	(S)	535	536	628	660	733	848	866
Paints and allied products	3,019	3,520	3,914	4,578	4,672	5,415	6,123	6,671	7,403	7,682
Fertilizers [2]	1,394	2,642	3,033	5,203	6,588	6,026	6,845	6,931	7,985	9,981
Adhesives and sealants [3]	580	954	1,152	1,404	1,464	1,655	1,873	2,075	2,366	2,426
Explosives	213	238	247	359	450	426	426	456	592	646
Printing ink	389	498	528	623	698	765	904	990	1,100	1,235

S Does not meet publication standards. [1] Includes products not shown separately. [2] Beginning 1972, synthetic ammonia, nitric acid, and ammonium compounds included in fertilizers. [3] Beginning 1972, excludes gelatin.

Source: U.S. Bureau of the Census, *Census of Manufactures, 1972,* and *1977,* and *Annual Survey of Manufactures*

NO. 1414. CHEMICALS—PRODUCTION, BY KIND: 1979 AND 1980

[**In thousands of short tons, except as indicated.** Data for chemicals shown are restricted to a selected group composed for the most part of inorganic chemicals and related products which are sufficiently important economically to justify publication. Includes data for chemicals produced by Tennessee Valley Authority, and by Government-owned privately operated plants. See *Historical Statistics, Colonial Times to 1970,* series P 248, 249, and 251, for sodium hydroxide, ammonia (anhydrous), and sulfuric acid respectively]

CHEMICAL	1979	1980
Acetylene [1] (mil. cu. ft.)	5,606	5,493
Aluminum chloride:		
Anhydrous (100% $AlCl_3$)	73	74
Liquid and crystal (32° Bé)	23	20
Aluminum sulfate (17% Al_2O_3) [2] (Commercial)	1,315	1,286
Iron free	117	116
Ammonia, synthetic anhydrous	18,634	19,653
Ammonium nitrate, original solution (100% NH_4NO_3)	8,293	9,127
Ammonium sulfate, synthetic (technical) [3]	2,363	2,136
Argon, refined (mil. cu. ft.)	8,129	7,906
Calcium carbide (commercial)	268	261
Calcium phosphate dibasic (100% $CaHPO_4$)	834	863
Carbon, activated [4]	84	81
Carbon dioxide (liquid, gas, and solid) [5]	3,780	3,710
Chlorine, gas [6]	12,291	11,421
Chrome, yellow and orange (C.P.)	33	28
Chrome orange, molybdate (C.P.)	13	10
Hydrochloric acid (100% HCl)	3,090	2,895
Hydrofluoric acid, anhydrous and aqueous (100% HF)	200	213
Hydrogen [7] [8] (billion cu. ft.)	106	106
Hydrogen [8] [9] (billion cu. ft.)		
Hydrogen peroxide (100% by weight)	114	116
Nitric acid (100% HNO_3)	8,916	9,232
Nitrogen (100%) (bil. cu. ft.)	427	479
Nitrogen solutions (100% N) (bil. cu. ft.)	2,321	2,773
Oxygen [7] (bil. cu. ft.)	456	431
Oxygen [9] (bil. cu. ft.)		
Phosphoric acid (100% P_2O_5)	10,318	10,938
Phosphorus (white and red)	460	432
Potassium hydroxide (88-92% KOH)	264	245
Potassium pyrophosphate (100% $K_4P_2O_7$)	42	24
Sodium bichromate and chromate	157	154
Sodium chlorate (100% $NaClO_3$)	269	278
Sodium hydroxide (caustic soda) (100% NaOH)	12,759	11,625
Sodium silicate (soluble silicate glass, liquid and solid) (anhydrous) [10]	813	786
Sodium sulfate:		
High purity (more than 99% Na_2SO_4)	509	464
Glauber's salt (100% Na_2SO_4-$10H_2O$)	611	675
Sulfuric acid gross [11] (mil. sh. tons)	43	44
Titanium dioxide [12] (100% TiO_2)	742	727

[1] Excludes quantities of acetylene produced and consumed by railroad shops, shipyards, and small establishments using portable generators. [2] Includes quantities produced and consumed by municipalities. [3] Excludes byproduct coke-oven production. [4] Includes data for decolorizing and water purification grades only. [5] Excludes quantities produced and consumed in plants manufacturing soda ash or urea. [6] Total production, including quantities liquefied for use, storage, or shipment. [7] 99.5-100%. [8] Excludes quantities produced and consumed in manufacture of methanol and ammonia, produced by ammonia dissociation process, or disposed of as waste, e.g. vented, used as fuel, etc. Excludes amounts of hydrogen produced in petroleum refineries for captive use. [9] Less than 99.5%. [10] Excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates. [11] 100% H_2SO_4. Includes sulfuric acid of oleum grades. [12] Composite and pure

Source: U.S. Bureau of the Census, compiled from manufacturers reports and published in *Current Industrial Reports,* series MA28A, MA28B, and MA28C

ERRATUM DOE/EP-0025

A number of typographical errors occured in Chapter 4 "Water Quality Analysis"

page 4-11: Figure 4.6 "Numbers are in 10 tons/yr."
page 4-12: Figure 4.7 "Numbers are in 10^3 tons/yr."
page 4-14: Figure 4.8 "Numbers are in 10^4 tons/yr."

page 4-10, column 1, subsection Biological Oxygen Demand
line 7 should read "28,460 Tons of BOD per year"

page 4-10, column 2, subsection Suspended Solids
line 3 should read "121,000 tons per year"
line 9 should read "21.5% of the total solar related suspended solids"

page 4-13, column 1, subsection Chemical Oxygen Demand
line 4 should read "of the maximum potential 3,170,000 tons of COD"

Summary:

(a) The analyses for BOD from solar thermal technologies (Table 4.7) and for COD from solar thermal technologies (Figure 4.8) are worst case analyses. With systematic, proper disposal, associated BOD and COD could be reduced to 1 percent of the figures presented.

(b) The primary source of BOD from biomass technologies (Figure 4.6) is from anerobic digestion of municipal sludge. The primary source of suspended solids from biomass technologies (Figure 4.7) is from wood pyrolysis. The results given assume 50 percent treatment without effluent recycling. With recycling and more efficient treatment the levels given, which are small compared with all other sources, could be reduced further. Overall, biomass harvesting is a much greater producer of erosion and suspended solids than is biomass technology operation.

Chapter 4

Water Quality Analysis

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CHAPTER 4

WATER QUALITY ANALYSIS

Introduction

This chapter examines the impacts on national water quality by examining pollution due to biomass residue harvesting; disposal of thermal heating and storage fluids in the municipal, industrial and utility applications; and wastes from pyrolysis of wood crop residues and municipal wastes. While wood harvesting for use in residential, agricultural and industrial applications is a significant part of the scenario, erosion and increased runoff due to the harvesting of wood is not considered. The concentrated use of wood residue is in the pulp and paper industry (71 percent of total quads), where the fuel is derived in part from the process wastes. Second, the harvesting of wood for pyrolysis and for residential wood use is highly local specific and not amenable to national or regional modeling.

A balanced analysis of the scenarios would take into account the reduction in water pollution associated with the displacement of conventional fuels and facilities between the low and the high solar cases. Water pollution from coal and uranium mining, as well as the disposal of power plant and facility wastes, is highly variable and site specific across the country. However, the gross magnitude of this displacement is up to 186 million short tons of coal in the year 2000, as well as up to 100 coal and nuclear power plants that would be displaced.

Most studies addressing national water quality lead to the following general conclusions. Of the three sectors (municipal, industrial, and agricultural), water pollutant loadings are greatest from agriculture, accounting for more than 50 percent of total pollution primarily by nonpoint source runoff. Municipal waste water treatment facilities are the second largest set of dischargers; the industrial sector ranks last. Within the set of industrial sectors, energy related emitters do not generally have a major impact on water quality, except various extraction activities and their related point and nonpoint source discharges.

In developing a water quality assessment program for TASE, a number of realities were taken into account. First, the total impact on water quality resulting from solar energy technologies would be very small on a national basis. Second, the water quality data base available on a national basis for solar technologies is not of high quality. Third, certain specific solar technologies are known to have water quality related problems which could cause local and/or technology specific environmental impacts.

On the basis of these realities, it was concluded that the water quality studies should focus on water quality degradation resulting from nonpoint runoff associated with biomass residue harvesting. This area was chosen because it coincided with an area already of concern environmentally— nonpoint source agricultural runoff. While fewer data were available, the waste disposal problems associated with solar technologies was deemed important due to the Clean Water Act (PL 95–217) and Resource Conservaton and Recover Act (PL 94–580) initiatives which emphasize concern and control of toxic materials in the aquatic environment.

Summary and Conclusions

- In certain land resource areas, the average relative increases in erosion from present levels to levels in the high solar case are as large as 18 percent.
- Because of the availability of agricultural areas with acceptable erosion rates, the significant impacts of erosion rates on water quality could possibly be minimized or eliminated by alternate siting patterns for crop residue harvesting.
- On average in the scenarios, oats, wheat and barley residues cause least soil erosion, but this can be highly dependent on land type.
- On average in the scenarios, soybeans, corn, sorghum and sugarcane result in greatest erosion. Again, this can be highly dependent on land type.
- In both scenarios, wheat and barley accounted for approximately 80 percent of energy harvested from residues, but only for 10 percent of the total increase in erosion. Thus, the remaining crops accounting for only 20 percent of the energy result in 90 percent of the erosion increase.
- Minnesota and North Dakota crop residues contribute significantly smaller amounts of erosion

per unit of biomass energy harvested in the low solar case due to use of low erosion crops.

- In the high solar case, Minnesota and North Dakota erosion per unit of biomass energy harvested increases radically due to changing cropping patterns associated with increased decentralized agricultural biomass use.

Water Quality Impacts from Biomass Production

Erosion, with its effects on water quality, is one of the more significant environmental effects expected from crop residue harvesting. High and low solar energy supply cases were evaluated with respect to their crop residue components and resulting erosion changes. Data to compute the erosion changes were based on present and potential cropping and soil conservation practices in large regions. The Universal Soil Loss Equation, designed to estimate erosion in relatively small areas, was used to project the erosion changes throughout the nation. This equation and related data have been used in 208 various studies, specifically addressing nonpoint source discharge. Because of the nature of the equation and available data, the erosion estimates were provided in this study to indicate geographical areas where crop residue harvesting would be environmentally acceptable or unacceptable, relative to other areas. The data were developed at the Land Resource Area (LRA) level of specificity as defined by the Soil Conservation Service (see Figure 4.1). Areas within each LRA were grouped by common characteristics, including farming and soil types, climate, water resources, and land use. Because of the common LRA characteristics, the LRA lends itself to erosion studies.

Harvesting crop residues in the conterminous U.S. would provide an equivalent of 128 × 10^{12} Btu/year in the low solar scenario, and 419 × 10^{12} Btu/year in the high solar scenario. The effects of erosion on water quality are not uniform throughout the nation, and may vary widely even within a watershed. A sediment delivery ratio has been proposed as a factor which could be applied to the Universal Soil Loss Equation to calculate the relationships between water quality and erosion within an area. Such ratios are available to a limited number of small areas and cannot be applied at the LRA level. The implication of erosion related to water quality is based on comparisons between erosion rate and water quality changes. In these types of comparative cases then, erosion increases become indicators of water quality changes, with nutrient and pesticide loadings increasing, as well as suspended solids loadings.

The increase in stream loading rates would occur from increasing the soils exposure to rain by removing or reducing soil cover. When crop residues are harvested, soil nutrients and biocides in the soil are susceptible to removal and transport to stream and lakes. The more severe results of sheet and rill erosion (caused by water forces), such as stream and lake eutrophication, fish kills, and reductions in aquatic food production, are already noticeable in many areas of the nation, even without residue harvesting. Figure 4.2 identifies the suspended solids concentrations in the nation. The highest concentrations of suspended solids in the nation is generally associated with agriculturally induced rill erosion.

National Results

According to calculations, about 286 million tons of soil are presently eroded annually from cropland where residue harvesting was considered. On a national average, residue harvesting would increase erosion by an estimated 0.7 percent on these lands in the low solar case, and by 2 percent in the high solar case. However, erosion increments in areas where crop residues would be harvested a reprojected to be significantly greater than the national average. In some Land Resource Areas the average relative increases are as high as 18 percent. Figures 4.3 and 4.4 illustrate the geographical occurrence of the relative erosion increases in the nation. The boundaries in the figures outline county boundary approximations to the 156 LRAs in the conterminous nation, defined by the U.S. Soil Conservation Service.

On the national average, oats, wheat, and barley residues cause the lease soil erosion per unit of energy (Figure 4.5). All of these results, however, may be more indicative of land used for crop production and crop management practices for specific crops. In the low solar scenario, wheat and barley accounted for 80 percent of the energy harvested from residues and 10.7 percent of the total increase in erosion. Similar results were characteristic of the 14 quad case. Tables 4.1 and 4.2 summarized the energy potential and associated soil loss estimates of individual crop residues at the national level.

Regional and State Results

Crop residue energy content according to geographic region is described in Table 4.3. In the low solar case, regions 6, 8, and 10 provide 74 percent of the total crop residue derived energy. However, the residue energy supply potential is not limited to these regions as is indicated by the smaller relative proportions assigned to the regions for the high solar case.

According to the state level erosion estimates summarized in Table 4.4, Minnesota and North Dakota crop residues contribute the smallest amount of erosion per additional unit of energy in the low solar case. The crop residues associated with these values are from wheat, oats, and barley in the Black Glaciated Plains (LRA 55) and the Red River Valley of the North (LRA 56). Nearly three-fourths of these areas are cropland;

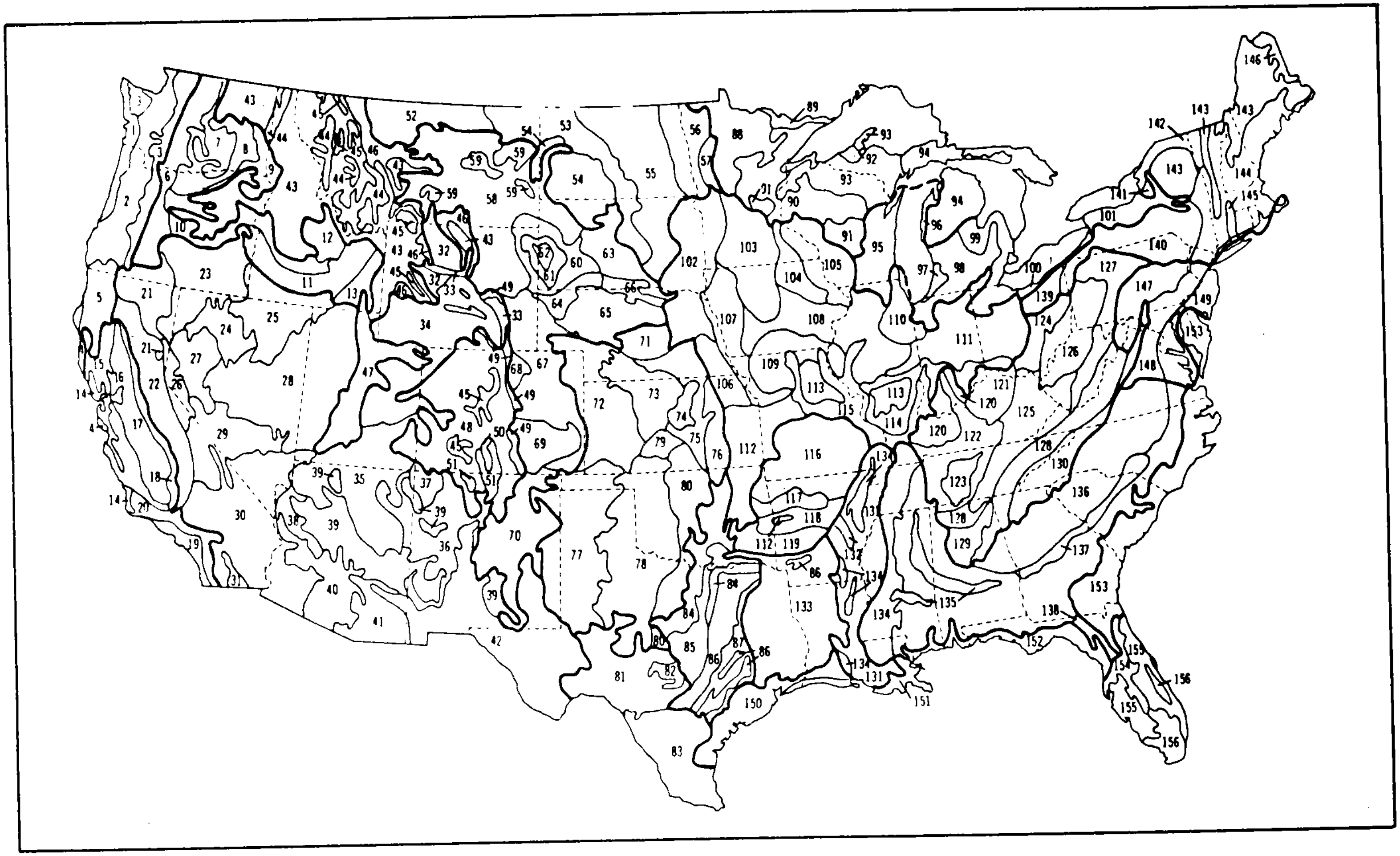


Figure 4.1
Land Resource Area
and State Boundary Map

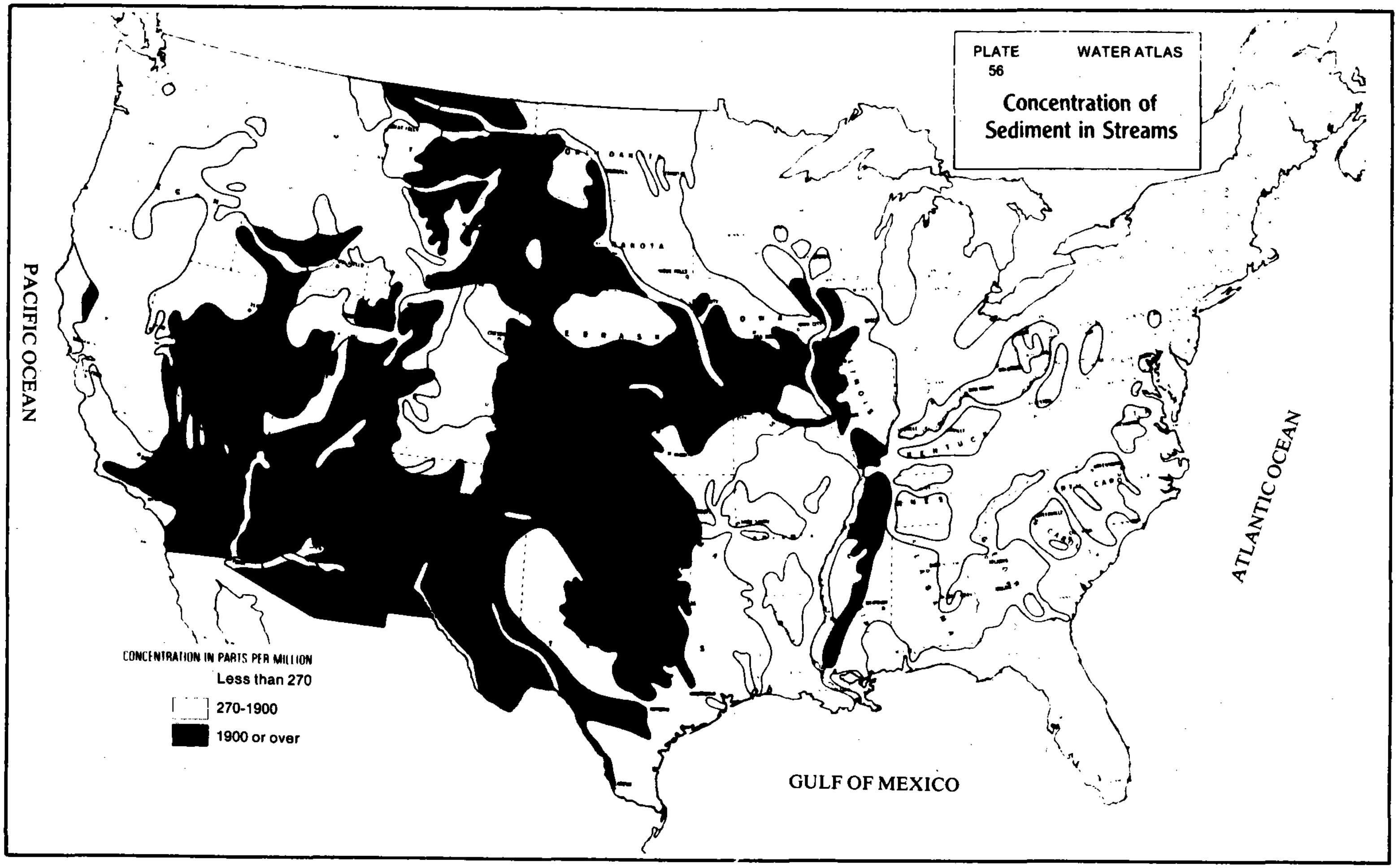


Figure 4.2
Concentration of
Sediment in Streams

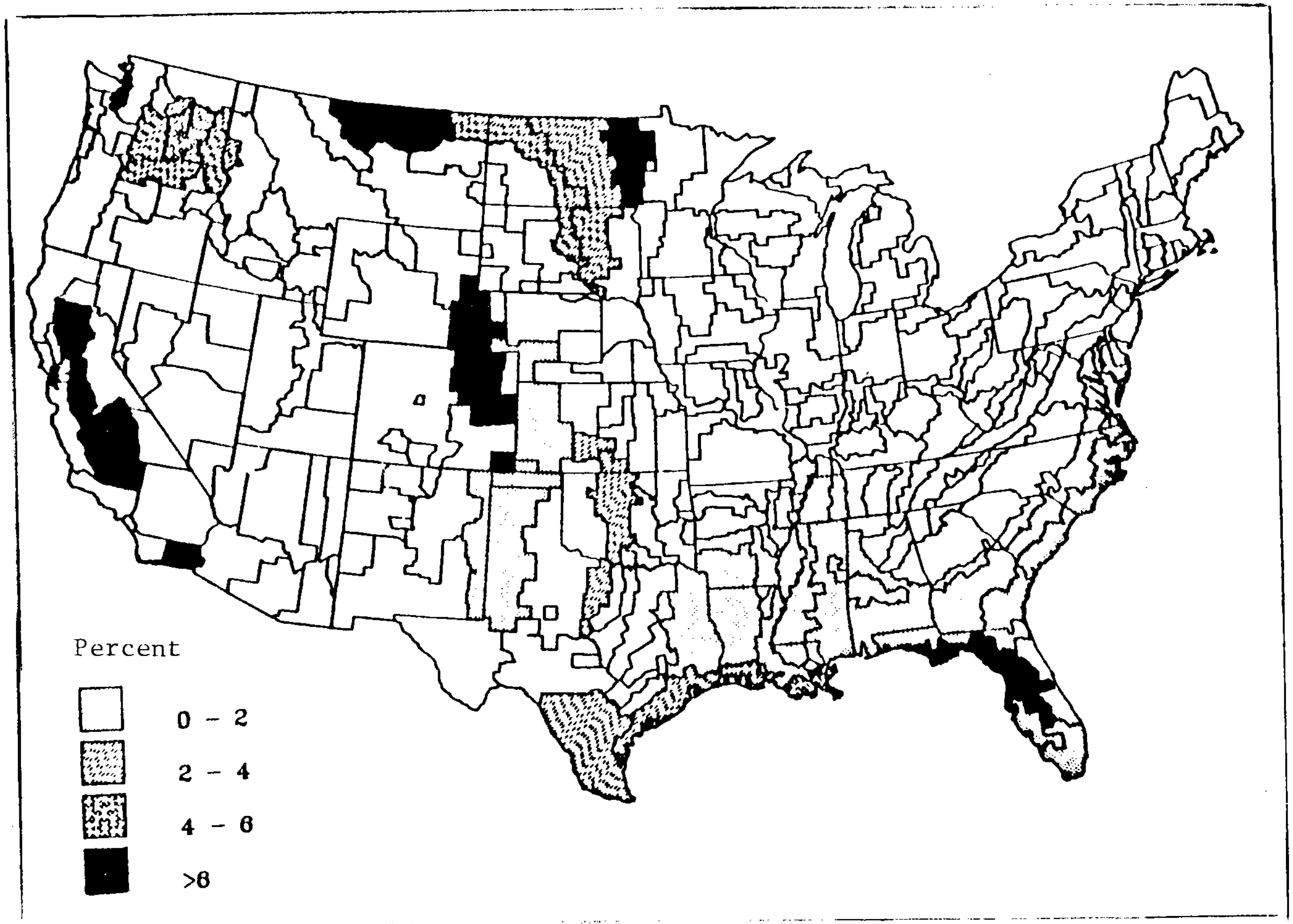


Figure 4.3

Annual Period: Percent Increase in Erosion
from Residue Harvest—LRA Aggregation (TASE 6)

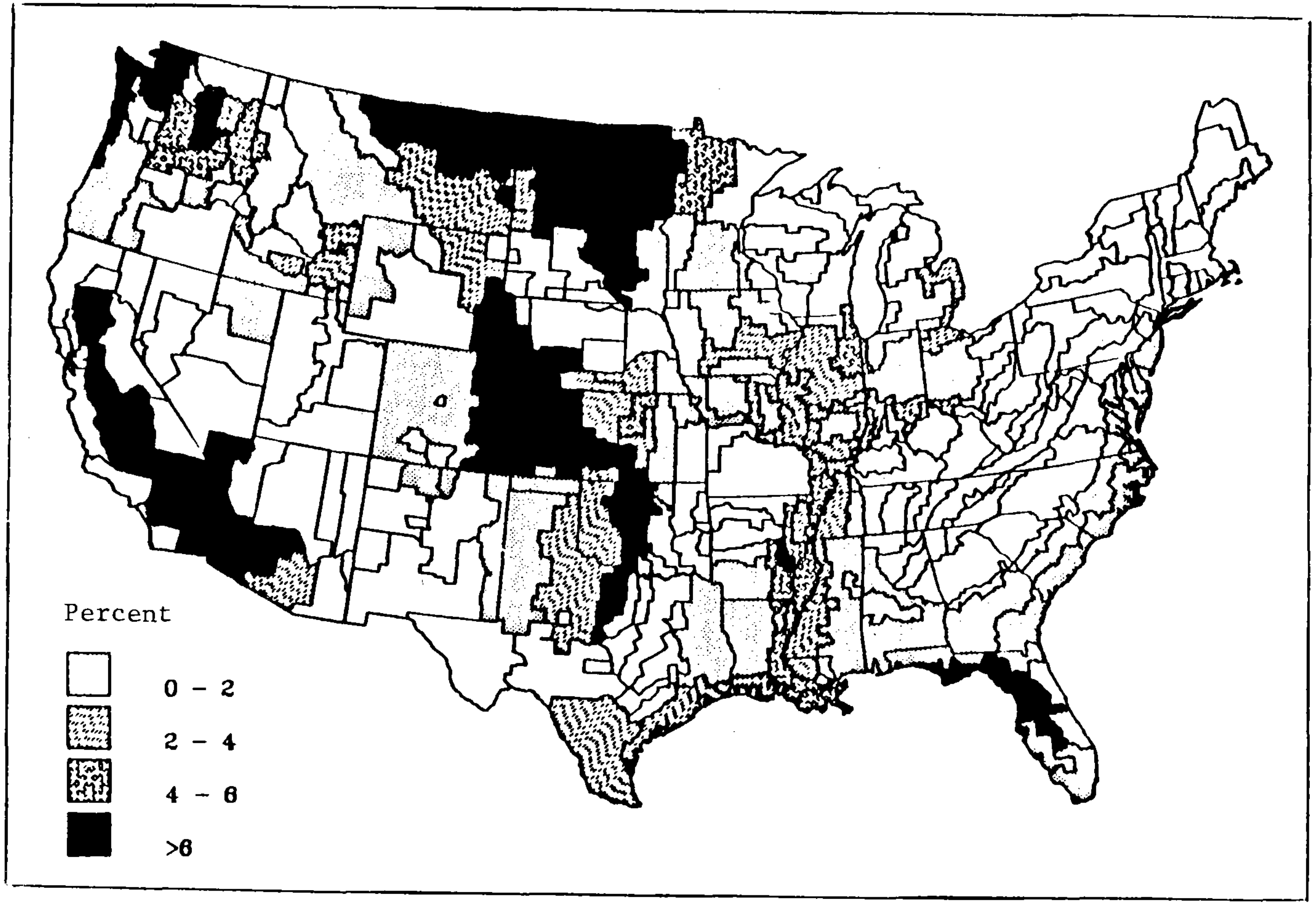


Figure 4.4
Annual Period: Percent Increase in Erosion
from Residue Harvest—LRA Aggregation (TASE 14)

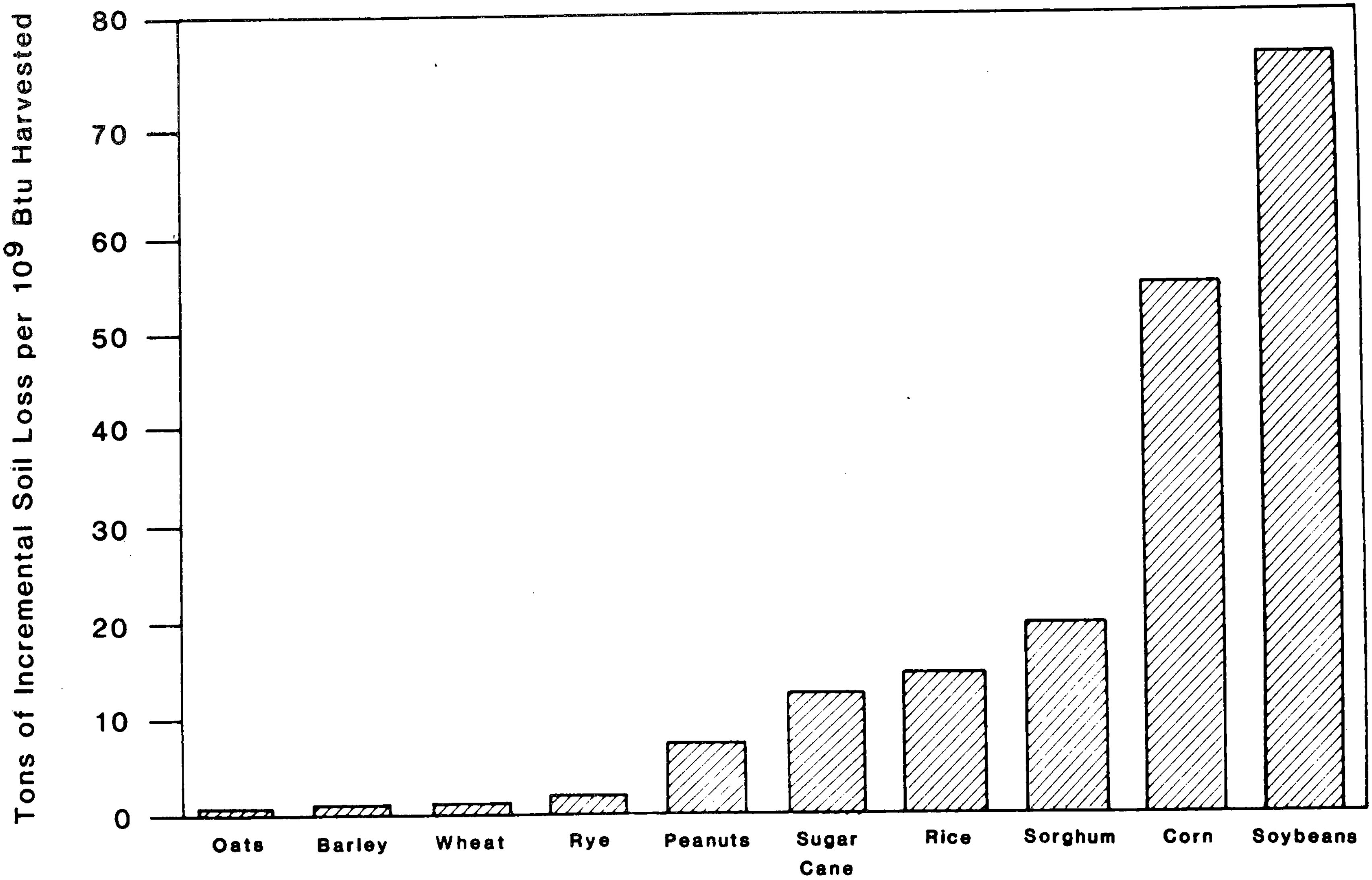


Figure 4.5

Additional Soil Eroded Per 10^9Btu Harvested (6 Quad Case)

TABLE 4.1

National Crop Residue Summary
6 Quad Case

Crop	Energy Harvested (10^{12} Btu*)	Base Annual Soil Loss		Additional Soil Loss Due to Scenario				Area**
		(10^5 Tons)	(Tons/Acre)	(10^5 Tons/Yr)	(Tons/Acre)	(% Annual)	(Ton/10^9 Btu)	10^6 Acres
Barley	42.6	46.9	0.26	0.59	0.05	1.34	1.0	1.19
Cotton (GN)	1.2	—	—	—	—	—	—	—
Flax	0.0	0.7	0.15	0.0	0.0	0.0	—	0
Oats	5.0	30.4	0.24	0.02	0.01	0.08	0.4	0.23
Peanuts	0.6	10.4	0.74	0.04	0.16	0.38	7.0	0.2
Rice	10.8	24.5	1.30	1.5	0.47	6.27	14.0	0.33
Rye	0.2	0.8	0.18	0.01	0.03	0.79	2.0	0.02
Soybeans	7.1	1267.5	2.70	5.36	0.57	0.42	76.0	0.94
Wheat	117.8	102.6	0.21	1.44	0.03	1.41	1.0	4.82
Corn	1.5	939.6	1.61	0.8	0.23	0.09	55.0	0.45
Cotton	1.6	297.7	2.54	7.48	1.08	2.52	460.0	0.69
Sorghum	2.6	135.7	0.93	0.51	0.11	0.38	19.0	0.57
Sugarcane	9.0	31.3	5.57	1.1	0.39	3.50	12.0	0.38
Total	200.0	2888.9	1.34	18.92	0.20	0.66	9.0	9.64

*Fossil Fuel Equivalent GN:GIN Trash **Study Inventory:215 × 10^6 Acres

TABLE 4.2

National Crop Residue Summary
14 Quad Case

Crop	Energy Harvested (10^{12} Btu*)	Base Annual Soil Loss		Additional Soil Loss Due to Scenario				Area**
		(10^5 Tons)	(Tons/Acre)	(10^5 Tons/Yr)	(Tons/Acre)	(% Annual)	(Ton/10^9 Btu)	10^6 Acres
Barley	80.0	46.9	0.26	1.16	0.04	2.5	1.0	2.90
Cotton (GN)	1.7	—	—	—	—	—	—	—
Flax	0.3	0.7	0.15	0.01	0.03	1.11	2.0	0.02
Oats	34.6	30.4	0.24	0.29	0.02	0.96	1.0	1.45
Peanuts	0.9	10.4	0.74	0.05	0.13	0.52	6.0	0.04
Rice	21.0	24.5	1.30	4.44	0.72	18.07	21.0	0.62
Rye	1.0	0.8	0.18	0.03	0.04	4.57	3.0	0.07
Soybeans	72.9	1267.5	2.70	23.81	0.28	1.88	33.0	8.50
Wheat	322.8	102.6	0.21	6.50	0.04	6.34	2.0	16.25
Corn	46.7	939.6	1.61	8.83	0.11	0.94	19.0	8.03
Cotton	3.0	297.7	2.54	11.71	0.75	3.94	390.0	1.56
Sorghum	6.8	135.7	0.93	2.24	0.13	1.67	33.0	1.72
Sugarcane	8.2	31.3	5.57	1.10	0.39	3.50	13.0	0.28
Total	600.0	2888.9	1.34	60.17	0.15	2.10	10.0	40.11

*Fossil Fuel Equivalent GN:GIN Trash

TABLE 4.3

Federal Region Summary of Crop Residue Energy Content

Federal Region	6 Quad Case		14 Quad Case	
	Energy Equivalent Harvested (10^{12} Btu/yr)	% of National	Energy Equivalent Harvested (10^{12} Btu/yr)	% of National
3	—	—	1.6	0.3
4	7.0	3.5	6.4	1.1
5	17.2	8.6	135.9	22.7
6	30.2	15.3	76.3	12.8
7	9.8	4.9	118.7	19.8
8	74.8	37.4	157.7	26.2
9	17.8	8.9	34.2	5.7
10	43.0	21.4	69.6	11.6
Total	200.0	100	600.0	100

current erosion rates caused by agriculture are estimated at less than 0.03 tons per acre.

Low Solar Case. Figure 4.3 indicates the largest *relative* increases in soil erosion rates would occur in California, Montana, North Dakota, and Florida. However, the Sacramento and San Joaquin Valleys (LRA 17) in California, where 90 percent of the land is used as farms and ranches, is the only LRA in the 6 quad case where additional erosion rates exceed 1 ton per acre. The relative erosion rate increases in the other cases are associated with LRAs where current erosion rates from agriculture are minimal. In LRA 17, rice and cotton residue harvesting would contribute 90 percent of the erosion increase of 12 tons of soil per acre annually. The energy equivalent of the rice and cotton

TABLE 4.4

State Level Erosion Estimates

	6 Quad Case					14 Quad case				
			Annual Soil Erosion					Annual Soil Erosion		
State	Energy Harvested (10^{12} Btu/yr)	% Total	Present Rate (Tons/Acre Annually)	% Change in Affected Area	Erosion Per Unit Energy Harvested (ton/10^9 Btu Annually)	Energy Harvested (10^{12} Btu/yr)	% Total	Present Rate (Tons/Acre Annually)	% Change in Affected Area	Erosion Per Unit Energy Harvested (ton/10^9 Btu Annually)
Arizona	—	—	—	—	—	5.9	1.0	1.0	2.2	3.0
Arkansas	—	—	—	—	—	19.7	3.3	3.5	6.3	70.0
California	17.8	8.9	2.6	8.6	40.0	28.3	4.7	2.6	14.0	41.0
Colorado	8.7	4.4	0.2	3.7	2.0	23.5	3.9	0.2	10.7	2.0
Delaware	—	—	—	—	—	1.6	0.3	2.3	5.9	33.0
Florida	7.6	3.5	2.1	4.5	11.0	6.4	1.1	2.1	4.5	12.0
Idaho	—	—	—	—	—	16.6	2.8	0.2	2.6	1.0
Illinois	—	—	—	—	—	57.5	9.6	1.4	3.7	17.0
Indiana	—	—	—	—	—	1.7	0.3	1.2	0.1	4.0
Iowa	—	—	—	—	—	21.0	3.5	1.0	0.8	7.0
Kansas	9.8	4.9	0.5	0.3	3.0	80.7	13.5	0.5	3.4	3.0
Louisiana	19.3	9.7	3.4	8.2	46.0	17.7	3.0	3.4	8.2	50.0
Michigan	—	—	—	—	—	4.1	0.7	0.2	1.4	2.0
Minnesota	6.2	8.6	0.4	0.3	0.2	56.4	9.4	0.4	1.7	2.0
Missouri	—	—	—	—	—	10.4	1.7	1.9	1.8	26.0
Montana	11.5	5.8	0.1	2.9	2.0	31.5	5.2	0.1	8.0	2.0
Nebraska	—	—	—	—	—	6.4	1.1	0.9	0.2	3.0
North Dakota	54.4	27.2	0.1	3.6	0.6	94.2	15.7	0.1	11.6	1.0
Ohio	—	—	—	—	—	16.0	2.7	0.9	0.9	4.0
Oklahoma	7.5	3.7	0.4	0.9	4.0	35.2	5.9	0.4	5.6	4.0
Oregon	6.1	3.0	0.3	1.2	1.0	9.2	1.5	0.3	2.0	1.0
South Dakota	—	—	—	—	—	8.4	1.4	0.3	0.5	2.0
Texas	3.9	1.9	0.6	0.2	5.0	3.6	0.6	0.6	0.2	5.0
Washington	36.8	18.4	0.3	10.0	1.0	43.8	7.3	0.3	5.5	1.0
Total	200.0	100				600.0	100			

residues is 2.1 × 10^{12} Btu/yr. A maximum allowable erosion rate of 5 tons per acre is usually marginally acceptable, and crop residue harvesting in this LRA would probably be restricted without more extensive soil conservation practices.

An alternative screening criterion for identifying erosion related water quality impacts is to compare the additional erosion rate in a Land Resource Area with its present erosion rate. Impacts on an LRA could be considered critical when present erosion rates are excessive (greater than 5 tons/acre annually) and projected additional erosion rates are greater than 1 ton per acre annually.

By this screening method, the Southern Mississippi Valley Silty Uplands (LRA 134), Gulf Coast Marsh (LRA 151), and the Sacramento and San Joaquin Valley (LRA 17) are areas susceptible to water quality degradation from crop residue harvesting. The sum of energy equivalents in these LRAs would be 11 × 10^{12} Btu/year from crop residues, which is 8.8 percent of the crop residue portion of the 6 quad solar energy scenario.

High Solar Case. For the requirement of 419 × 10^{12} Btu of energy from crop residues in the 14 quads case, the areas where the relative increase in erosion is above tolerance limits are more numerous. These areas are in addition to those found with the low solar case, and occur primarily in the Midwest and in the Western Slope Olympic and Cascade Mountains (LRA 3). Except for the Sacramento and San Joaquin Valleys (LRA 17), the actual erosion increase in these areas is estimated at less than 1 ton per acre annually. The level of crop residue harvesting projected for these LRAs would probably not be restricted on the single basis of the relatively small erosion rate increase.

If resulting erosion rates were considered significant by the second criterion, i.e., erosion rates exceed 5 tons per acre annually and resulting erosion rates are projected to exceed 1 ton per acre annually, then 7.6 × 10^{12} Btu/year would be restricted from crop residue harvesting in the same two LRAs (134 and 151) also restricted in the low solar case. However, the total energy sited in these LRAs was increased to 6.1 × 10^{12} Btu/year in the high solar case. The total energy sited from crop residues in the three LRAs (LRAs 17, 134, and 151) is 23 × 10^{12} Btu/year, or 5.6 percent of the total residue derived energy in the high solar case.

Conclusions

Erosion. Soil tolerance limits ranging from 2 to 5 tons of soil erosion per acre annually have been suggested as acceptable. Present erosion rates from agricultural activities in many areas of the nation are found in this study to be less than 2 tons per acre annually, and would remain below this erosion rate with crop residue harvesting. Many of these areas also lie within regions where suspended solids concentrations in surface streams are low. Calculations indicate three Land Resource Areas (LRA 17, 134, and 151) presently exceed acceptable limits, and crop residue harvesting would increase erosion rates by at least one additional ton of soil per acre annually. Because of the availability of agricultural areas with acceptable erosion rates, the significant impacts of erosion rates on water quality could likely be eliminated by resiting crop residue harvesting activities. Ultimate siting of crop residue harvesting will reflect economic in addition to environmental considerations. As residue harvesting becomes economically competitive with other energy forms, the dynamics of crop substitution could change the crop pattern from the static one on which this analysis was based.

The eventual sites from which the residues are harvested will be from areas much smaller than the LRA levels used in this study. The method of normalizing the Universal Soil Loss Equation data to the LRA level of detail masks severe erosion problems. Thus, the results of this study should be considered a system for screening areas where crop residue harvesting would be most severe, based on the characteristics of the region. Implementation and best management practices to control and minimize the effects of agricultural erosion and pollution will be required to implement the practice of crop residue harvesting.

The study did not estimate the magnitude of nutrients and biocides associated with the soil particles that would be delivered to the stream during the erosion process. In some cases, these parameters would be more citical to water quality than erosion or suspended solids. The unavailability of acceptable sediment delivery ratios precludes the estimations of these parameters in the study.

Biological Oxygen Demand (BOD). The BOD contributed from solar type technologies is projected to originate from energy conversion facilities such as low Btu gas from municipal sludge, municipal solid waste and wood; ethanol from corn, wheat, and wood molasses; and methanol from wood. These technologies would produce a total of 2,8,460 tons of BOD per year. The projected data on a federal region basis was presented in Figure 4.6. None of the 10 regions would receive more than 20 percent of the total solar-derived BOD. The solar-derived BOD in each region would not contribute more than 0 to 3 percent of the total regional BOD.

Suspended Solids. The projected suspended solids loading rates for the 14 Quad case in the year 2000 amount to a national total of 121K tons per year from solar technologies. This is 0.003 percent of the total suspended solids projected in the nation from all economic activities. The solar technologies contributing to suspended solids are the same as those generating BOD. None of the regions are affected by more than 21.5% of the total solar-related suspended solids, for the 14 quad case in the year 2000. The projected data on a federal region basis are shown in Figure 4.7.

Toxic Waste Disposal From Solar Thermal Systems

Solar Thermal Heating and Cooling Systems

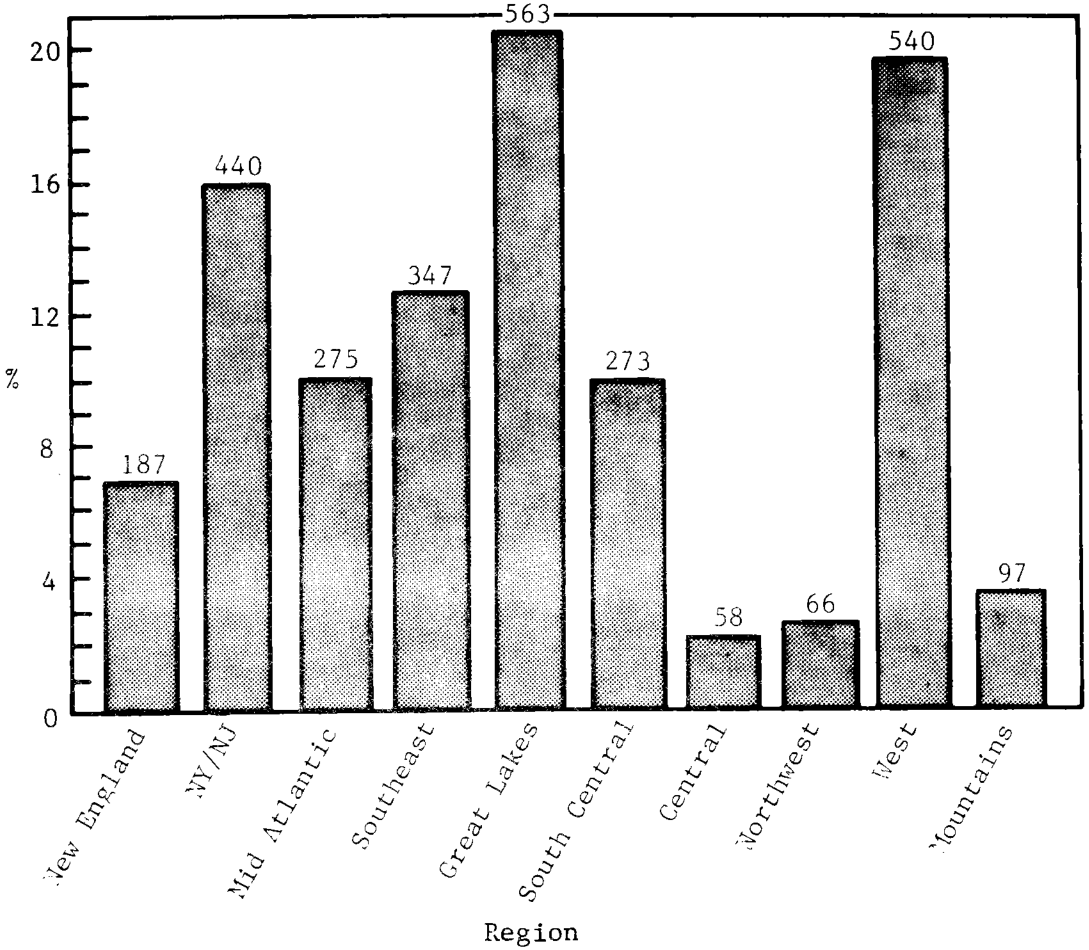
Municipal water quality can be potentially impacted by the discharge of various solar thermal working fluids, which are to be more likely utilized in concentrated urban and suburban areas and at some industrial sites. This section examines the upper limits of working fluid discharges expected from solar heating and cooling systems, and solar industrial process heating systems.

Biochemical Oxygen Demand. In the 14 quad solar case, solar heating and cooling systems would be installed throughout the nation. These systems require an average of one gallon ethylene glycol per 2.72 × 10^6 Btu heating capacity, of which 25 percent of the volume would require treatment for disposal. The material can be degraded biologically to safe end products in an aerobic environment. When the ethylene glycol is discharged to sewage systems and waterways, oxygen in the water is depleted by the material, which has a biochemical oxygen demand (BOD_5) of 0.78 lb/lb of compound. The total oxygen demand (TOD) is the stoichiometrical amount of oxygen required to completely oxidize a substance. BOD_5 is the actual amount of oxygen used in the 5 days under a defined set of conditions to oxidize a substance. Table 4.5 is a summary of the BOD by ethylene glycol over time and compares the BOD with the TOD. An estimated total of 3.9 million tons of BOD_5 would be generated annually according in the 14 quad case. Table 4.7 summarizes the BOD_5 associated with the direct solar heating and cooling

Table 4.5

Ethylene Glycol BOD/TOD Comparison

Time Average	*BOD lb/lb*	*% of TOD*
5-day	0.78	60
10-day	1.06	82
20-day	1.15	89

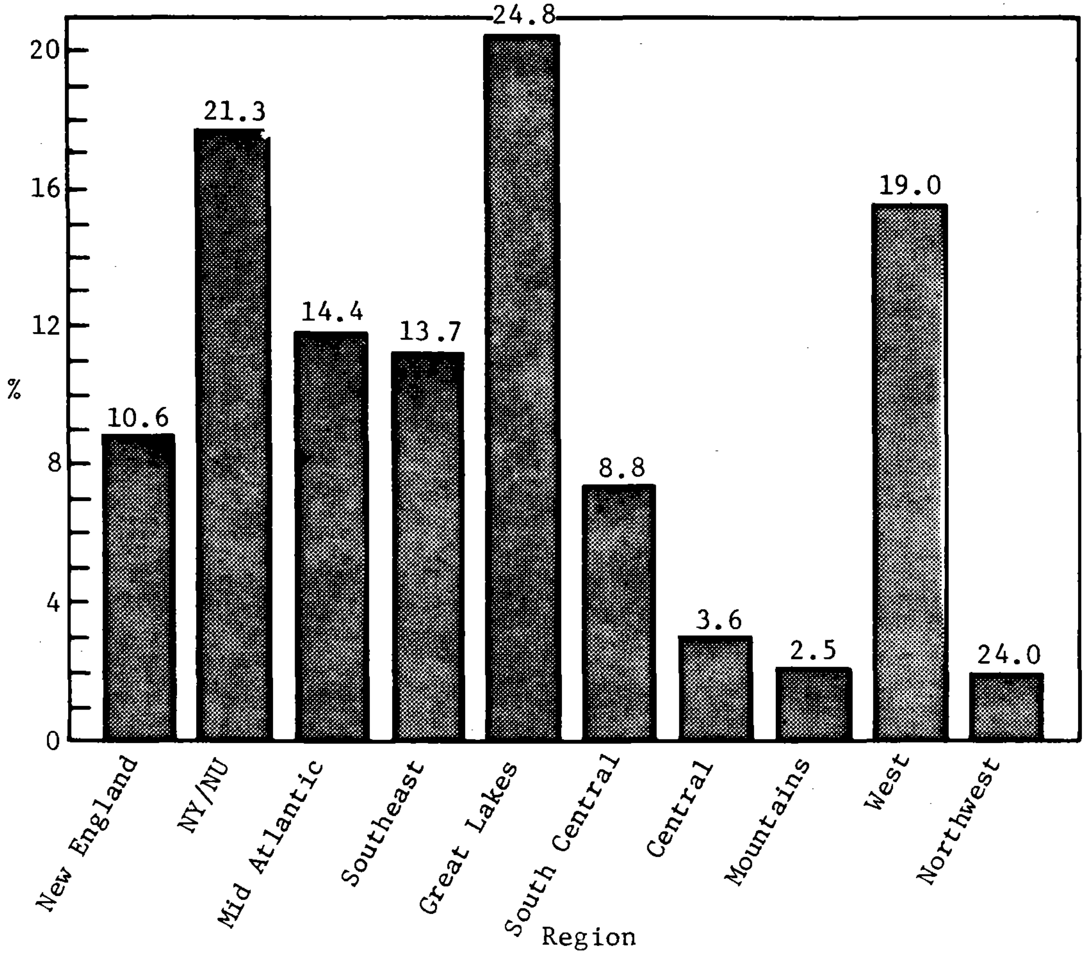


Bar Chart

Numbers in 10^3 tons/year

Figure 4.6

Biological Oxygen Demand From Solar Activities
14 Quad Case
Year 2000



Bar Chart

Numbers in 10^3 tons/year

Figure 4.7
Suspended Solids from Solar Activities
14 Quad Case
Year 2000

systems and low temperature industrial process heating systems using ethylene glycol in the 14 quad scenario.

Chemical Oxygen Demand (COD). The projections of COD generated from solar technologies would originate from disposing of ethylene glycol discharged from the technologies listed in Table 4.6. Of the 317 tons of COD projected from solar activities, no federal region would receive more than 20 percent of the solar related COD (see Figure 4.8) in the year 2000 for the 14 quad case.

Table 4.6

TASE Technology Which Use Ethylene Glycol

Resident Heating (Active)
Residential Heating and Cooling
Domestic Hot Water
Community Hot Water
Low Temperature Process Heat
Medium Temperature Process Heat

Conventional ethylene glycol products on the market are mixtures of the compound and other chemicals which are added primarily to inhibit corrosion in the cooling and heating system. Some of these mixtures contain additives regulated by the Resource Conservation and Recovery Act (PL 94-580); their disposal would be regulated by the law, depending on the volume of coolant. Some of the additives are chromic acid, sodium mercaptobenzothiazole, sodium molybdate, sodium chromate, and ethylenediamine tetra-acetic acid.

Disposal of the mixtures would be required because the quality of the fluids degrade over time. Three possible methods of disposal have been proposed: direct discharge into waterways; wastewater treatment facilities; and burial into soil.

In water, ethylene glycol is considered to be completely biodegradable. Large quantity disposal should not be allowed, however, because of the BOD of the compound and the toxicity of the additives (ethylene glycol is also toxic and fatal to human adults at doses at 100 mg/l).

Although waste water treatment plants provide the oxygen required to reduce the BOD, most facilities also chlorinate their discharge. Intermediate products of ethylene glycol decomposition, such as aldehydes, react with chlorine to form chlorinated hydrocarbons. Chloroacetaldehyde, derived from aldehyde in the presence of chlorine, is a compound listed as hazardous waste by PL 94-580.

Medium and High Temperature Industrial Process Heating and Power Systems

The TASE solar technology baseline includes a medium temperature solar process heating system, a solar-assisted pulp mill, which uses Therminol 66 as a heat transfer medium. Therminol 66 $(C_6H_5)_2C_6H_4)$ is a mixture of terphenyls, whose toxic properties are not well understood. It is estimated that from 4.8×10^8 gallons to 9.7×10^8 gallons of Therminol 66 could be circulating in heat transfer loops by the year 2000 under the TASE scenarios.

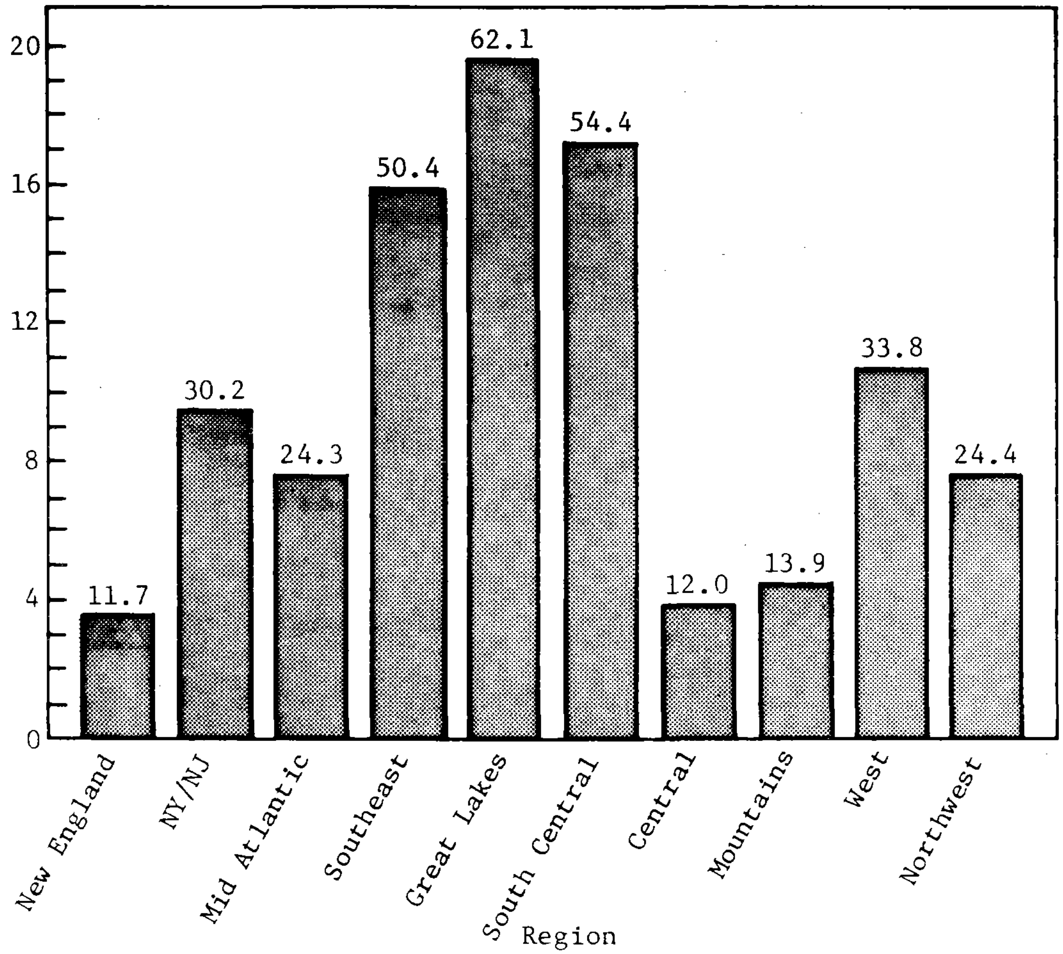
The Industrial Total Energy System characterized in the TASE technology baseline uses DOW-A as both a heat transfer and storage medium. For storage purposes, the DOW-A is mixed with gravel in a 25 percent DOW-A/75 percent gravel mixture. DOW-A is an aromatic hydrocarbon, composed of diphenyl, $C_6H_5C_6H_5$, and diphenyl oxide, $(C_6H_6)_2O$. The lowest lethal dosage of DOW-A, established by tests with rats, is given as 4380 mg/kg of body weight. The system also uses DOW-A in a separate loop. Toluene may be the most troublesome substance associated with any of the TASE solar thermal systems.

Table 4.7.

Potential BOD Impacts of Solar Heating and Cooling Systems and Low Temperature Process Heat Using Ethylene Glycol (TASE High Solar Case)

System Type	*Capacity (10^{12} Btu/yr)*	*Ethylene Glycol (10^3 Tons per Annual 10^{12} Btu Capacity)*	*Volume Discharged Annually* (10^6 gal/yr)*	*Equivalent BOD_5 (10^6 tons/yr)*
Hot water	923	5.8	28.8	1.0
Heating and cooling	463	5.6	13.9	0.5
Active Heating	1,343	8.4	60.6	2.2
Low temperature industrial process heating	203	4.1	4.5	0.2
Total	2,932	23.9	107.8	3.9

* Assumes 1/4 of total volume discharges annually—or a 4 year product life.



Bar Chart

Numbers in 10^7 tons/year

Figure 4.8
Chemical Oxygen Demand from Solar Activities
14 Quad Case
Year 2000

Chapter 5

Water and Land Resource Analysis

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CHAPTER 5

WATER AND LAND RESOURCE ANALYSIS

Introduction

This chapter describes the potential effects on water and land resources from the deployment of solar and biomass technologies in the year 2000. Four major topics were examined:

- water resource impacts
- land use impacts at the community level
- land resource impacts on rural communities
- land use impacts technology focus

Summary and Conclusions

- The study concluded that water availability, under the technological assumptions of the TASE scenarios, is largely unaffected by the switch between solar and conventional energy development.
- The solar energy scenario represents a slight water savings over the displaced conventional technologies; however, this net savings is on the order of tenths of a percent of total projected annual water consumption at the end of this century.
- Potential shortages are possible for certain communities where large concentrations of solar collectors are sited and consume large but periodic quantities of wash water from a municipal supply system. This could cause seasonal problems in municipalities whose water systems are stressed or subject to temporary shortages; however, this problem should be controllable and not constrain local solar penetration.
- If silviculture farms had been included in the scenarios, water use could have been of significant concern on a national and regional basis.
- In the Western United States, increased development of a solar energy base will not create additonal water consumption problems; in fact, solar development should slow the rate of increasing water use for energy-related development.
- In all but the most dense land-use sectors (commercial business districts), communities can meet significantly more on-site energy demand than expected with solar systems with little or no community level environmental impacts. In the residential sector, urban sprawl is not required.
- Local government controls (i.e., solar rights) to increase solar access can have a substantial effect on the total solar contributions from small scale solar energy systems. The total contribution, however, has wide regional variations which is influenced by availability of insolation, technology application, and physical characteristics of the community.
- In areas where increased food production, energy development, and urbanization are expected to occur simultaneously, competition for land for food production could intensify.
- Erosion is the primary adverse rural land use impact of bioconversion.
- If utilized to their maximum potential, the municipal biomass conversion processes could affect existing municipal land use practices. These bioenergy activities, in some instances, will be compatible with or enhance each category of existing land use.

Water Use Impacts

In the early stages of the TASE Project development, there was consideration given to the concept of vast silvicultural plantations, each one covering tens of thousands of acres of irrigated land and feeding a central wood-fired electric generating facility. These energy farms would have required vast quantities of geographically compact land and water. Prior to the actual analysis of the TASE scenarios this concept of "mining biomass" was dropped from the technology file as too extravagant of capital cost and environmental risks. This reduced and dispersed the solar energy related impacts on water and land use to the point of insignificance, on a quantifiable basis.

The existing TASE scenario represents a bioconversion energy base which relies on agricultural and forestry residues, as well as municipal solid wastes and purchases from commercial loggers and private land owners. It is not expected that biomass utilization should affect irrigation water demands, so water availability will not really affect the supply of the biomass resource.

It is entirely possible that water availability may be affected indirectly by increased harvesting of crop and forest residues. Soils stripped of their biomass canopy are more easily eroded. The soil loss from these harvested lands could increase sediment loadings to local reservoirs and thus decrease their expected useful life. Although something is known about the micro-level effects of erosion, the link between on-site soil loss and sediment delivery to down-stream points is unknown. For instance, during periods of high water flow, streams will tend to scour their own channels for silt and gravel; thus, the amount of sediment transported by the stream is not solely determined by contributions from surface runoff. As a stream at high flow picks up sediment, it will tend to slow the velocity of the water and thus reduce the scouring effect. However intransigent the estimation problems, it is well to bear in mind that water availability is affected by water quality, and some degradation of water quality due to increased biomass harvesting must be anticipated. Unfortunately, the magnitude of such an impact, even at an aggregate level, is difficult to estimate.

Calculation of Solar/Biomass Water Consumption

The regional estimates for water consumption by solar technologies were derived and separated into two classes of use:

- *Mandatory water use*—process and cooling cycle water; this quantity of water is assumed to vary directly with energy production.
- *Discretionary water use*—this class of water consumption is made up entirely of water which is assumed to be used to wash the solar collectors. This usage is relatively independent of energy generation, and subject to voluntary control.

The reader should be aware that the water savings projected to occur from displaced conventional utilities is overstated because the conventional technology data base assumes that all utility boilers employ wet cooling towers. This mode of cooling is extremely intensive in its consumption of water and is not expected to achieve such dominance in the utility industry, especially in the West. To estimate discretionary water use values, the square feet of collectors coming on line in each region between the TASE 6 and the TASE 14 scenarios were derived. Given the area of collectors to be washed, each technology was assigned an assumed number of annual washings according to the annual use patterns of the reference system. (Space heating applications, for example, are not washed vigorously in summer months.) A coefficient of one-half gallon per square foot per washing was used uniformly across all collectors.

Mandatory water consumption coefficients were taken from the supporting documents for each technology application. This category involves process water for biomass and municipal waste conversion facilities, cooling water for utility solar thermal and biomass facilities, and coolant loop water for those decentralized solar thermal systems which employ ethylene glycol and water as a heat transfer fluid in the collector loop.

Calculation of Displaced Water Consumption

The water use coefficients used to calculate the water consumption of displaced steam-electric generating plants are described in other TASE documents. One coefficient is used for all coal-, gas-, and oil-fired plants (7.97×10^6 ft^3/10^{12} Btu input) and another for all nuclear plants (10.45×10^6 ft^3/10^{12} Btu input).

Because the water consumption of fossil-fired plants differs from that of nuclear plants, it was necessary to calculate the amount of each type of fuel displaced in each federal region. Substitution vectors for the utility section are described in the detailed report on TASE scenario development. These vectors define the shares of fossil (oil, coal, and gas) and nuclear power displaced in each region.

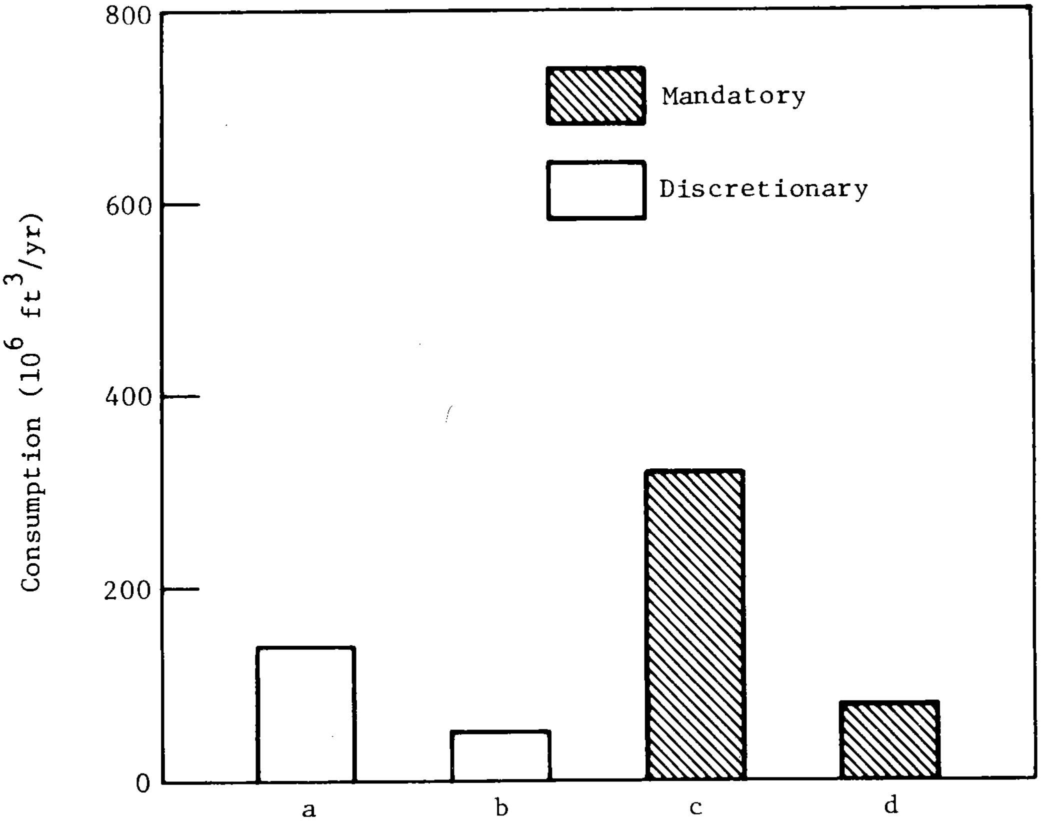
The water uses of the displaced fossil and nuclear sectors in each region were calculated by multiplying the total amount of electricity displaced be appropriate share (fossil or nuclear) and water-use coefficient (fossil or nuclear). The total water consumption of the displaced utilities is the total of the consumption of the two sectors.

Eastern United States

Federal Region 1: New England

The solar energy systems allocated to Federal Region 1 to meet the TASE high solar levels for the year 2000 have a calculated water consumption of 591×10^6 ft^3 year, 1159.9×10^6 ft^3/year less than the conventiona systems they replace. Figure 5.1 shows the consumption of each of the water-using technologies in federa region 1, divided into mandatory and discretionary (washing water) components. This compares the calculated solar energy consumption to the water use of the displaced electric utilities. Eighty-seven percent of the total water consumed is used by urban systems. Slightly over half of the urban consumption is considered discretionary.

Urban areas in Federal Region 1, especially along the densely populated Massachusetts/Rhode Island coastline, have experienced water supply problems during droughts. The TASE high solar case, though showing a net decrease in water use, does emphasize urban technologies in federal region 1. If water consumption shifts from rural power plants to urban systems, some existing supply problems may be aggravated. However decentralized urban technologies have relatively large discretionary and very small mandatory water requirements. Most of the mandatory urban consumption is associated with conversion systems for municipal solid wastes. Such facilities can be sited with regard for the water requirements.



a. Solar Thermal Res/Comm

b. Solar Thermal IPH

c. Municipal Solid Waste

d. Biomass/Wood

Figure 5.1
Consumption of Water Using Technologies—Region 1

Federal Region 2: New York/New Jersey

In Federal Region 2, the solar energy systems used in the TASE high solar case for year 2000 would consume 1138.4 × 10^6 ft^3/year of water, 2170.4 × 10^6 ft^3/year less than the systems they replace. Ninety-seven percent of all the consumption is by systems likely to be located in or near urban areas. Forty-two percent of the urban consumption is considered discretionary, water used for cleaning solar collectors. All rural water use in this region is mandatory. Figure 5.2 shows the yearly water consumption of each water-using solar technology in the region. Figure 5.6 compares the solar consumption, divided into rural, urban, mandatory, and discretionary components, to the consumption of the displaced conventional systems.

In Federal Region 2, the solar technologies displace almost three times as much water consumption as they create, but essentially all of the solar consumption is by urban technologies. Some urban areas in the region, especially in the Delaware River Valley, have had drought related water supply problems. Local conditions may restrict the siting of conversion facilities for municipal solid wastes, the largest urban water users. Decentralized urban facilities are heavily allocated to this region, but their water use, which is mostly discretionary, can be adjusted during periods of short supply.

Federal Region 3: Middle Atlantic

The technologies allocated to Federal Region 3 in the TASE high solar case for the year 2000 have a calculated water consumption of 1344.9 × 10^6 ft^3/year, 306.1 × 10^6 ft^3/year less than the conventional systems they replace. Figure 5.3 Shows the solar water use, by technology, for the region. Figure 5.6 compares use by urban and rural technologies, and their mandatory and discretionary components, to the consumption of the systems they displace. Sixty-five percent of all solar water use is by urban systems; almost half that use is discretionary. Only 17 percent of rural water use is discretionary.

The deployment of solar technologies at the levels shown in the TASE high solar case should have very little effect on water supplies in Federal Region 3. The net difference between the two cases is very small. While some urban areas in the region have experienced water shortages during prolonged drought, mandatory consumption by the urban technologies is a small fraction (less then 1 percent) of the current water consumption in the region, and most of that is used by municipal solid waste systems whose water requirements can be considered in the siting of individual facilities.

Federal Region 4: Southeast

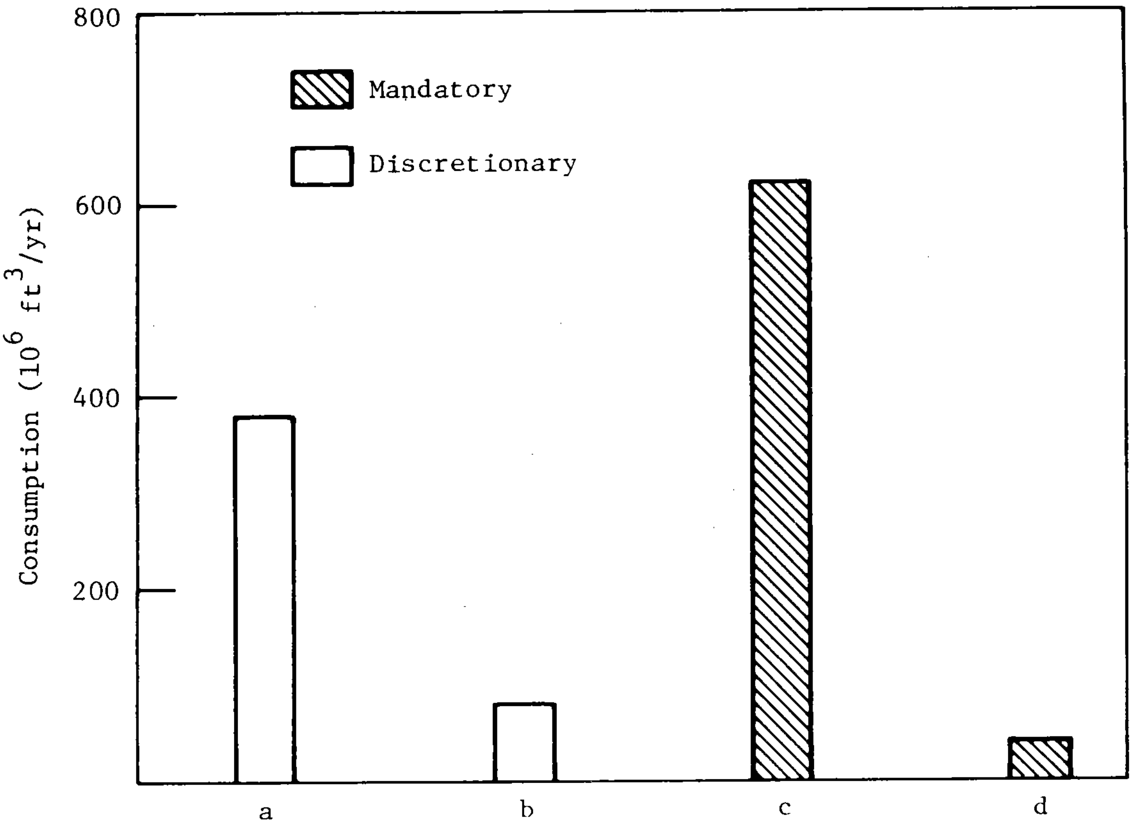
The calculated water consumption of the solar energy systems needed to meet Federal Region 4 allocations in the TASE high solar case is 3648.2 × 10^6 ft^3 year, 748.2 × 10^6 ft^3/year less than the consumptio of the systems they replaced. The solar consumptio is shown, by technology, in Figure 5.4. Figure 5.6 compares the solar consumption, characterized as rural o urban, mandatory or discretionary, with the water us of the displaced conventional thermal electric plants In Federal Region 4, 68 percent of solar consumptio is by systems considered rural. Thirty-two percent o the consumption urban, and more than half of the urban consumption is discretionary wash water.

Though the Southeast is abundantly supplied wit water generally, availability problems have occurre in periods of drought where large cities such as Birmingham, Alabama; Atlanta, Georgia; Charlotte Greenville, and Winston-Salem, North Carolina ar situated inland, away from large river mainstreams Southern Florida, where irrigation is important, als has experienced water supply problems during dry periods. Though water consumption by solar technologie is relatively high in federal region 4, there is a smal total net reduction compared to conventional utilities and the solar substitution should have little effect o water supplies. Very little of the water use falls int the urban and mandatory category that might aggravate existing urban water supply problems. Consumption that is both urban and mandatory is almost totall used by technologies for converting municipal soli waste. Such facilities can be sited with regard for thei water demands. Wood pyrolysis, one major rural an mandatory water use, is unlikely to be important i southern Florida. Solar thermal electric utilities ma be desirable there, but would face the same coolin water supply problems as conventional steam-electri facilities.

Federal Region 5: Great Lakes

The solar energy systems used in the TASE hig solar allocation for Federal Region 5 have a calculate water use of 2281.1 × 10^6 ft^3/year, less than half th 5497.4 × 10^6 ft^3/year consumption of the systems the displace. The water used by each solar technology i shown in Figure 5.5. Other technologies which displac some electricity, but do not use water, contributed to th calculated displacement of electric utility generatio Figure 5.6 compares the consumption of the mandator and discretionary components of solar urban and rura systems to the displaced water use. While 75 percent o solar consumption in this region is urban, more tha half of that urban use is discretionary (wash water).

Water supplies are generally not limited in Federal Region 5, though some urban areas, especially i the densely populated corridor along southwester Lake Michigan, have experienced local water suppl problems in tributary basins. These local problems ma be influence the siting of combustion, incineration, an pyrolysis units for municipal waste, the largest mandatory water consumers in the urban technology ca



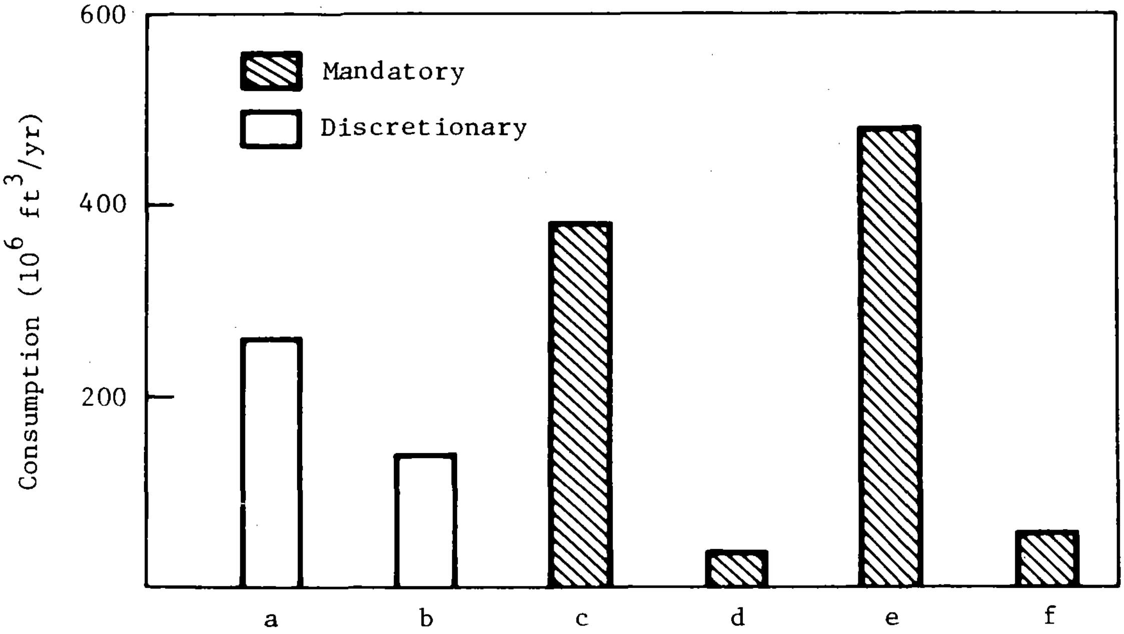
a. Solar Thermal Res/Comm

b. Solar Thermal IPH

c. Municipal Solid Waste

d. Biomass/Wood

Figure 5.2
Consumption of Water Using Technologies—Region 2



a. Solar Thermal Res/Comm

b. Solar Thermal IPH

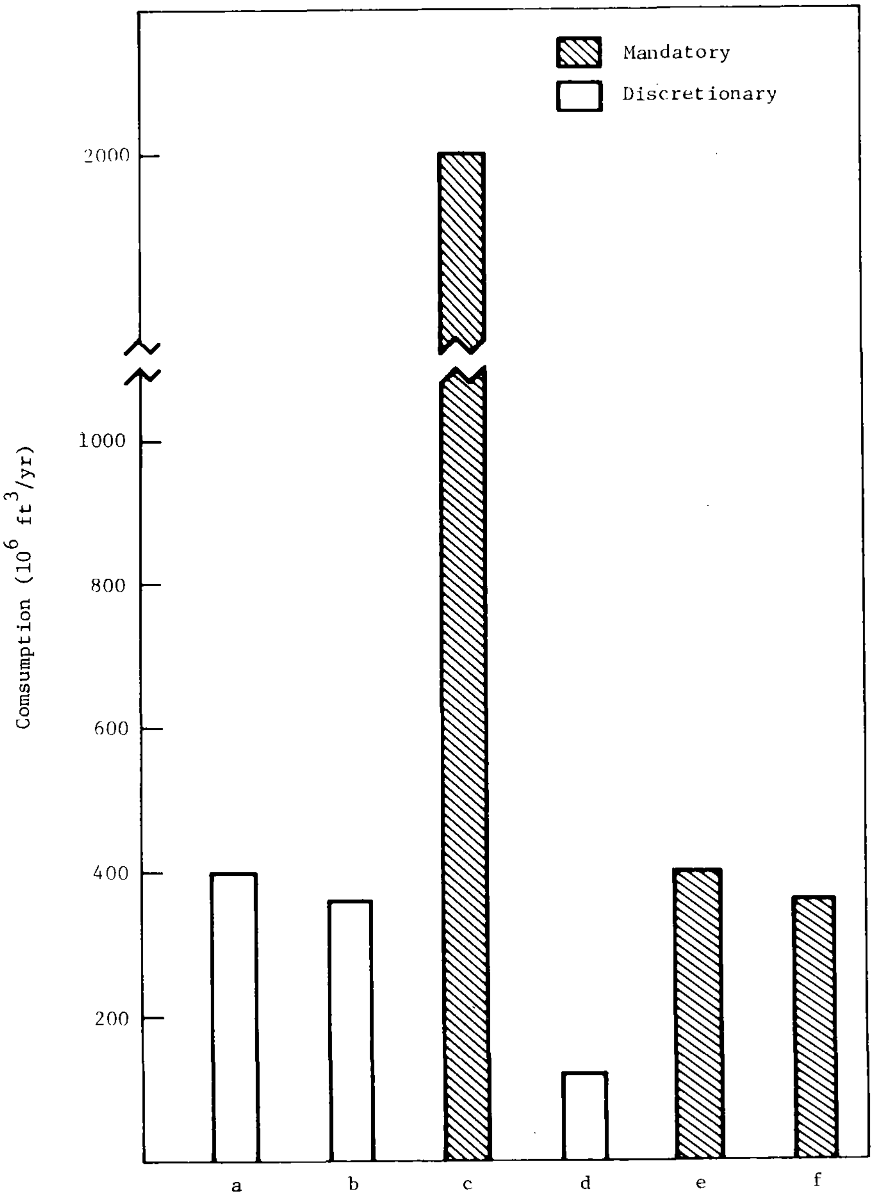
c. Utility Solar Electric

d. Utility Biomass

e. Municipal Solid Waste

f. Biomass/Wood

Figure 5.3
Consumption of Water Using Technologies—Region 3



a. Solar Thermal Res/Comm

b. Solar Thermal IPH

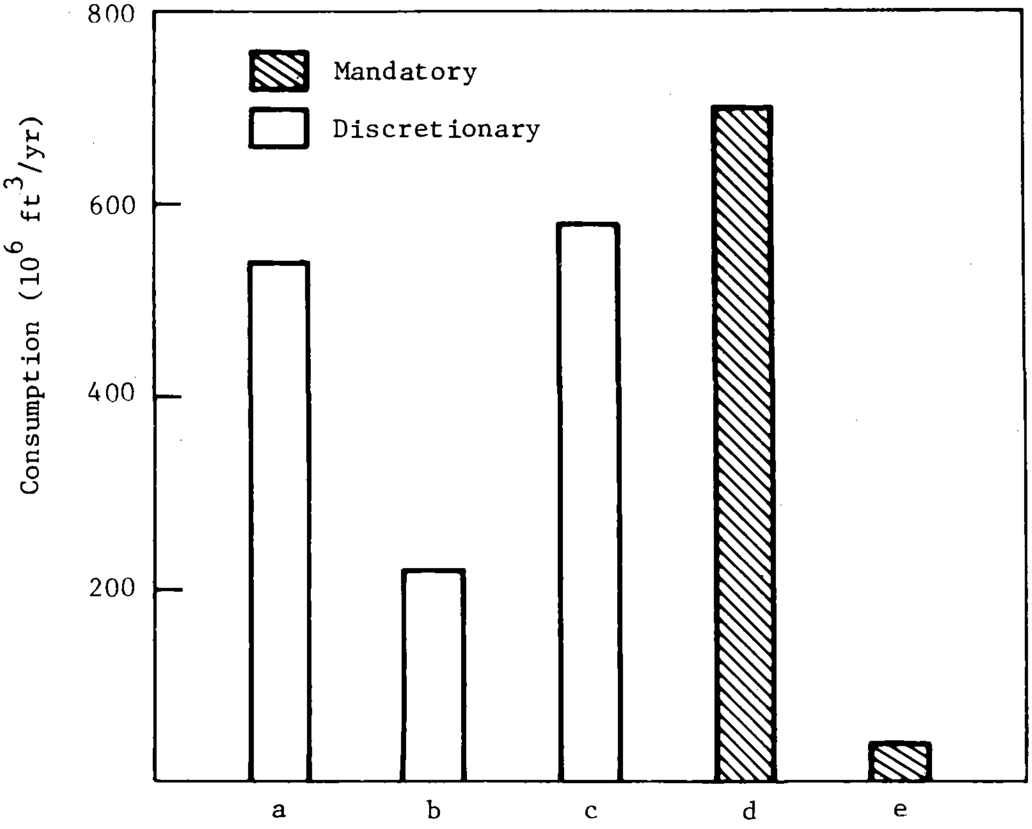
c. Solar Thermal Utility

d. Photovoltaics

e. Municipal Solid Waste

f. Biomass/Wood

Figure 5.4
Consumption of Water Using Technologies—Region 4



a. Solar Thermal Res/Comm

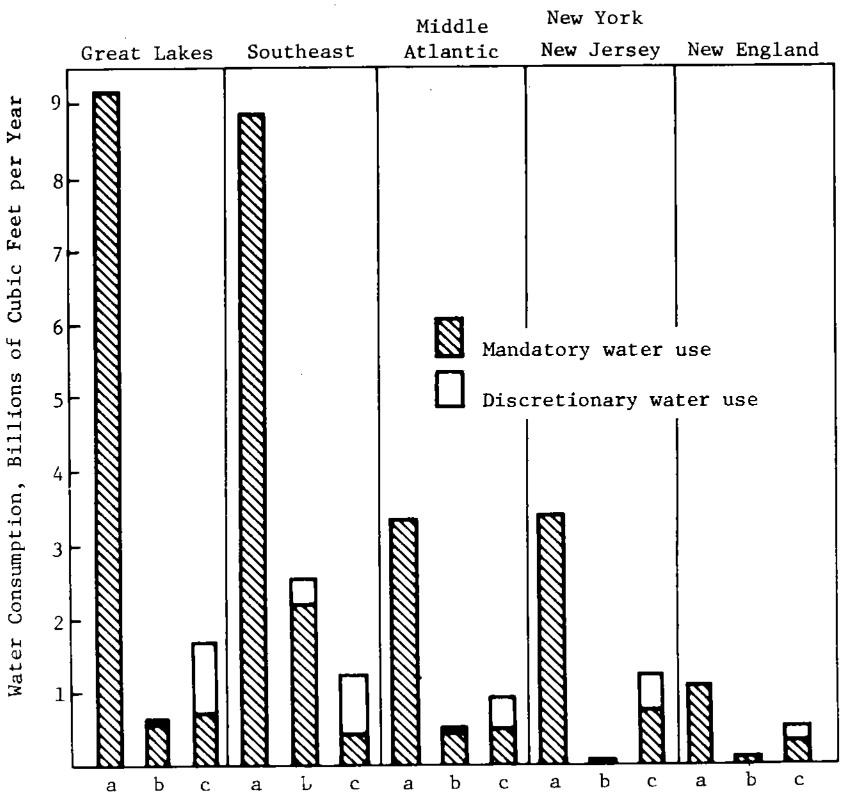
b. Solar Thermal IPH

c. Utility Solar Electric

d. Municipal Waste

e. Biomass/ Wood

Figure 5.5
Consumption of Water Using Technologies—Region 5



a: displaced water consumption from fossil and nuclear fueled utilities

b: rural water use associated with solar/biomass energy systems

c: municipal water use associated with solar/municipal waste conversion systems.

Figure 5.6

Regional water use characteristics of the TASE 2000 solar penetration increment in relation to water savings from displacing conventional energy systems. (Regions 1-5) egory. Discretionary water use associated with residential and commercial solar thermal systems will place some additional demands on municipal supplies, but the mandatory water consumption associated with the systems is negligible. Both the water requirements of the solar systems and the net water use displaced by those systems are small compared to existing water consumption in the region, equal to approximately 1.3 and 1.9 percent of the 1975 consumption by all water users.

Western United States

Between the TASE 6 and the TASE 14 scenarios, the siting of solar/biomass systems and the displacement of conventional facilities led to relatively uniform impacts across the western six federal regions. For this half of the country, solar systems require 10.5 billion cubic feet of water annually, but they are capable of displacing 16.5 billion cubic feet of water use by conventional systems which would otherwise meet the energy load. Slightly more than 25 percent of the water used by the solar/biomass technologies is classified as discretionary water use and could be subjected to active controls (recycling of wash water by industrial applications) and passive controls (reducing the amount of washing during temporary water shortages). Since water is generally a limiting resource to energy development in the West, the solar option would appear somewhat attractive. There is, however an important trade-off between the solar and conventional alternatives: increasing energy reliance on dispersed solar facilities would shift some additional amount of energy related water use onto urban supply systems. About 27 percent (2.8 billion cubic feet per year) of the solar related water use is expected to be supplied from urban water supplies. Of this amount, 66 percent (1.9 billion cubic feet per year) is discretionary consumption and could be curtailed periodically to ease seasonal water supply problems. This problem of increased urban water demand is not as severe as it may appear; for example, Federal Region 6's share of the solar-related urban water use is about 1 billion cubic feet annually. If per capita annual water consumption is assumed to be 8 cubic feet per day, then the incremental urban water use due to solar would be equivalent a 340,000 increase in the region's municipal population. As of the 1970 census, federal region 6 had a population of over 20 million. Clearly, increasing water use by nonrural solar applications is likely to be far less of a planning problem for Sun Belt cities than will be the expected increases in population over the next few decades.

Fully 73 percent of the projected incremental water use by solar systems in the West (7.7 billion cubic feet annually) is projected to occur in rural or remote areas; the bulk of that (6.9 billion cubic feet per year) is classified as mandatory usage. About 95 percent of the total consumption is related to central solar utilities (the rest is consumed for biomass synfuels).

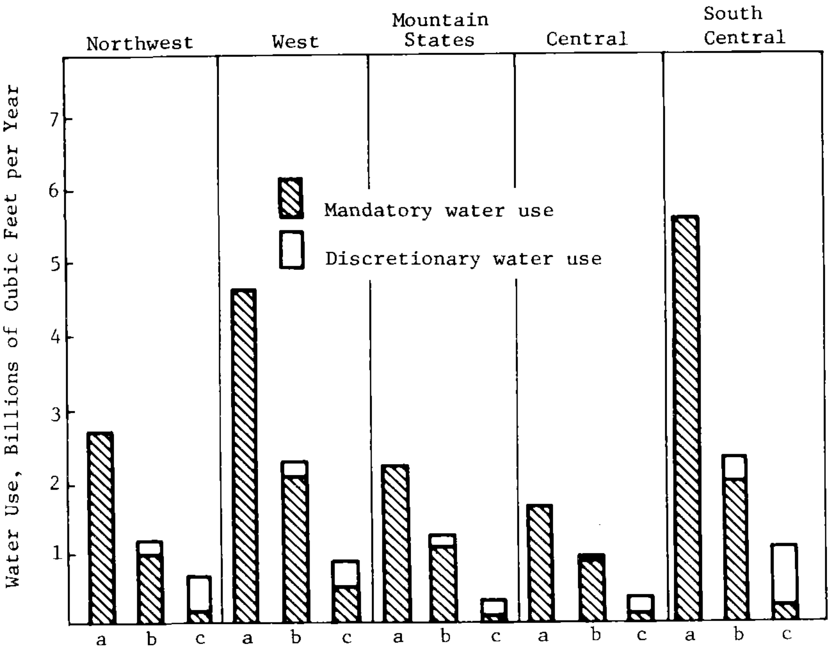
Since that water use which is assumed to be displaced from conventional energy generation is expected to come from nonmunicipal water supplies, competition between energy development and agriculture would be significantly eased. (The incremental water demand by solar in rural areas is half that of the conventional increment.)

Conclusions

In conclusion, it is fair to presume that increased development of a solar energy base in the western United States will not create any additional problems in terms of water consumption. In fact, solar development should help slow the rate of increasing water consumption for energy related activities. The solar option may slightly worsen the competition between municipalities and agriculture for local water supplies; however, this incremental demand appears relatively insignificant compared to the problems many western cities will have meeting the water demands of increasing population.

In the Western United States, the TASE scenarios for the year 2000 define a solar energy increment which would consume an estimated 10.5 billion cubic feet of water per year. This solar increment would, however, displace 16.5 billion cubic feet per year due to the reduction in the number of thermal-electric generating facilities required under the high solar scenario. Since cut in water use is largely caused by the displacement of base load electric plants, it is reasonable to assume that municipal water supplies will not be affected. This may not be strictly true in all cases, since utilization of underground supplies by utilities will incrementally increase the pumping cost to all users of the aquifer; in the Southwest and West (Federal Regions 6 and 9), it is rather common for municipal supplies to be drawn from deep wells. Some cities such as Tucson, Arizona, already have high water extraction costs and considerable subsidence caused by groundwater mining. Along the Texas coast, water withdrawal from fresh-water aquifers sometimes causes salt water intrusion which slowly degrades the water supplies. It is not likely that a utility plant would be sited to jeopardize urban water supplies; nevertheless, utilities in the West will become more reliant upon groundwater resources in the future, and any impacts on this water use will be distributed widely and will be of concern to many users (primarily agriculture).

Figure 5.7 shows the estimated levels of regional solar related water use against the regional values for displaced water consumption from fossil- and nuclear-fueled facilities. All five federal regions in the West were quite similar in their patterns of solar related water comsumption. Figure 5.8 shows the relative percentages of municipal water use as a share of the region's solar related consumption. It is notable that solar energy development in the Western United States is



a: displaced water consumption from fossil and nuclear fueled utilities

b: rural water use associated with solar/biomass energy systems

c: municipal water use associated with solar/municipal waste conversion systems.

Figure 5.7

Regional water use characteristics of the TASE 2000 solar penetration increment in relation to water savings from displacing conventional energy systems. (Regions 6-10)

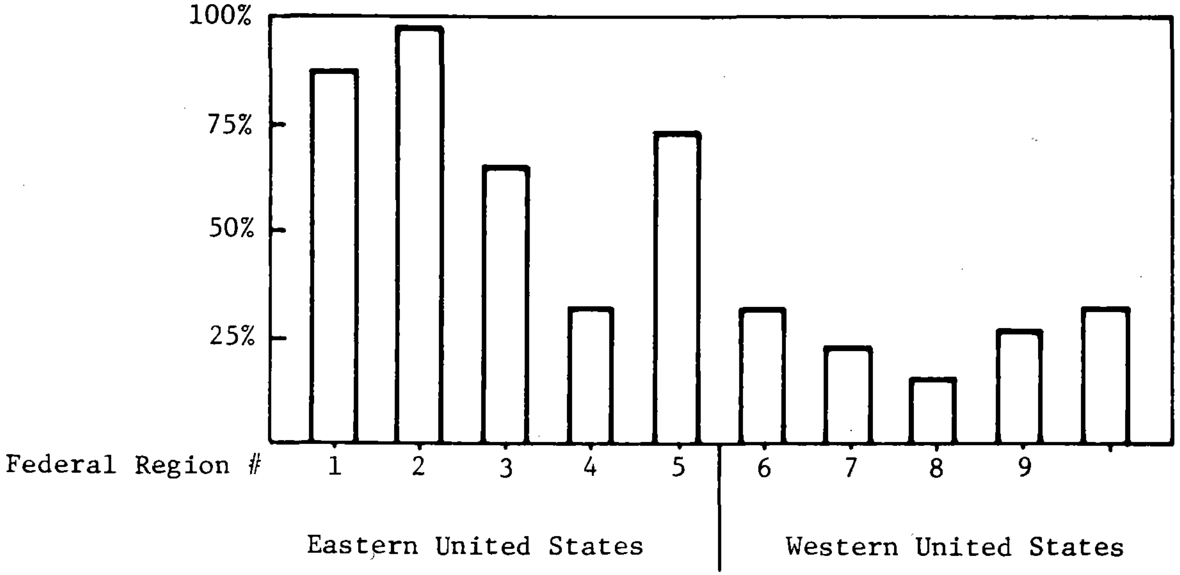


Figure 5.8

Municipal (non-rural) water use burden as a percent of total regional water used by solar-related facilities for TASE 2000.

expected to rely heavily on utility solar thermal conversion facilities; Figure 4 shows that 70 percent or more of the regional water demand for the solar increment is rural. Figure 5.9 displays this relationship.

From 25 to 30 percent of the solar related water use is expected to draw from or compete directly with municipal water supplies. This competition may threaten solar development. To a large degree this measured increase in municipal water demand is classified as discretionary water use (wash water for the solar energy collector arrays) and thus is responsive to controls such as conservation and voluntary curtailment. Figure 5.10 shows the relative split between mandatory and discretionary municipal water demand from increased solar energy penetration. In general, the municipal regions of the West have solar related water consumption patterns dominated by discretionary water use. This will greatly reduce the impact of dispersed solar development on aggravating seasonal water supply problems which are a periodic fact of life in some areas. Aside from the potential for voluntary conservation by individuals, the large industrial solar thermal applications are generally large enough to justify some form of wash water recycling which would greatly reduce the amount of water consumed. Figure 5.11 shows the percentage of discretionary, municipal water use attributable to industrial solar energy applications in the five western federal regions. In the West, industrial solar sytems account for about one-third of the measured discretionary water use in municipal regions. Thus, with a certain amount of conservation, the burden on municipal water systems of dispersed solar energy systems should not aggravate any existing water supply problems.

Land Use Impacts at the Community Level

The objective of this study was to examine the physical, spatial and land use related impacts of decentralized solar technologies applied at the community level by the year 2000. Competition for land and, more specifically, insufficient on-site collector area to achieve a particular level of solar energy supply, influences land use. The results of the study provide a basis for evaluating the way in which a shift toward reliance on decentralized energy technologies may eventually alter community form. The project assumes that the physical form of communities in the year 2000 will resemble today's communities in other respects.

Six land use types representative of those found in most U.S. cities were analyzed according to solar penetration levels for the year 2000:

Residential Sector

1. single family detached dwellings (SFD)
2. multiple family row house apartments (MFD)

Commercial Sector

3. strip development
4. warehouses
5. central business district

Industrial Sector

6. central industrial facilities

The land use types evaluated may be thought of as "energy sensitive land-use patterns," varying with respect to end use demand and land use density characteristics which influence on-site solar supply. Various solar energy supply systems were examined, including solar thermal electric collectors with short-term storage (i.e., two to three day storage) and cogenerating photovoltaics with long-term storage (i.e., between seasons).

The analysis determined the maximum on-site collector area for each land-use type, and the percentage of parcel's total on-site energy demand that can be provided by each technology using this available collector area.

Major Findings of Phase I Study

Assuming a typical land use mix of the land use types studies, a community can achieve the scenario goals for the year 2000 using on-site technologies which meet the current state of art system performance specifications.

Of the individual land use types examined, only the commercial central business district cannot achieve the scenario goal on-site. The deficit in the central business district, however, can be more than offset by the ability of other use types to exceed the solar scenario goals.

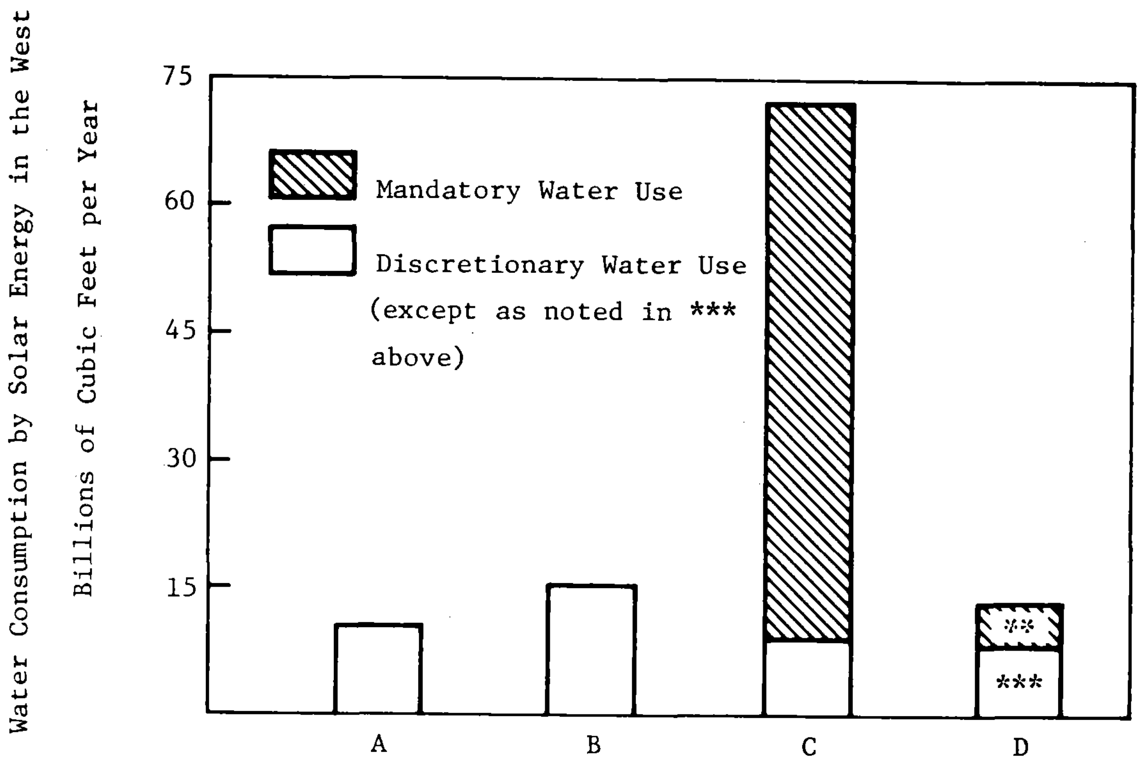
In the residential sector, low density, detached single family development (i.e., urban sprawl) is not required to meet the goals of the solar scenario. Only by using cogenerating photovoltaic systems with long-term storage can detached single family development achieve greater independence from conventional energy than denser residential development patterns.

Central city industrial location could not meet the solar scenario goals using only direct solar technologies: additional renewable resources, e.g., cogeneration, wood, or municipal residues, would be required.

The increased levels of solar energy supply are limited by the quality and availability of energy supplied by a given technology and by the demand for a particular quality of energy within each land use sector. However, decentralized solar technologies can produce substantially greater amounts of on-site energy supply than the DPR scenario projects.

Improvements in on-site energy supply can occur by controlling some of the following elements in land development that affect shading and orientation:

- vegetation
- street, lot, and roof orientation/configuration



A: Residential and commercial solar thermal applications

B: Industrial process energy solar thermal applications

C: Utility applications of solar and biomass powered facilities

D: Non-utility biomass and municipal solid waste conversion plants

**Mandatory processing water use
***Mandatory boiler make-up water use

Figure 5.9

Water Consumption (annual) in the western United States by technology category for TASE solar energy increment in the year 2000.

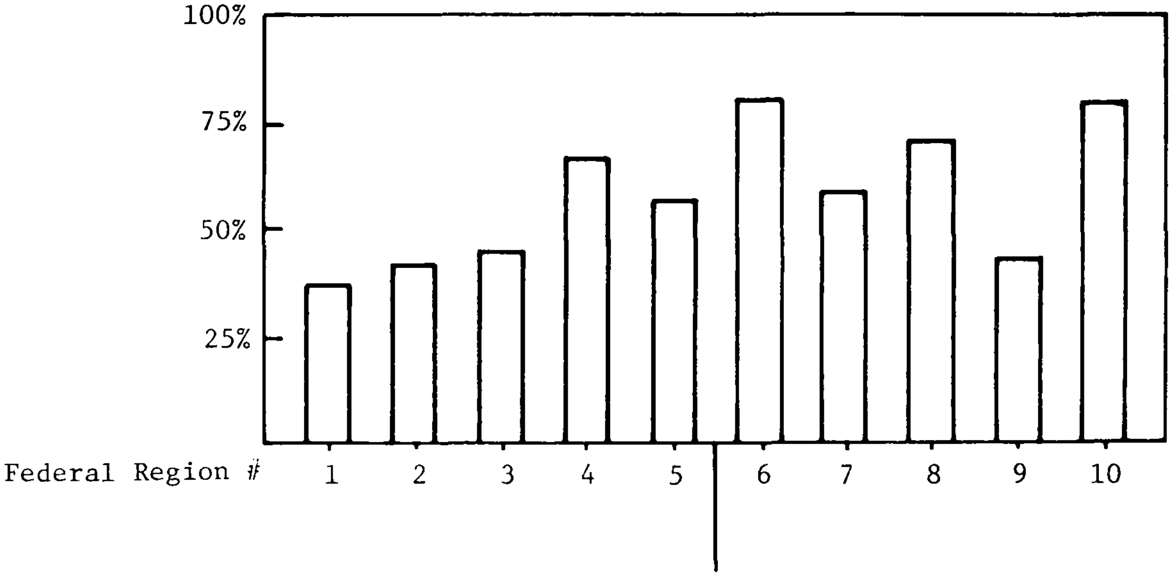


Figure 5.10

Discretionary water use (wash water for solar collector arrays) as a percent of regional municipal water consumption related to increased solar energy penetration in 2000.

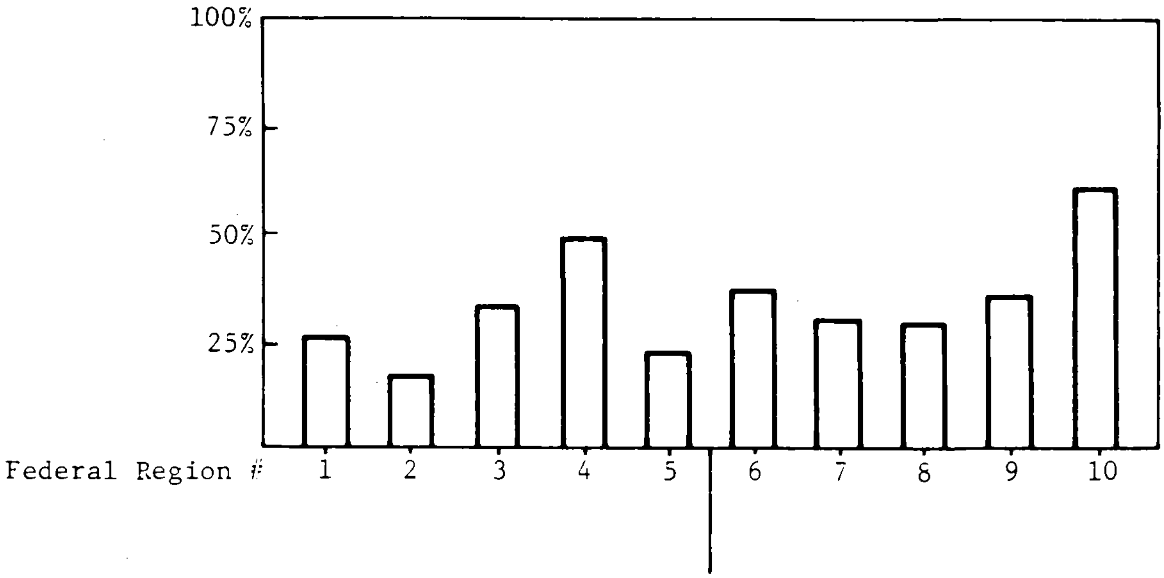


Figure 5.11
Discretionary water use by industrial solar thermal applications as a percent of total municipal, discretionary water use in the given region.

- height of adjacent buildings
- density

The major environmental impact of implementing on-site solar systems will be loss of vegetation. Removal of 15 to 35 percent of the tree canopy will be required to meet the scenario goal in the single family development case.

Approach of Phase II Study

The second phase of this study focused on the interregional and intraregional differences in the potential for on-site solar supply in the residential and industrial land use sectors. Analysis included characterizations of energy demand by region and by types of residence or industry, estimates of conservation, and estimates of the regional distribution of housing prototypes and industrial activity.

Findings -Residential Land Use Sector

The greatest contribution by on-site thermal energy supplies are *not* in the South or West where the solar insolation is the highest. The relatively higher thermal energy demand (even after conservation), together with the substantial existing housing inventory combine to give the north-central region the highest direct solar potential (as well as the greatest potential savings due to conservation) in the U.S. This slightly greater potential of about 25 percent grows even more dramatic if the output of technologies is improved, or if solar access within communities is increased by local government controls for reducing shading from trees or adjacent structures, combining to give the north-central region a 30 to 60 percent greater solar potential.

The West generally has the lowest solar thermal potential despite the high relative supply per unit. The small proportion of the total U.S. inventory in the West, only 17.1 percent in the year 2000, together with a relatively higher proportion of new construction (where conservation potential is greater) combine to overcome the relatively higher per unit solar potential.

The scenario goal for on-site solar supply in the residential sector does not require an increase in the output of conventionally available solar thermal technologies with short-term storage. But it will require the effects of local government to reduce the impacts of tree shading in the single family dwelling component of the housing stock. With maximum efforts by local government *and* improved technology performance, 47.6 percent of the nation's annual end-use demand in the residential sector could be met by on-site thermal technologies in the year 2000.

The potential for currently available technologies to provide solar thermal energy appears to be comparable to the potential reduction in the base demand that can be achieved with conservation. Only in the highest density residential pattern (high-rise multi-family dwelling) is the potential solar contribution consistently less. For the remaining residential patterns, the potential solar contribution is substantial in both existing structures and in projected new construction in all regions of the country.

The South and West enjoy the lowest annual end-use consumption per unit of residential development. With a combination of conservation and local government initiatives to control tree shading, the northeast and north-central regions can actually reduce their unmet energy demand per unit in new construction below that of the South with similar measures. The higher per unit energy demand in existing stock will remain in the north-central and Northeast, but the difference in therms per year can be cut by as much as 50 to 90 percent. It is in the colder climates, with larger heating demands, where solar thermal technologies can make their greater contribution.

Local government controls designed to increase access can have a substantial effect on the total solar potential, increasing the usable solar energy by about 43 percent in the total U.S. residential stock with either currently available technologies or with technologies with double the output. Regionally, this effect varies from a low of a 26 to 27 percent increase in the West to a high of 47 to 54 percent increase in the north-central region due to the implementation of solar access controls. The actual result will depend upon which technology is being used and what the total housing inventory will be in the year 2000.

Doubling the output of solar thermal technologies with short-term storage will increase the solar potential of the U.S. housing stock by 22.7 to 24.5 percent, depending on the amount of new construction. However, the increase varies dramatically by region. The increase in potential in the West could be as low as 1 or 2 percent because of the high insolation rate as well as the low thermal demand. The greatest impact from improved technologies will be in the north-central region, where solar potential could increase by 33 percent.

The amount of annual solar thermal energy supply that can be developed in housing built between 1980 and the year 2000 is only 33 to 67 percent of the amount that could be developed in the existing residential inventory expected to remain to the year 2000.

From 65 to 83 percent of the solar potential in the residential sector in the year 2000 is in the single-family detached component of the housing stock, depending on regional variation in thermal demand, housing characteristics, and technology performance. Because only 38 percent of the U.S. housing stock is projected to be single family dwelling in the year 2000, the contribution from this component is largely the result of the high thermal demand (even after conservation) and the availablity of sufficient roof area to locate collectors on-site.

In each region, the higher density land use pattern will have a lower unmet energy demand, regardless of which technology or which combination of energy saving policies is implemented. Trends show an increase in the proportion of multifamily dwelling units over the next 20 years. Even though this form of construction has less solar potential in comparison to single-family detached housing units, the unmet demand in the entire residential sector, after conservation and the implementation of the maximum solar supply, could be reduced an additional 9.7 to 16.9 percent. Increasing residential density can be seen as an additional policy alternative to solar access controls or improved technologies for producing the net effect of a lowered reliance nonrenewable energy sources.

Findings -Industrial Use Sector

The largest market for industrial solar technology installation is likely to be retrofitting existing plants, because of the slow turnover rate in the industrial sector.

Conservation in major fuel consuming industries which require temperatures far beyond the capability of existing collectors offers the most substantial, near-term option to reduce fossil fuel use. Conservation does not affect land very much, except that new cement industries will be constructed. One such means of conservation in the industrial sector is cogeneration, which has certain land use and environmental implications.

Industrial building design and land use characteristics (flat roofs, development on flat terrain <5 percent slope, and near railway/highway corridors where solar access is available) prove favorable to installation of collectors. The ratio of site to building area, which varies both interregionally and intraregionally, will be a critical determining factor if extra collector area is needed.

Northeast, urban locations are likely to have the most limited site: building area ratio, and thus will benefit most by conservation measures to reduce process demands, especially for industrial processes requiring flat plate collectors.

Performance characteristics for evacuated tubes show the least seasonal and regional variations in comparison to flat plat and parabolic troughs. For industries requiring a temperature rate of less than 350°F, regional location should not limit the solar contribution.

Over 57 percent of food processing energy is consumed in the Northeast and north-central states. Retrofitting existing industries in these regions should enable a large contribution to the solar scenario for the year 2000, especially if evacuated tubes are appropriate for the end use demand, or if the demand for flat plate collectors is seasonal when performance is best in these regions.

The major portion of chemical energy consumption occurs in the South, where there are many opportunities available for solar contribution. Many of this region's industries use processes within temperature ranges of existing collectors.

Land Use Impacts of Bioconversion on Rural Communities

The purpose of this study was to examine land use impacts from bioconversion on rural communities. The bioconversion technologies can be divided into two major categories: biochemical and thermochemical.

Anaerobic digestion and aerobic fermentation are biochemical processes. Each of these converts biomass to a usable energy source through biological pathways which rely on microorganisms as a "catalyst."

Direct combustion and gasification are thermochemical processes. Each of these processes converts the energy contained in woody or cellulosic biomass to heat.

With the exception of aquatic biomass, the feedstocks for the bioconversion technologies originate on the farm or in the forest, and therefore are land intensive. Although the current land use practices in rural areas are amenable to biomass implementation, the realization of a massive rural energy program based on bioconversion would affect existing uses.

Land quality and availability, competition for land with other uses, and the uses or abuses of the land that affect water or air quality will be important issues. In some cases, the impacts will be adverse. For example, if more land must be brought into production to supply grain for alcohol fuel production, a region might have to rely on marginal lands to supply the demand. In regions where class one to class three land is not available and marginal lands are used improperly, erosion will be a threat. Table 5.1 identifies the land capability classes. Erosion can increase silt and sediment in surface water supplies and increases runoff of pesticides and fertilizer.

On the other hand, there may be an opportunity to improve existing environmental conditions. For example, livestock confined in a feedlot excrete manure which in most cases is collected, stockpiled, and allowed to leach into the ground water. If this manure were collected and deposited in a methane digester, the nutrients, protein, and gas could be used as fuel (Schellenbach et al., 1977. The local nonpoint pollution problems inherent in some regions with feedlots would be improved, and the resources recovered and recycled.

The degree and type of damage or opportunity will vary from region to region. Although there are large areas of the U.S. that will have similar qualities, there are vast differences between these areas in farm size, cultivation practices, market condition, land availability and water quality.

Bioenergy production at the local level will create change in existing land use patterns. These changes can be beneficial or detrimental depending upon farm management practices.

TABLE 5.1

Land Capability Classes

Class	*Characteristics*
Land suited for cultivation:	
1	Suited to a wide range of crops; nearly level: low erosion hazard; productive soils; can be intensively cropped; favorable climate.
2	Some limitation on suitable crops; require conservation practices to prevent deterioration or improve air and water relationship within soil.
3	Limitations restrict: (a) amount of clear cultivation; (b) timing of planting, tillage, and harvesting, and (c) choice of crops; require conservation practices more difficult to apply and maintain than those on class II land.
4	May be suited to only two or three common crops; yields may be low in relation to inputs over a long period; management and conservation measures more difficult to apply than for those on class III land.
Land generally not suited for cultivation:	
5	Nearly level; limitations which are impractical to remove may include wetness, frequent overflow, stoniness, climate limitation.
6	Continuing limitations which cannot be corrected may include steep slope, stoniness, severe climate; unusually intensive management necessary if used for common crops.
7	Unsuited for cultivation; impractical to supply pasture improvements or water controls.
8	Cannot be expected to return significant benefits from management for crops, grasses, or trees.

The potential for bioenergy production depends upon the availability of land the existing agricultural infrastructure. Crop residue, crops grown for energy, and the siting of energy facilities will vary with the regional differences in land, water, and existing agriculture.

Land use in the United States can be divided into five broad categories (U.S. Congress, 1975). These categories are production of food and fiber; energy industry and commerce; housing and community; transportation; and finally, recreation and open space.

If deployed to their maximum potential, the technologically available bioenergy conversion processes will affect existing land use practices at the local level. These bioenergy activities, in some instances, will be compatible with or enhance each category of existing land use.

Demand for land to produce alcohol feedstocks will compete with existing uses, which could displace land currently devoted to food and fiber. If corn is the existing product, the benefit in dried distillers grain would actually improve local the protein market (Hertzmark, 1979). Shifts in production may also be needed. For instance, soybeans are not good candidates for alcohol fuel production. If a farmer shifted to corn production there would be a regional loss in protein, since soybeans contain much more protein than corn.

An alternative to crop shifting is increase in land brought into production. The land is, in some cases, available, but quality is an important variable. Any expansion of cropped acreage will expose more land to soil erosion and make it a greater source of nonpoint pollution. As the quality decreases, the danger from pollution and soil degradation increases (Zeimetz, 1979).

Any land practice that exposes soil to erosive forces of wind or rain represents an environmental hazard. The degree of danger depends on soil texture, surface geology, and climate. Finely graveled clay soils are more prone to erosion than sandy soils. Sand soils tend to absorb water, where clay soils are easily suspended and carried away (Zozogni, 1980). Slope/links and slope/gradient, crop management, and frequency and intensity of wind or rain storms are important considerations.

Competition for land for perishable goods will intensify. Food production, energy development, and urbanization cannot occur in the same place at the same time without creating issues. Land prices will escalate.

Concern for the environment has become a major public concern in the past decade. Land is considered as a threatened natural resource. Bioconversion deployment will create a challenge at the local level to maintain renewable energy supply while recognizing dangers inherent to the future of the land.

Whole tree harvesting can disturb water tables terrestrial and aquatic systems. It can degrade the landscape (Carlisle et al., 1979). Aesthetic, cultural, and recreational values of the land can be diminished. Bringing more land into production can also bring about visual degradation; for example, channelizing improves drainage in underdrained fields, but leaves unsightly ditches. By contrast, increase in trees or vegetation on barren land will be an aesthetic improvement.

Clearly, erosion is the primary adverse land use impact from bioconversion. By covering stretches of the hydrographic network (which is the area of greatest flow) with grasses and other water absorbing belts, soil loss can be diminished (Vilenskii, 1957). No-till practices are also a mitigation strategy. Fields can be planted with a grass or sod cover, then killed with herbicide. Crops can be planted directly in this protective cover (Phillips et al., 1980). This no-disturbance alternative to moldboard plow and disk operation (which in contrast make friable and easily transported soil) can virtually eliminate erosion. In the event that residues become so necessary to these communities that marginal land be planted for alcohol crops, then no-tillage practices must be deployed to mitigate erosion potential (Flain, 1979).

Land competition would be less of a problem if the land base were used more effectively. Efforts should be concentrated on waste utilization. Combined cycle systems, such as a fermentation facility, a feedlot, and an agriculture operation, can reduce transport cost and use the existing land base more intensively. Cattle can be fed distillers grain mixed with stover (the manure harvested for methane). The wastewater lagoons could produce algae or fish.

The energy potential from biomass is a promising resource and the conversion technologies are available; however, the potential to affect the use of land exists. Since there are a number of constraints to development, existing energy needs must be matched with this potential.

Solar Energy Land Use Impacts: A Technology Perspective

Land in the legal sense is the natural environment and all its attributes within which all production takes place. Mineral, soil, air, water, and biotic resources are tied together in the general context of land. As noted, land use in the United States may be divided into five broad categories: production of food and fiber; energy, industry, and commerce; housing and community; transportation; and, finally, recreation and open space. Almost any geographic region of the country will exhibit vast differences in the scope of land uses. For example, farm size, cultivation practices, market conditions and availability of land due to competing land uses will vary tremendously from one agricultural region to the next. One national level assumption of acreage where land is treated as a uniform quantity and dealt with in an accounting framework is a misleading analytical approach. Land simply cannot be compared in isolation from its local environment as can other resources with more uniform characteristics.

In the early stages of the TASE scenario development, the concept was proposed of vast silvicultural plantations which encompassed tens of thousands of acres of contiguous lands. This implied concentrated land use impacts, that is, several large land use "hot spots" in various parts of the U.S. Due to resource limitations and the implications of concentrated environmental degradation, this concept was dropped by DOE. Instead, residues and wastes from land already in production were assumed to be collected for energy production. The land use impacts are therefore related to the effects of residue removal and not to effect of increased competition for land.

The current assumptions in TASE relating to biomass supplies imply very dispersed land use issues such that the impacts could only be resolved on a county by county basis. Furthermore, many of the adverse local land use impacts associated with the TASE biomass technologies could be eliminated or greatly reduced by scaling down the size of the systems. However, the larger number of smaller systems required will impact more localities. The following discussion presents some of the land use related impacts of the different classes of solar energy systems.

Solar Thermal Collectors (Space, Water, and Industrial Process Heat Applications

These systems range from small (30 to 50 square feet) collectors to vast arrays covering an area of several city blocks. These solar energy applications are not expected to cause any significant land use impacts, with the possible exception of zoning ordinances which might serve to protect an individual's access to solar insolation. In general, the systems in this category will be roof mounted arrays; in the case of large industrial applications where the roof area my be indequate or unsuitable, an area adjacent to the plant would be required (such as over a parking lot or storage yard). In either case, the impact to local use patterns should be trivial; since the collectors need to be sited at the point of energy use, a firm or individual either has a place to put a collector or it considers an alternative energy source. It seems most likely that industrial applications of solar thermal energy systems will generally be sited over an area which encompasses an activity which would be necessary in the operation of the firm regardles of the chosen source of process heat.

Wind Energy Conversion Systems

The TASE scenario considers 1.6 million small (15 kW) and 38 thousand large (1.5 MW) wind turbines.

The smaller system is designed for residential and light industrial applications and would likely be built very close to the point of electric demand (thus minimizing transmission distances and line-loss). In this sense, the small wind systems would be applicable where existing space allowed the erection of a tower without endangering adjacent property in the event of the system falling down.

The large wind turbines are assumed to be suited to utility applications and the site would require about half an acre per system plus any right-of-ways for transmission lines and service roads. Wind systems siting is highly dependent on the availability of favorable wind regimes, i.e., lake and ocean shores and mountains. Most of these areas are either occupied or dedicated to recreation or open space, and thus there would likely emerge significant land use conflicts due to the proposed siting of a WECS. These large applications will also require a safety zone around them which is free from buildings or public thorough fares in the event that a blade might break loose and be thrown from the turbine. These safety zones may encompass about eight to ten acres per system; however, they would still be suitable for applications such as agriculture or forestry. Since it is typical for utilities to site power plants in areas of low population density, it does not seem likely that the introduction of central wind systems will alter the pattern of land acquistion by the utilities.

Central Solar Electric Facilities

This set of technologies includes both photovoltaic and solar-powered, steam-electric facilities, both of which require rather large collector fields. On an output energy basis, these central solar systems utilize considerably more land area than a comparably sized conventional generating plant.

Municipal Waste Conversion Facilities

The fact must be taken into account that if municipal waste is not used as an energy source, it must be disposed of by other means such as incineration and landfilling. The study accounts for the land area required by the conversion facility itself, but does not consider the benefits of reducing the area otherwise necessary for waste disposal. This is highly site specific and related to local waste disposal practices, and this is not amenable to meaningful analysis.

Biomass Conversion Facilities

The biomass scenario considered in the TASE Project consists of large central biomass conversion plants. All biomass fuels are assumed to be residues or byproducts of agriculture and forestry activities and are further assumed to be purchased at the plant door or in cogeneration with a residue of the pulp and paper process. Thus, no land is explicitly committed to the production of biomass fuels because the TASE biomass technologies use the waste product of food and fiber production. If the scenario had, for instance, included grain fermentation technologies for the production of fuel alcohol, the land use impacts would be discernible since a primary agricultural product with many competing uses would be consumed for energy production and some amount of farmland would have to be assumed as "committed" to the biomass fuel cycle. Thus, the biomass element of the TASE scenario can have significant land use impacts :

1) The wood gasification plant consumes 1275 tons per day (50 percent moisture) of wood, all of which is assumed to be purchased at the plant from private concerns and individuals. This implies the possibility of many light-and medium-duty trucks (one to six tons) as well as large tractor trailers converging on the plant every day. This would tend to cause major traffic congestion problems for area residents (the low Btu content of the gas requires that it be produced within a few miles of its ultimate users). Furthermore, since no stipulation is made concerning tree harvesting practices of the suppliers, it is impossible to assume a level of degradation to public or private forest lands.
2) The anaerobic digestion technology for animal manure requires 750 tons per day of raw manure, all of which is assumed to be bought at the plant from individual farmers. The potential impacts resulting from the transport of this amount of a rather unsavory substance over public roads and possibly through residential areas are disconcerting. Furthermore, it is likely that the trucks would have to travel fully loaded in both directions since 60 percent of the incoming manure (by weight) would be a waste product of digestion and would probably be returned to the farms for disposal as fertilizer. Possible health and property effects caused by accidents or carelessness in the transportation of these large daily quantities of raw manure are certain to block such centralized systems in many livestock areas. An examination of the feasibility of on-farm generation of electricity from anaerobic digestion of manure indicates that the technology could be economically attractive at current costs. Thus, it appears that emphasis on anaerobic digestion technologies which eliminate or minimize the transportation of the manure feedstock would be less hazardous and more practical.

In general, about 50 percent of the biomass energy supplied in the TASE solar increment is derived from large, central facilities (not including cogeneration from pulp and paper process wastes). With the assumption concerning decentralized biomass supplies, the transportation impacts loom large when discussing land use. Resource areas, particularly forest lands, will suffer from increased truck traffic both on and off the road. As well, the size and capabilities of the transporters will range from pick-up trucks to tractor trailers smaller vehicles should be presumed to be loaded at, or beyond, their designed load-carrying capacity. This sort of local situation poses significant risks to life and property along the major supply routes.

It should be apparent that any recognizable land use impacts resulting from solar energy development will probably stem from the biomass component. It must be remembered that biomass is a fuel and as such is a renewable local resource as long as demand does not exceed the level of sustainable supply. Since biomass in its crude state has a low energy value per pound, minimum transportation costs imply maximum value of the resource. This means that large biomass facilities can be surrounded by areas of excess demand and the attendant impacts of resource overutilization. Any such impacts could be averted by local planning. In the absence of any planning, localities could surpass an "impact threshold" where sustainable harvest rates are exceeded over a certain area and the quality and appearance of the land would be degraded. The biomass siting analysis done by TASE was oriented towards assuring that the demand for a certain biomass resource did not exceed "practical" limits at least at the county level. The land use impacts related to the biomass scenario are more a function of the size of the reference technology and not the type of conversion process itself. A greater reliance on decentralized technologies would tend to reduce the likelihood of surpassing a local impact threshold if they are widely dispersed. However, this will tend to increase the overall area impacted by biomass collection and the number of localities impacted by associated biomass transportation and conversion.

The land use assessment was based on case studies of integrated biomass energy plans for fifteen agricultural regions. The existing cropping patterns were identified from local extension data, and the total amount of residues available (and in some instances the amount of additional land which could be brought into production) were used to determine sustainable supplies of biomass feedstocks. The substance of the work focused on identifying localized bioenergy potential and the associated land use issues which would otherwise have escaped attention if the analysis were based only on an aggregated set of national level assumptions.

Chapter 6

Indirect Emissions Analysis

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CHAPTER 6

INDIRECT EMISSIONS ANALYSIS

Introduction

This section describes the key issues related to both the indirect economic and environmental consequences arising from solar energy development.

Summary and Conclusions

- The indirect residuals of both solar and conventional energy development largely depend on the level of investment, and are quite insensitive to the precise set of industries stimulated by that investment. This generalization seems to hold well for all residuals except water pollutants, and all technologies except photovoltaics.
- Photovoltaic systems have significantly larger levels of indirect residuals per dollar of investment than any other technology considered, largely because of the very high input of electricity (and its attendant generating residuals) required by the manufacturing process. In fact, the indirect SO_x emissions resulting from the deployment of 1 trillion Btu's (fossil fuel equivalent basis) of dispersed photovoltaics would be approximately 10,000 tons. To put this figure in some perspective, a coal-fired utility of comparable energy output and in compliance with all projected SO_x emission regulations would only generate 500 tons of SO_x per year. Thus, it is possible that the manufacturing of photovoltaic systems could create more pollution than it would displace.
- Aside from photovoltaics, it generally appears that the indirect residuals resulting from an enhanced rate of solar energy development should not be significantly different from the indirect residuals associated with a conventional energy path. The results do imply that there may be a slight environmental penalty associated with industry-related emissions of particulates, carbon monoxide and industrial sludges. The magnitude of this penalty, however, does not appear to be very significant with respect to operating residuals from conventional energy soures. This conclusion results from the basic premise that the level of investment in solar technologies in excess of their conventional counterparts will be equaled by a decrease in consumption/investment in other areas of the economy (which will displace their indirect residual attributes). It should be noted that this is an area which deserves further study, since the nature and timing of such displaced consumption will greatly affect the resultant net indirect impacts to the environment as well as the economy.
- While the year 2000 indirect residuals appear relatively small, the significance of indirect impacts in general will be dependent on the *growth rates* of the most materials intensive solar technologies.
- Because significant solar growth begins only after several years before the analysis year, rapidly increasing indirect residual growth rates through and after the year 2000 could lead to significant local pollution problems, particularly in areas where industrial growth occurs to meet solar manufacturing requirements. This outcome can be greatly affected by national solar policy and goals during the late 1990s and first years of the 21st century, and by the magnitude of imported finished metal products for use in solar systems.

Purpose and Scope

The first area of analysis focused on the determination of the net environmental impacts of substituting renewable energy forms for conventional and other nonrenewable sources. In particular, given a baseline forecast of the economy and the environment to the year 2000, the assumption of further penetration of solar energy technologies have two compensating factors which must be analyzed. The first arises from the requirement to produce materials such as glass, steel, and copper to construct solar facilities. This leads to an increase in the emissions of pollutants. However, the penetration of solar energy is also accompanied by the need for less capacity in the technologies which it is replacing (primarily nuclear and fossil fuel related facilities). This tends to reduce the emissions in other supplying sectors. The *net* indirect environmental effect of these capital expenditure changes is a key issue addressed in this study.

The second area of analysis deals with broader macro-level adjustments that are likely to characterize an economy moving toward increased reliance on renewable energy. In addition to the substitutions described above, there are likely to be changes in the overall composition of final demand. In particular, the increase in total capital expenditures from a shift toward solar energy may be accompanied by a reduction in other compenents of final demand. There is no conclusive evidence to suggest that a scenario representing more solar energy should have a level of GNP (i.e., total final demand) different from a baseline scenario. In our scenarios, the level of GNP was projected to increase over time, but was held constant across scenarios. The increase in solar energy, as noted, causes higher aggregate levels of expenditures. For a given GNP projection, compensating effects could take place in any other components of final demand. To simplify analysis, and because of resource limitations, we have attempted to assess the single case where reductions in personal consumption expenditures make way for the additional resources needed to meet the capital requirements of a scenario with higher levels of solar energy. The net indirect environmental effects of these two compensating factors is the key concern here.

Each issue addressed here represents a part of the overall concern with the environmental consequences of renewable energy. Together, they present a generally comprehensive view.

Approach

This section provides a brief summary of the methods used. The issues and objectives stated in the previous section were addressed by a set of analytical techniques that combined engineering information on the capital cost of developing alternative energy technologies with input-output methods and environmental data bases to estimate relevant indirect environmental impacts.

SEAS provided the general framework for the analysis. Several components of the overall system were isolated for the analysis reported here. Some key inputs—technology characterization and capital cost estimation—were developed outside the model.

As a first step, analysis of the indirect environmental impact of constructing alternative energy technologies required specification of the quantities of various materials such as steel, glass, and fabricated metals, as well as services such as trade and transportation that are needed to put the technology "in place."

Environmental impacts are not just the result of production of steel, glass and other materials used in energy facilities, but are also caused by a whole range of higher-order impacts, for example, the use of electricity to produce steel, coal to produce electricity and so on. Input-output methods are ideally suited for this type of analysis used in the second step. They calculate the total amount of input needed from each sector o the economy to produce a given "bill-of-goods." The bill of-goods in the present example is the set of materia requirements physically in place at the energy site Production of this bill-of-goods triggers all the indirec impacts calculated with the input-output model.

The final step in the analysis was converting these economic impacts into environmental impacts. The SEAS model provided the necessary "residual coefficients" to measure the amount of a given pollutan (e.g., SO_x, BOD) emitted per unit of activity in each sector of the economy. Conversion of output impacts to emission impacts thus involved a simple multiplication of two vectors. It is important to note that, like the production techniques represented in the input-output matrix, these residual coefficients do vary over time Two factors are primarily responsible for this: first, the assumption that all sectors will comply with relevant environmental standards; second, that changes in process techniques within a sector (e.g., changes in methods for producing aluminum or cement) imply changes in the amount of pollutant emitted per unit of activity While the first factor always has a positive impact on residuals, the latter can have an effect in either direction.

Findings

In general, it would be expected that accelerated solar energy development will have a rather profound effect on the output of American industry. Although biomass and municipal solid waste conversion systems which rely on direct combustion to raise steam or process heat will closely resemble their coal-fired counterparts in utility and industry applications, direct solar and wind energy conversion systems represent a radical departure from the general "materials requirements" of the conventional energy systems. For example, the TASE solar increment (8.2 quadrillion Btu's over fifteen years) will require an estimated 400 square miles of plate glass (about as much as the windows of 4 million single family residences). This solar related glass requirement is about 750 times the direct glass requirement of the base case scenario. In addition to the difference in direct material requirements, it must be remembered that the high solar case carries a far larger capital cost burden than a more conventional energy path. In terms of energy investment alone, the solar increment is 2-1/2 to 3 times more expensive than the corresponding conventional increment. The net capital investment required by the increased shift to solar energy (net of the displaced capital requirement of the TASE conventional energy increment) approaches $12 billion on an annual basis; this runs close to 1 percent of projected GNP.

One central assumption to the derivation of an estimate of net indirect environmental impacts of solar energy development is the assumption that GNP will not be affected by shifting available capital to solar energy investment. If capital is invested more intensively in solar energy development, additional capital will have to arise from displaced investment and/or consumption elsewhere in the economy. There are several different sectors of GNP which would be expected to contribute some of the additional solar investment capital: government (through tax credits or direct subsidies); private investment (industrial plant and equipment); and personal consumption (consumer durables and nondurables). Due to the limited scope of this task, it was not feasible to examine more than one such investment/consumption scenario. Thus personal consumption expenditures (PCE) was selected as the proxy for other displaced capital consumption due to increased solar energy investment. This implicitly yields the assumption that government will not alter its position in other sectors of the economy due to any subsidies for the increased solar development rate. Additional burden would probably fall on taxpayers, and PCE might be expected to carry a significant share of the impact.

The input data which describes the various energy conversion systems were scaled so that each reference technology yields a common measure of energy displacement/demand (one trillion Btu's on a fossil fuel equivalent basis). This allows a common basis across the energy conversion systems for a comparison of the indirect residual attributes. By disaggregating the TASE incremental scenario into its constituent technologies, it is possible to better resolve the issues to which any conclusions may be highly sensitive.

Since energy output per system is held constant, it is a simple matter to graphically express each reference technology with respect to its material (capital) cost and the resulting industrial pollution by emissions category. Figure 6.1 is a map of capital costs versus SO_x emissions for the generic energy systems considered. It proved infeasible to plot the photovoltaics system on an informative scale with the other technologies; the very high capital costs and the industrial emissions from this system caused it to be out of bounds for meaningful graphics. Due to the rather extreme cost of photovoltaics, the analysis of the indirect residuals for this system will be treated as a special case later in this report. In Figure 6.1, a pronounced linear relationship between capital cost and SO_x emissions is immediately apparent. The precision of this linear relationship suggests that industry-related emissions of SO_x for all energy systems depend upon the level of capital investment and are independent of the material mix of the different systems. The linear response depicted in the figure is not simply a case of spurious correlation of the results, but is a very persistent trend across all residual categories. Figures 6.2 through 6.6 plot capital cost versus emissions for several other different residuals (particulates, NO_x, suspended solids, industrial sludge, and water consumption). The linearity of the results is highly suggestive of an underlying relationship, whereby indirect environmental residuals are sensitive to total investment per system and not the industsrial mix of that investment.

Table 6.1 summarizes the results of a graphic inspection of the simulation results for all residuals considered in the indirect residuals study. The last column of the table rates the relative strength of the linear estimate for each emission.

TABLE 6.1

Correlation of Simulation Results

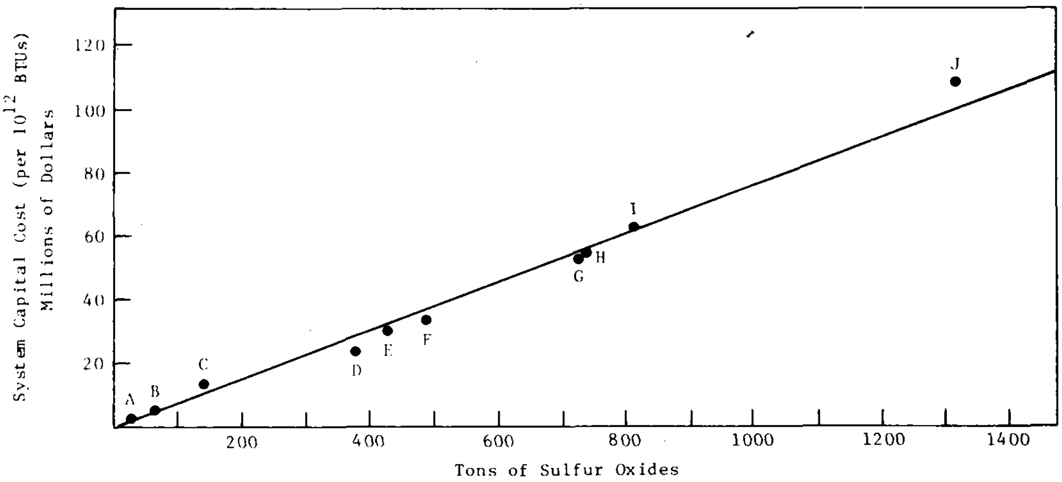
Residual Category	*Residual Classification*	*Apparent Linear Correlation*
AIR POLLUTION	Particulates	strong
	SO_x	very strong
	NO_x	very strong
	Hydrocarbons	very strong
	CO	very strong
WATER POLLUTION	Suspended Solids	weak
	B.O.D.	weak
LAND USE/WASTE DISPOSAL	Industrial Sludge	strong
	N/C Solid Wastes	strong
RESOURCE USE	Water Use	very strong

Only water quality showed an apparently weak correlation with capital cost of the energy technologies. This may indicate a greater sensitivity of water pollutant emissions to the materials mix of the different energy technologies, or it may indicate a weakness in coverage by the residuals data base.

The apparent linear relationship between capital investment and manufacturing related emissions for energy development is significant. If it can be determined that, for most energy related investments, the associated indirect emissions fall along a rather narrow expansion path, then research needs only to search for investments which clearly fall outside the expansion path (as the case with photovoltaics). It should not be presumed that the numerical relationship between investment dollars and indirect emissions exists uniquely anywhere within the model. It is instead an artifact of several assumptions which are driven as if the relationship were an exogenously defined parameter.

The estimated indirect emissions per dollar of investment for all technology classes forms a relatively compact set (compact with respect to the regression line). Such compactness of the indirect residuals set is influenced by three general relationships.

- The characteristic pattern of industrial energy use changes over time. From the mid-1970s to the mid-1980s, the model projects a largely increasing role for fossil fuel consumption. From the mid-1980s through 2000, industrial activity becomes more reliant upon electricity. Thus the share of indirect emissions associated with industrial energy consumption grows significantly



Figure/ Key

A : Aggregated biomass technologies, proportions of different reference systems correspond to the TASE mix.

B : Fluidized Bed, coal fired, utility boiler.

C : Aggregated vector of all conventional technologies displaced by solar energy between TASE 6 and TASE 14.

D : Utility scale central wind energy system.

E : Utility scale central solar thermal facility.

F : Aggregated vector of all solar/biomass facilities which were sited between TASE 6 and TASE 14.

G : Residential/Commercial sector applications of solar thermal heating, cooling and hot water systems. Proportions of each reference technology conform to those in the TASE scenario.

H : Same as "G" however the mix of technologies corresponds to the proportions found in TASE 14.

I : Industrial process heat applications of solar collectors, the vector contains the relative proportions of the three reference systems as found in TASE.

J : Dispersed wind energy conversion systems (residential application).

Figure 6.1

Comparison of Capital Costs and Sulfur Oxide Emissions for Selected Energy Technologies

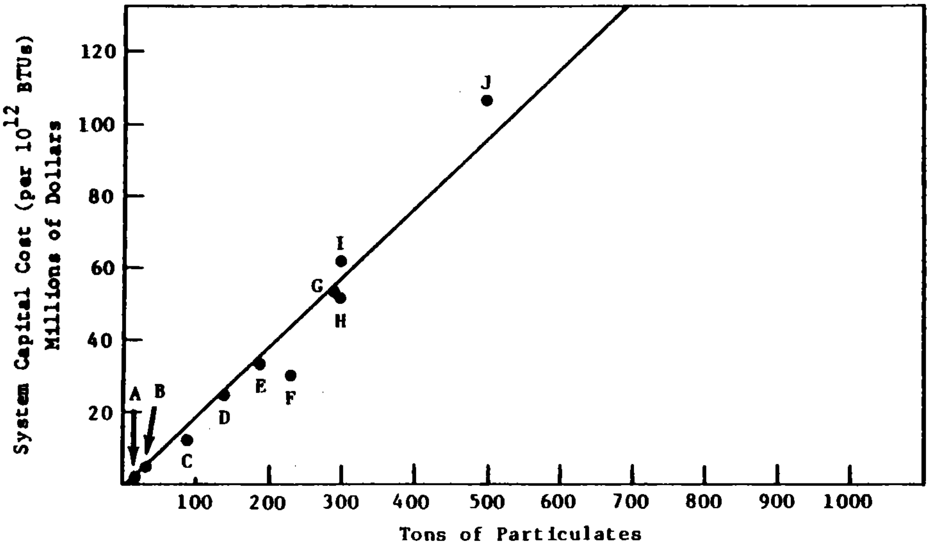


Figure 6.2
Comparison of Capital Costs and Particulate Emissions for Selected Energy Technologies

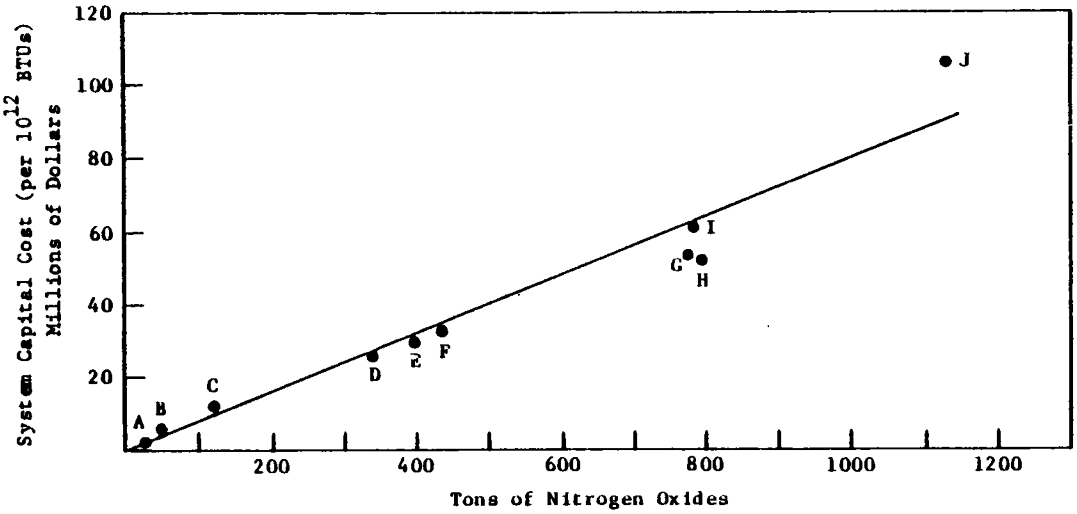


Figure 6.3
Comparison of Capital Costs and Nitrogen Oxide Emissions for Selected Energy Technologies

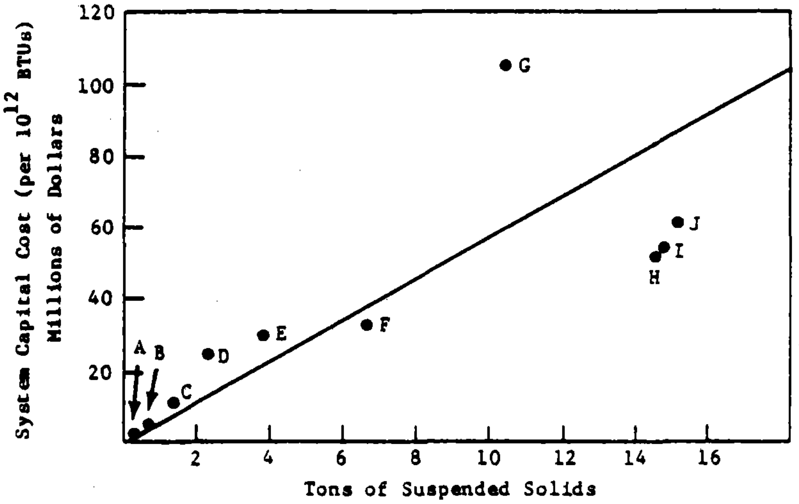


Figure 6.4

Comparison of Capital Costs and Suspended Solids from Selected Energy Technologies

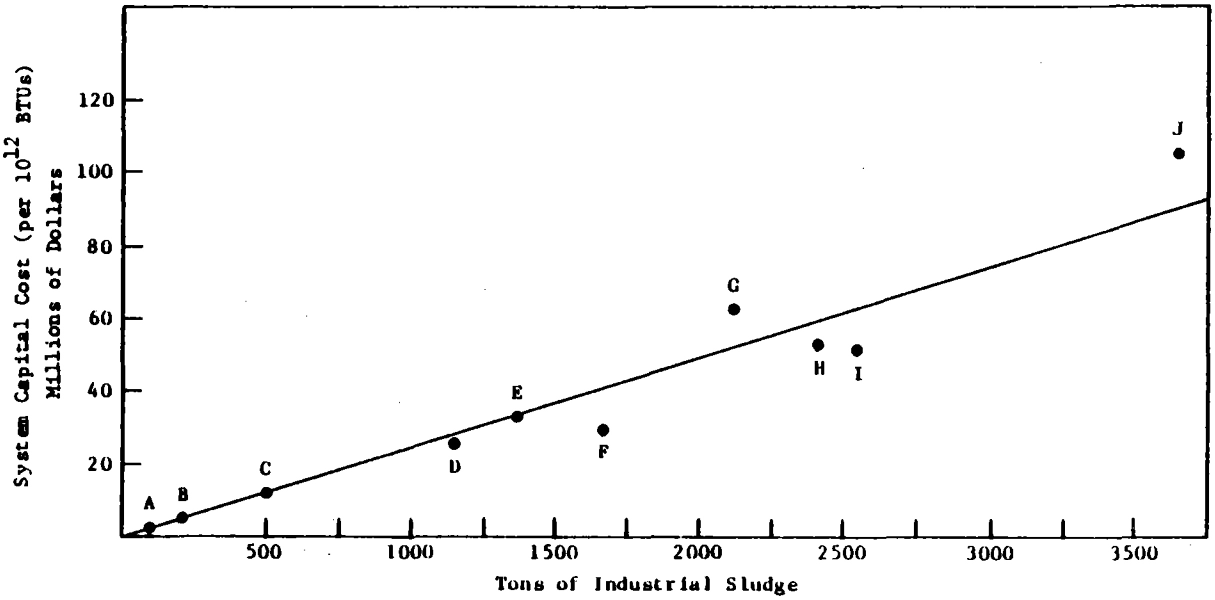


Figure 6.5

Comparison of Capital Costs and Industrial Sludge for Selected Energy Technologies

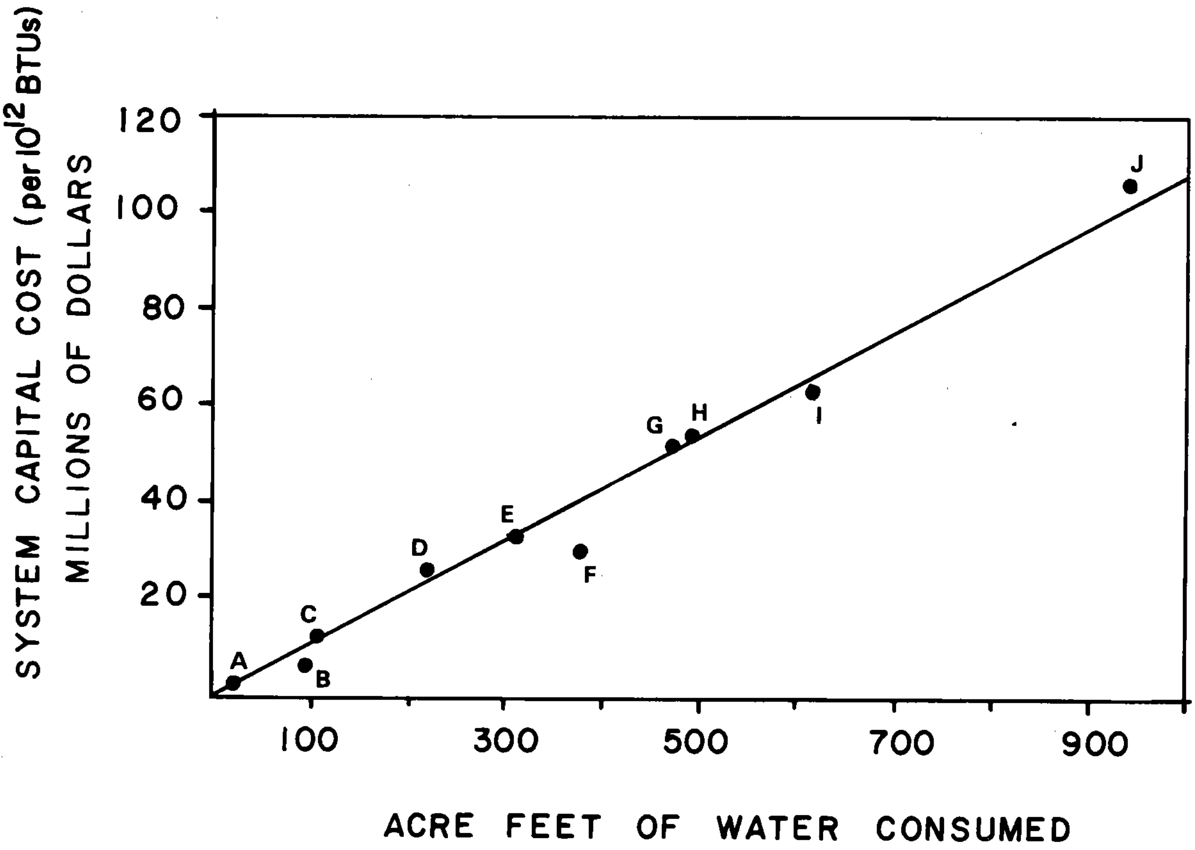


Figure 6.6
Comparison of Capital Costs and Water
Consumption for Selected Energy Technologies

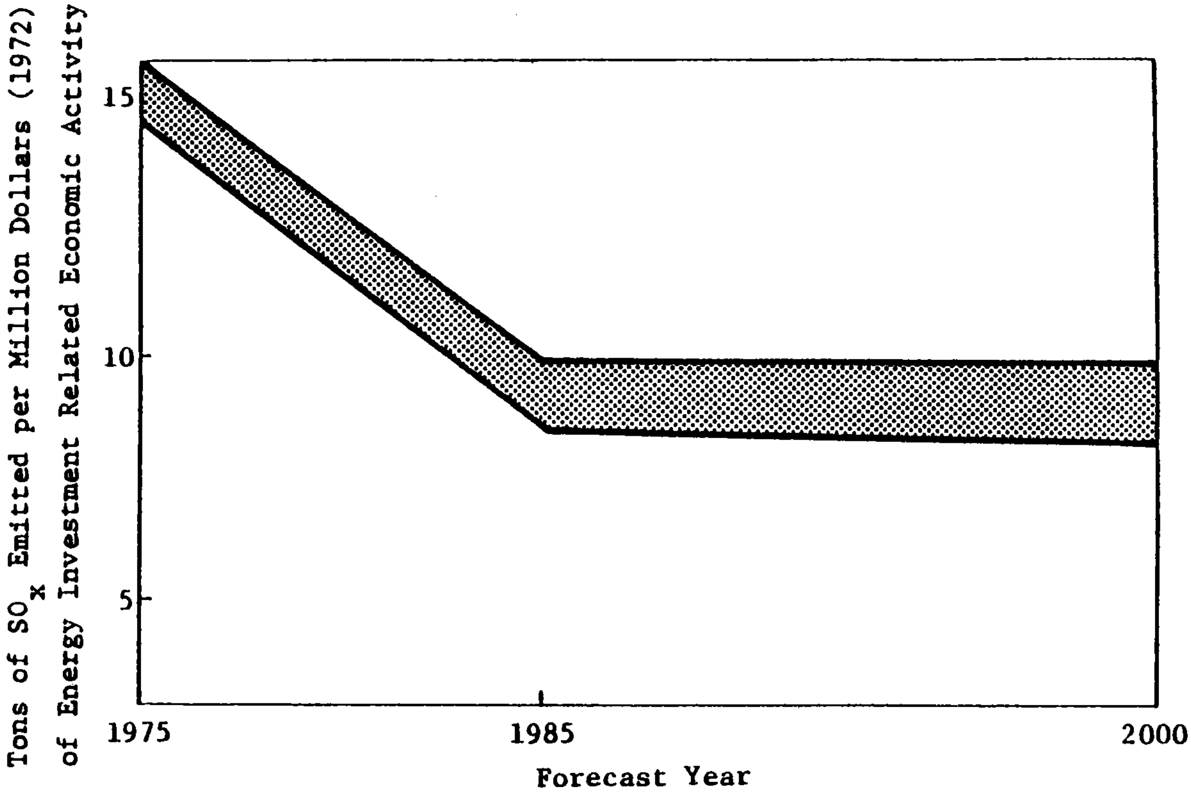


Figure 6.7
Tons of SO_x emitted per million dollars worth of economic activity. The expansion path encompasses the range of derived coefficients for all of the energy related investments (except photovoltaics).

larger. This effect should tend to damp the variability over time of the indirect emissions per dollar for different energy investment options.

- Over time, the economy is projected to increase the complexity of its interindustry dependencies. This is to say that a stimulus to a given sector of the economy will elicit broader impacts over time to other sectors of the economy. This effect stipulates that, in general, the impacts related to industrial activity resulting from energy related investments will become broader and more general over time, thus tending to lessen the differences between alternative energy investments in terms of indirect pollution per dollar of capital investment.
- Due to the assumptions in the model which concern the effects of environmental regulation and industrial compliance, the indirect residuals associated with a given level of general economic activity will decrease over time. This effect should reduce the absolute differences in indirect emissions related to different energy investment options in the model's out-years.

These three points imply that the set of estimated indirect residuals per dollar of investment-induced economic activity should become more compact over time. Figure 6.7 is a map of the temporal effects of the model's assumptions on SO_x emissions per dollar of economic activity induced by investments in the different energy technologies; all technologies except photovoltaics fall within the boundaries of the expansion path depicted in Figure 6.7. The vertical cross-section of this expansion path will define the relative compactness of the SO_x emissions set at different points in time. Contrary to expectations, this aggregate expansion path actually becomes less compact over time. The visual impression given in Figure 6.7 is that if the expansion path were projected backwards (to the 1972 baseline perhaps), something close to a point estimate of SO_x released per dollar of GNP might exist. Such a result would not be very reassuring.

In addition to comparing the indirect environmental residuals from the construction of conventional versus solar tehnologies, it is necesssary to evaluate the indirect residuals resulting from a similar level of expenditures on consumer goods. How do the indirect environmental effects of a $100 million expenditure on residential wind energy systems differ from the effects of that same amount of money spent on automobiles, refrigerators, food, and the like?

We argue that there will be a substitution of conventional (non-energy) consumer goods for solar energy systems in the economy. Thus, for a given projection of GNP, the attempt to build a more solar-dependent energy base is likely to be accompanied by downward adjustments in many other components of final demand. Personal consumption expenditures (PCE) were chosen as a component of GNP against which to test the argument, because PCE is the largest single component of GNP.

In specifying the components of a PCE basket of consumer goods, the projections of the INFORUM model were relied upon for detail. In particular, the projections of the TASE 6 scenario between the 1990 and 2000 periods for personal consumption expenditures were used to derive the allocation of incremental PCE among the approximately 150 sectors which contribute to the typical consumer's market basket. This incremental vector was then assumed to represent the reductions in PCE which might result from an increase in expenditures on a solar future. It must be emphasized that this is simply one of the several reasonable assumptions which might be made concerning the types of adjustments in final demand.

TABLE 6.2

COMPARISON OF INDIRECT RESIDUALS PER DOLLAR OF CAPITAL EXPENDITURE

(Energy, PCE, Photovoltaics)

Residual Classification	*Energy Related Investment; Tons of Residual per $10^6 (1972)*	*Personal Consumption Expenditures; Tons of Residual per $10^6 (1972)*	*Photovoltaics Investment; Tons of Residual per $10^6 (1972)*
Particulates	4.6— 6.2	2.9	6.4
SO_x	11.2—14.6	14.8	53.5
NO_x	9.5—14.0	9.9	30.4
Hydrocarbons	2.8— 3.0	2.3	4.3
CO	43.0—50.6	19.6	37.2
Suspended Solids	.1— .3	.2	.2
B.O.D.	.1— .3	.2	.1
Industrial Sludges	33.7—41.1	29.7	116.6
N/C Solid Wastes	225—236	238.3	603.1
Water Use*	8.4— 9.7	5.5	4.9

*Water use in acre feet

Table 6.2 displays a comparison of the indirect residuals per dollar of capital expenditure for energy related investment and PCE. It is notable that in only four residual categories (particulates, carbon monoxide, industrial sludges, and water use) does there appear to be a real difference in residual multipliers. The implication here is that, for those residual multipliers which are approximately equal for energy investments and PCE, the net indirect environmental emissions related to increased solar energy development should be close to zero. It is hoped that future work in this area will consider a broad range of displaced investment packages so that a sensitivity analysis can be performed to look at the impact on net indirect residuals under differing assumptions about where the additional investment capital will come from. Thus, an expansion path could be defined for indirect emissions associated with nonenergy related investment (similar to that in Figure 6.7). Its dimensions and location could then be compared to the expansion path of the same residuals associated with the energy investments. Such a comparison would add a great deal of resolution of the issue of net indirect impacts.

Photovoltaics, per dollar of investment, generally yield more indirect residuals than any other technology class. By and large, this result is dictated by the tremendous input of electricity to the manufacturing process. Thus, silicon crystal photovoltaic cell manufacture reflects the emissions of the utility sector. Clearly, there seems to be some cause for concern if photovoltaics is to become a significant contributor to the U.S. energy base. This conclusion should be held as preliminary, since only one of several processes for photovoltaics manufacturing was considered. It is quite possible that the specification chosen is far more energy intensive than most future expectations. The photovoltaic cell manufacturing technique which was selected for the characterization is one of many possible processes, and reflects current state-of-the-art rather than the goal of one of the more efficient emerging techniques.

CHAPTER 7

Economic, Employment and Materials Resource Analysis

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CHAPTER 7

ECONOMIC, EMPLOYMENT AND MATERIALS RESOURCE ANALYSIS

Introduction

This chapter addresses the probable effects on the economy, employment, and materials resources from the construction and deployment of various solar and biomass technologies associated with the TASE scenarios. These effects are discussed at the national, regional and local levels.

This chapter describes basic assumptions and major findings. Direct and indirect impacts are explored. Direct impacts are the result of operation, installation, and construction of solar and other energy technologies. Indirect impacts are associated with industries that manufacture solar and other energy system equipment and components.

Summary and Conclusions

- Most renewable/solar energy technologies are, and will probably continue to be, capital and labor intensive. Market penetration of these technologies will therefore require considerably more capital investment than conventional substitutes required.
- Total investment in projected energy activities increases by $330 billion over the twenty-five period. This is roughly 25 percent more than the labor and capital required by the TASE 6 scenario in the energy sector of the economy.
- Additional investment in solar installations will be primarily at the expense of reduced investment in coal and nuclear facilities. Utilities will need to raise more capital in the MPG Case to finance new solar and biomass power plants. Solar and biomass facilities will require a higher proportion of total capital investment as compared with their proportional contribution to energy supply.
- Labor requirements for both construction and operation of such facilities will be correspondingly larger. From 1975 to 2000, the TASE 14 scenario, with 14 quads of solar energy in 2000, calls for 2.8 million more employee-years of construction and 2 million employee years of operation and maintenance labor than the TASE 6 scenario. Differences would be most noticeable from 1990 to 2000, when the market penetration of solar systems increases dramatically. The average net annual construction, operation, and maintenance employment difference between the scenarios for 1996 to 2000 is about 300,000 employee-years per year.
- The principal local effect on employment is that the average community or county will experience significantly greater energy employment under the high solar scenario. Compared to the low solar scenario, this increased employment will also be much more widely and evenly distributed geographically and temporally, more highly correlated with existing and future building, settlement and business patterns, and less demanding of short-term construction-related employment and population migrations and the social and economic impacts they can cause.

ECONOMIC AND EMPLOYMENT IMPACTS

Approach

Energy scenarios which specify the amount of primary energy available from each source (type of energy facility) serve as the basic input to the chain of models—an energy supply planning model and a U.S. input-output model with detailed mineral sectors at the four-digit SIC level. The TASE 6 and TASE 14 scenarios serve as the input scenarios with detailed specifications of the potential oil, gas, coal, nuclear, solar, wind, ocean, and biomass energy sources required to meet the projected demand for energy.

The Energy Supply Planning Model (ESPM) translates the scenarios into the number of energy facilities of each type which must be constructed to meet the projected levels of energy supply. The 122 facilities include coal mines, various types of power plants, oil wells, and solar and wind generators. The model includes algorithms for calculating the transportation facilities required to move coal, oil, gas, and other energy fuels. The numbers of trains, pipelines, trucks, etc., are estimated on the basis of projected energy supply and demand (origin and destination) for each federal region of the country.

The capital cost and labor requirements to construct and operate each facility constitute the basic data in the ESPM. They are sub-divided into 140 detailed categories. On the basis of these data, the direct capital costs and labor required to meet the prescribed energy supply scenario are computed. Lawrence Berkeley Laboratory modified the 1978 ESPM data base to include data on solar and other renewable technologies. The detail for the twenty solar and renewable technologies was furnished at the four-digit SIC level by the national labs, including Argonne, Brookhaven, Lawrence Berkeley, Los Alamos, and Oak Ridge.

Capital costs include expenditures on equipment, labor, and materials. Equipment and materials costs are disaggregated into two digit SIC I/O sectors. These capital expenditures are treated as a final demand vector in the I/O table. The output of each industry required to meet this final demand is estimated for the next twenty years. The two final demand vectors are presently disaggregated to match the I/O table sectors. The equipment and materials demand vector is disaggregated using fractional shares in the Gross Private Domestic Capital Formation vector, and the labor demand vector is disaggregated using the shares in the Personal Consumption vector. Employment associated with the direct output is estimated using coefficients adjusted to include changes in future productivity.

Direct Impacts of Construction

The TASE 6 scenario calls for $1370 billion of capital investment between 1975 and 2000, whereas TASE 14 scenario requires $1700 billion in the same period. Investment in solar facilities increases from $300 billion to $720 billion, an increase between the two scenarios. Investment in other energy sources, i.e., coal, oil, nuclear, gas, etc., declines from $1080 billion to $980 billion. For both scenarios, investment increases with time. Average annual investment increases from $44 billion in the 1976 to 1985 period to $64 billion in the last decade in the TASE 6 scenario (Table 7.1). In the TASE 14 scenario, it increases from $47 billion to $86 billion over the same period (Table 7.2). Investment in solar facilities increases steadily whereas it declines in nuclear, coal and gas industries. These investment figures may be compared with a fixed nonresidential investment of $76 billion in 1978.

Solar technology investments account for a disproportionate share of the dollars invested in energy given their projected contribution to the national energy supply. In the BAU Case, solar is projected to contribute 6 quads of energy or 5 percent of the national total of 118 quads in the year 2000. This projected level of solar energy supply requires an investment of $18 billion a year, or 28 percent of capital invested in the energy sector during the last decade. In the MPG Case, solar is projected to supply 12 percent of the total U.S. energy supply, however, it could require up to 55 percent of the capital invested in energy.

It is also worthwhile to note that these investment shifts are magnified in certain sectors. Table 7.3 illustrates these shifts. For example, utility scale solar technologies in the year 2000 provide 7 percent of the electricity produced by the utility sector in the MPG. To supply this amount of energy requires 32 percent of the capital investments of the utility industry over the 25-year period as compared to 9 percent in the BAU Case. Over this 25-year period the investment in power plants will increase by 9 percent although the electricity generation will be lower by 10 percent in 2000 in the MPG Case as compared to the BAU Case.

Table 7.1
Average Annual Employment Impacts—TASE 6

Capital Investment (10^9 \$)	1976–85		1986–90		1991–2000	
	SOLAR	TOTAL	SOLAR	TOTAL	SOLAR	TOTAL
Manpower	1.3	10.9	3.7	15.1	5.2	16.7
Materials	1.0	8.1	4.3	12.2	6.2	13.9
Equipment	.3	11.1	1.5	14.6	3.3	16.7
Other		14.0		16.2		17.0
Total	3.2	44.1	11.4	58.1	17.8	64.3
Employment (10^3 employee-years)						
Direct Construction	37	331	110	459	156	516
Direct Operation	53	1112	101	1370	214	1825
Indirect	111	1169	336	1462	442	1405
Total	201	2612	547	3291	812	3746
Indirect Employment (per 10^6 \$ Capital Investment)						
In Materials, Equipment and other Costs	36.2	33.4	30.9	29.5	26.1	32.6
In Manpower	43.1	39.7	38.9	38.1	33.6	43.4
Employment per 10^6 Total Capital Investment						
Direct	11.6	7.5	9.7	7.9	8.8	8.0
Indirect	38.4	35.1	33.0	31.7	27.6	27.1
Indirect/Direct	3.3	4.7	3.4	4.0	3.1	3.4

Table 7.2
Average Annual Employment Impacts—TASE 14

Capital Investment (10^9 \$)	1976–85		1986–90		1991–2000	
	SOLAR	TOTAL	SOLAR	TOTAL	SOLAR	TOTAL
Manpower	2.8	12.2	8.8	19.7	10.5	19.8
Materials	2.3	9.2	10.1	17.6	15.3	22.0
Equipment	0.8	11.4	5.1	17.6	11.5	22.0
Other	1.2	14.4	4.7	18.5	10.5	22.4
Total	7.1	47.2	28.7	73.4	47.8	86.4
Employment (10^3 employee-years)						
Direct Construction	82	369	2	597	397	689
Direct Operation	80	1134	182	1432	437	1978
Indirect	244	1307	843	1916	1179	1954
Total	406	2810	1289	3945	2013	4621
Indirect Employment (per 10^6 \$ Capital Investment)						
In Materials, Equipment and other Costs	39.1	33.7	30.7	29.8	25.6	25.2
In Manpower	43.2	43.2	38.1	41.8	32.9	33.0
Employment per 10^6 Total Capital Investment						
Direct	11.5	7.8	9.2	8.1	8.3	8.0
Indirect	38.6	36.3	32.7	31.8	27.4	27.1
Indirect/Direct	3.4	4.7	3.6	3.9	3.3	3.4

Table 7.3
CAPITAL INVESTMENT IN CONSTRUCTION OF ENERGY FACILITIES
(Million 78 \$)

	Cumulative Total (1976–2000)	
	BAU	*MPG*
Coal		
1 Underground Coal Mine	18,500	16,700
2 Surface Coal Mine	18,400	16,500
3 Coal Gasification and Liquefaction	65,500	65,500
4 Coal Fired Power Plant-Low BTU	59,700	47,300
5 Coal Fired Power Plant-High BTU	45,800	33,700
6 Coal/Waste Power Plant-Hi BTU Coal	1,000	4,300
7 Sulfur Oxide Removal	36,200	29,200
8 Coal Train	15,700	14,100
9 Coal Slurry Pipeline	5,400	4,800
10 Other Coal Transportation Facilities	1,800	1,600
Subtotal	268,000	229,300
Oil		
11 Oil Recovery—Lower 48	277,700	276,100
12 North Alaskan Oil Recovery	1,900	1,900
13 Oil Refineries	22,200	21,800
12 Alaskan Oil Export	400	400
15 Onshore Oil Import	500	500
16 Underground Oil Shale Mine	3,300	3,300
17 Oil Shale Retorting and Upgrading	14,000	14,800
18 Oil-Fired Power Plant	2,400	2,700
19 Crude Oil Pipeline—Lower 48	1,800	1,800
20 Alaskan Oil Pipeline	2,000	2,000
21 Oil Tanker	3,800	3,900
22 Oil Barges	200	200
23 Oil Tank Truck	6,000	6,000
24 Product Pipeline	3,500	3,500
25 Refined Products Bulk Station	800	800
Subtotal	341,400	339,700
Gas		
26 Gas Recovery—Lower 48	133,000	127,600
27 North Alaskan Gas Recovery	2,000	1,800
28 High BTU Gas-Fired Power Plant	100	100
29 Gas Pipeline-Lower 48	12,100	10,400
30 Gas Distribution Facilities	23,000	19,900
31 Alaskan Gas Pipeline	6,800	6,800
Subtotal	176,900	166,600

Table 7.3 (Continued)

	Cumulative Total (1976–2000)	
	BAU	*MPG*
Nuclear		
32 Uranium Mining and Enrichment	19,600	5,600
33 LWR Fuel Fabr., Reprocessing and Disposal	3,200	3,100
34 Light Water Reactor	144,300	115,100
Subtotal	167,100	123,800
Solar, Biomass, Hydro, Others		
35 Dam + Hydroelectric Power Plant	16,800	17,400
36 Pumped Storage	3,700	3,700
37 Geothermal Power Complex	6,300	6,300
38 Solar Space Heating	82,900	183,800
39 Solar Space Conditioning	17,500	40,900
40 Central Solar Receiver	4,500	54,500
41 Pyrolysis-M.S.W.	2,400	23,100
42 IPH-Medium, Paper/Pulp	65,000	130,000
43 Combustion/Cogeneration-Paper/Pulp Waste	2,700	3,700
44 IPH-TES	22,500	45,100
45 Residential Photovoltaics	10,900	16,700
46 Central Wind Energy Conversion System	19,300	47,700
47 Residential Wind System	5,400	42,500
48 Active Solar Domestic Hot Water Heating	17,400	36,200
49 Passive Solar Domestic Heating	10,400	52,300
50 Anaerobic Digestion of Municipal Sludge	1,000	1,000
51 Centralized Photovoltaic System	5,000	11,500
52 Biomass Combustion	100	1,600
53 Woodstoves	500	1,000
54 Rail Line	1,200	1,200
55 Transmission Lines	32,300	31,100
56 Electricity Distribution Facilities	92,600	88,100
Subtotal	420,600	839,400
TOTAL	1,374,100	1,702,900

A large fraction of this additional investment will be required in the last decade, 1991–2000. Solar power plants will account for sixty percent of the total investment during the last decade. Investment in other power plants amounts to only 40 percent in the MPG Case as compared to 82 percent in the BAU Case during this last decade. Total investment in the MPG Case is higher by 16 percent than in BAU Case during the same period. Utilities may face difficulty raising this capital if other more attractive investments were available. It may also affect the utilities bond rating in the marketplace thereby making capital more expensive to borrow.

The energy technologies installed in the residential/commercial sector also require a larger proportion of investment in the MPG Case. These technologies would supply 3.8 quads or 3 percent of the total U.S. supply of energy using distributed SHACOB, wind, photovoltaic, and wood stoves. To provide this energy would require investments of $24 billion or 28 percent of all energy investments in the year 2000. In the industrial sector, 6 percent of the energy can be supplied using only 15 percent of the investment dollars. This is attributed to the high percentage of biomass use. Biomass, in all sectors in the MPG, provides 5.7 quads of energy or 5 percent of the national supply and requires only 2 percent of the investment dollars.

The fiscal resources needed to manufacture, construct, and install solar systems would have to be shifted from conventional energy resources primarily from coal and nuclear.

Over the 25-year period, the electric utility industry could see lower investments in nuclear and coal-fired power plants of 20 and 23 percent respectively. Transmission and distribution investments would be lower by 5 percent as a result of a shift to more decentralized systems. Investments in uranium mining and processing would decline sharply as few nuclear plants are built in the latter decades. Oil extraction, coal mining, and gas extraction would observe lower levels of investments on the order of 1, 10, and 4 percent. These smaller investments would occur as a result of reduced demands for fossil fuels in the MPG Case.

Construction labor requirements for the TASE 6 and TASE 14 scenarios are 10.8 million employee-years and 13.5 million employee-years, respectively. Labor required for potential solar industries accounts for roughly 25 percent of total labor required for TASE 6 scenario. This fraction is almost doubled to 47 percent of the total labor required for the TASE 14 scenario. Labor requirements for solar industries are 133 percent larger in the TASE 14 scenario. Average annual labor requirements increase from 370,000 employee-years from 1976 to 1985, to 690,000 employee-years from 1991 to 2000, an increase of 86 percent for the TASE 14 scenario. Requirements increase from 330,000 to 520,000 employee-years, an increase of 56 percent for the TASE 6 scenario.

Solar industry labor requirements increase from 82,000 to 397,000 employee-years for the TASE scenario and from 37,000 to 156,000 employee-years for the TASE 6 scenario. Labor requirements for all other energy industries such as coal, oil, gas, and nuclear power are substantially lower in the TASE 14 than in the TASE 6 scenario. Over the twenty-five years, 896,000 fewer employee-years are required in other industries in the TASE 14 scenario. The decrease in manpower requirements is more than compensated by the additional 3.63 million employee-years of employment created by the solar industry. Figure 7.1 illustrates these changes.

The solar industry projected in the scenarios is broad enough to employ a mix of skilled and unskilled labor. Some of the technologies, such as solar space heating, require primarily manual labor; central solar receivers require a mix generally similar to conventional power plants. As a result, requirements for both skilled and unskilled labor increase substantially in the TASE 14 scenario. Requirements for chemical, civil, and mechanical engineers increase: understandably, fewer petroleum, geological, nuclear, and mining engineers are needed. Most skills, such as carpenters and pipefitters, are required in increasing numbers; however, requirements for boiler-makers and linemen decrease in every period.

Average annual employment for engineering skills doubles in the TASE 14 scenarios for civil and mechanical engineers, increasing to 16,000 employee-years annually. Requirements for chemical engineers increase fivefold from 450 to 2400 employee-years annually. These figures may be compared with the number of engineers in nonmanufacturing private industry in 1977; civil engineers, 71,000; mechanical engineers, 71,000; and chemical engineers, 14,000.

In 1977 the total employment in nonresidential building construction and in public utility construction amounted to 1.65 million employee-years. The Bureau of Labor Statistics (BLS) projects an increase in this employment to 2.23 million by 1990. The TASE 14 scenario calls for an increase from 370,000 to 690,000 employee-years from the first to the last ten year period, or roughly an increase from 22 percent to 31 percent of the projected BLS figures; in the TASE 6 scenario it increases from 20 percent to 24 percent. Part of the TASE 14 increase would be accounted for by solar space heating and air conditioning, a residential building construction activity. The requirements for nonresidential building construction and public utility construction employees would be reduced.

Overall, the increased need for construction employees should not pose a formidable problem, because of the total number of employees already in the construction industry. Some workers with specific skills, however, will find fewer jobs available, particularly in some of the engineering fields.

Among the investment requirements for solar technologies, solar space heating (SSH) requires by far the largest capital investment, followed by wind generators, industrial process heat (IPH)-medium, and central solar receivers. Solar space heating requires an additional $101 billion, wind generators and IPH-medium require an additional $65 billion each, and central solar receivers require an additional $50 billion more in the TASE 14 scenario than in the TASE 6 scenario.

Direct Impacts of Operation and Maintenance

The TASE 14 scenario calls for 38.3 million employee-years from 1975 to 2000, an increase of 2.1 million employee-years over the TASE 6 scenario. The solar industry will gain 2.8 million employee-years over this time. The coal industry is the largest loser, with 610,000 employee-years lost over the same period. The nuclear industry which potentially will lose 400,000 employee-years in the construction of nuclear facilities, will lose only 67,000 employee-years in the operation and maintenance of these facilities. Losses in the gas and oil industries are minor.

Solar space heating is the largest contributor to increased employment in the solar industry, with an increase of 1 6 million employee-years. Regional distribution of increased solar employment is similar to the distribution of solar industry construction employees. Within the coal industry, coal mining is the largest loser, with 365,000 employee-years lost. The decrease in coal mining employees will occur primarily in the Mid-Atlantic, North-Central, South-Atlantic, and Midwest regions. The New York/New Jersey and Pacific Northwest regions show minor gains in coal mining employment.

Indirect Impacts

Indirect employment associated with industries supplying goods for energy construction activity is almost three times larger for solar activities in the TASE 14 scenario than in the TASE 6 scenario. Average annual indirect employment in the TASE 14 scenario from 1991 to 2000 amounts to 1.95 million employee-

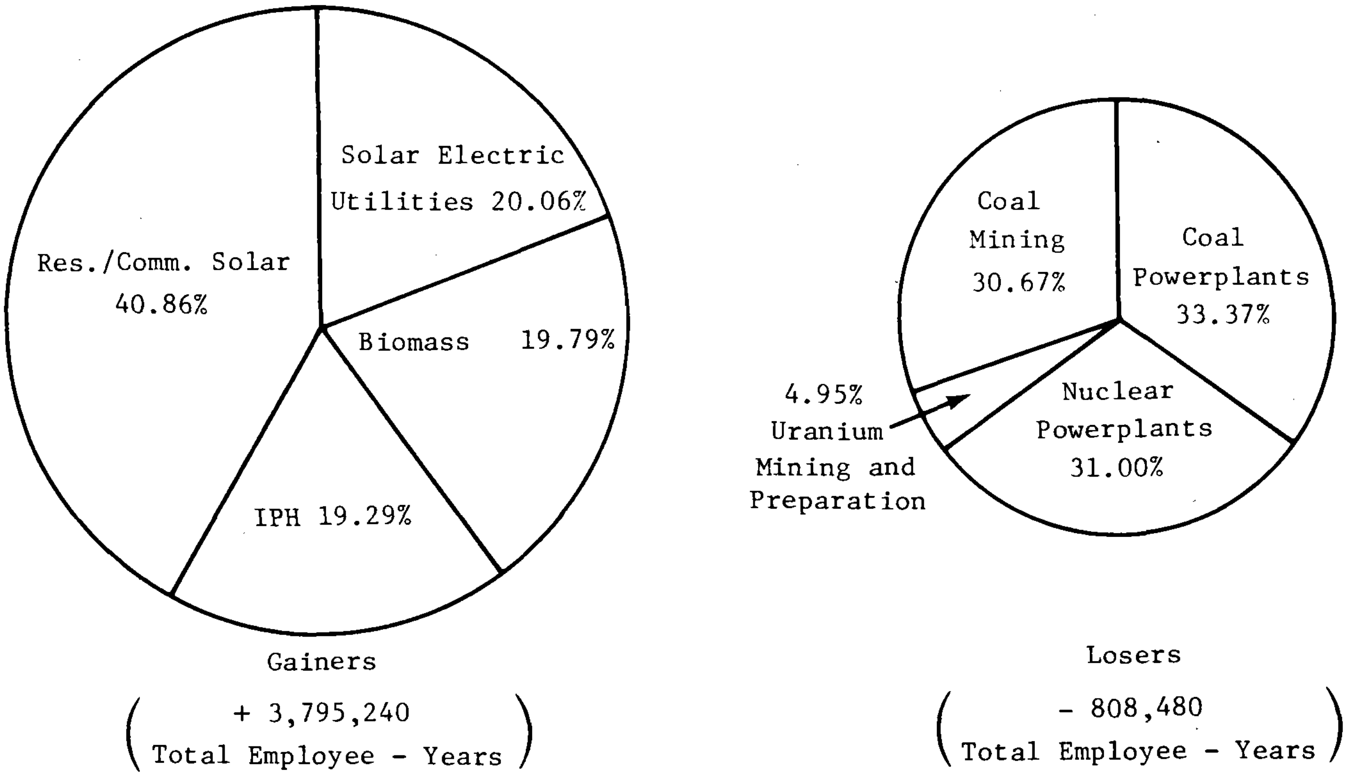

Figure 7.1
Scenario Employment Differences—14Q—6Q
for the Energy Technologies Examined

years (Table 7.2), compared to 1.40 million employee-years (Table 7.1) in the TASE 6 scenario.

Total annual employment in the energy sector, which includes direct and indirect construction employees, plus operation and maintenance employees, increases from 2.61 million to 3.75 million in the TASE 6 scenario, and from 2.81 million to 4.62 million in the TASE 14 scenario. The total employment in solar and associated industries increases from 200,000 to 810,000 and 410,000 to 2.01 million in the TASE 6 and TASE 14 scenarios, respectively.

In all time periods, a dollar spent for materials and equipment generates less indirect employment than a dollar spent on labor. Indirect employment amounts to 3 or 4 times the direct employment. In all cases, the solar sector has less associated indirect employees than the overall energy sector per dollar spent. Ratios of indirect to direct employment range from 3.1 to 3.4 for solar facilities; they range from 3.4 to 4.7 for all energy facilities. The ratios generally decrease with time, since average labor productivity for the economy is assumed to be higher than for energy construction activity. The ratio for solar facilities do not change significantly, indicating that labor intensity in solar construction changes in the same proportion as it does in associated industries.

Indirect employment in manufacturing industries increases faster in the TASE 14 scenario than does overall employment. Construction of solar facilities in the TASE 14 scenario generally provides more stimulus to manufacturing industries than to other sectors of the economy.

It should be pointed out that these indirect impacts may not represent a net increase in employment and may impact the economy as a whole. If the economy were operating at full employment, energy sectors would have to compete against other industries for employees. Only if workers with the required skill categories were unemployed would a net increase in employment be seen.

Regional Employment Impacts

Large differences in solar space heating investment occur mainly in federal regions 5, 6, 4, 9 and 2 (Table 7.4). Wind generators require heavier investment in TASE 14 over the TASE 6 scenario in regions 4 and 5. IPH-medium investment is larger in regions 4, 6 and 10; central solar receivers will require more investment in regions 4, 6 and 9.

Differences in labor requirements between the two scenarios for the solar technologies are dominated by solar space heating, IPH-medium, solar space conditioning and central solar receivers. SSH requires 1.4 million employee-years, IPH-medium requires 480,000 employee-years, central solar receivers need 370,000 employee-years, and solar space conditioning requires 320,000 employee-years more lab or in the TASE 14 scenario than in the TASE 6 scenario. The same regions which will benefit from the heavier investment will also require increased labor. Wind generators are an exception, since these are not labor intensive. Solar space conditioning will affect primarily regions 5, 6, 4, 2 and 9.

The South Atlantic, Midwest, and Southwest regions (4, 5, 6) will experience far higher investment and employment from increased solar energy than other regions. Each region will gain slightly over 600,000 employee-years in the solar industry over the twenty-five years. At the same time, each region will lose over 55,000 employee-years in the coal industry. These regions, along with New York/New Jersey, the West, and the Northwest, will also lose substantial employment in the nuclear industry. This industry is expected to decline by 420,000 employee-years from 1975 to 2000. Coal mining is expected to be the largest loser.

TABLE 7.4

Differences in Manpower Requirements for TASE 14 and TASE 6 Scenarios
(1976–2000 in Man-Years)

FEDERAL REGION:	*NE 1*	*NY NJ 2*	*MID-ATL 3*	*SOUTH ATL 4*	*MID-WEST 5*	*SW 6*	*CENTRAL 7*	*NC 8*	*WEST 9*	*NW 10*	*COASTAL*	*TOTAL*
Solar	121,700	298,500	257,800	650,100	629,200	618,000	150,500	201,100	413,500	292,700		3,633,100
Coal	(4,000)	(2,900)	(33,500)	(57,200)	(55,600)	(59,500)	(5,600)	(27,600)	(31,000)	(2,700)		(279,700)
Oil	(–)	(–)	(200)	(300)	600	(9,900)	(200)	(500)	600	0	(640)	(10,600)
Gas	800	(2,700)	(4,200)	(10,700)	(6,600)	(35,600)	2,300	(2,600)	(7,500)	(1,500)	(235)	(68,600)
Nuclear	(19,200)	(40,400)	(12,300)	(90,250)	(160,300)	(27,100)	(–)	(1,400)	(31,000)	(35,800)		(417,700)
Other	(2,100)	(11,962)	(12,100)	(40,400)	(10,900)	(15,876)	(2,293)	(7,900)	(11,200)	(4,284)		(119,100)
Total	97,100	240,500	195,500	451,200	396,400	470,100	144,700	161,200	333,300	248,400	(900)	2,737,500
TASE 6	324,800	590,300	723,200	1,776,800	1,664,500	2,795,000	442,900	794,200	904,800	612,300		10,765,700
TASE 6 Solar	99,900	218,100	228,800	461,000	438,900	454,700	96,700	130,700	309,900	274,900		2,713,600
TASE 6 Solar / TASE 6	.31	.37	.32	.26	.26	.16	.22	.16	.34	.45		.25

Local Employment Impacts

The employment and community impacts of the low (base case) and high (maximum practical) solar scenarios were compared. Two kinds of impacts on employment resulted: those that would create local social or economic problems due to excessive employment needs; and those that would be easily absorbed by the local force, creating local job benefits.

The solar technologies contained in the scenarios are highly varied. Those which require the most on-site employment are the electric utility central thermal and wind systems; the agricultural/industrial process heat TES, medium temperatures and agricultural and forest residue combustion systems; and the systems for heating and cooling buildings, including hot water. Except for the central solar thermal power plants, all of these systems are small and widely dispersed geographically. However, the magnitude of the number of systems, employees, and localities affected by these technologies requires extensive analysis to adequately understand the local direct employment effects of the TASE scenarios. Figure 7.2 illustrates the employment intensities for major technologies examined in the TASE Project.

Factors which affect the impact of energy facility employment on localities can be classified as either technology-related or community-related. Technology-related factors include:

- the size of the facility, especially the peak and average number of employees required
- the duration, fluctuation, and types of employment required
- The type of location and auxiliary inputs required the projected rate of penetration in the energy market
- the employment intensity (ratio of employment to energy output) of the technology

Community-related factors are the key determinants in translating employment requirements into social and economic effects for the locality. The most important community-related factors are:

- local availability of workers to fill the jobs required by the energy facility
- the ability of the community to assimilate additional transient and im-migrating workers, which in turn depends on community size, complexity, and social structure

There is tremendous variation in the availability of labor and the assimilative capacity of communities across the nation. While populous urban centers might experience little more than marginal changes due to the construction and operation of a large new energy facility, rural and relatively isolated areas can expect significant effects from the same development. Some counties can more than double their population as construction workers and their families migrate to the work area for months or years. Social conditions often deteriorate during such boom periods, as traditional institutional and social structures in the community break down, and as local services (housing, recreation, safety, education, health, etc.) fail to meet burgeoning demands. Attempts of local governments to satisfy such demands can be very costly.

Conventional Electric Power Plants. The TASE low scenario projects that 746 new electric power plants will begin operation from 1976 to 2000: some 385 counties will host one or more of these new plants. The high solar scenario requires about 9.4 percent less electricity from conventional sources. Only 658 new plants in 295 counties are projected under this scenario for the same period. Thus, there are ninety-eight plants (sixty-seven coal, thirty-one nuclear) in ninety counties that are built in the low but not the high solar scenario. Since these plants and counties indicate the differences between the scenarios, they will be labeled as differential. The projected startup date for almost all of these differential plants is between 1990 and 2000, when the solar systems' market penetration increases sharply.

A separate analysis of the power plant employment impacts of each scenario leads to the following estimates about the effects of constructing, operating, and maintaining the ninety-eight differential plants through the year 2000.

- A total of 520,440 employee-years to build, operate and maintain these plants over the scenario period is required and an average of about 50,000 employee-years per year in the last five years. (See Table 7.5.)
- An average of 5814 total additional employee-years per differential county is required by these plants, with a range of 1,763 to 14,176.
- Eighteen of the ninety differential counties (20 percent) are projected to experience construction-related population increases of 5 percent or more above their level, without these plants. Such rates of increase tend to cause socioeconomic "boom town" problems and are singled out here for that reason. For all counties, the range of projected differential population increases is 0 to 45 percent.
- The average cost of providing full governmental services for the differential population increases in the eighteen most affected counties would be about $1.34 million per year per county.
- Of these eighteen counties, four are in Texas two each are in Florida, Oklahoma, and Washington; and one each is in California, Georgia Mississippi, North Dakota, Oregon, Tennessee West Virginia, and Wyoming.

Mining and Fuel Preparation. Estimating the general employment requirements for mining and preparing the fuel required by the differential power plants

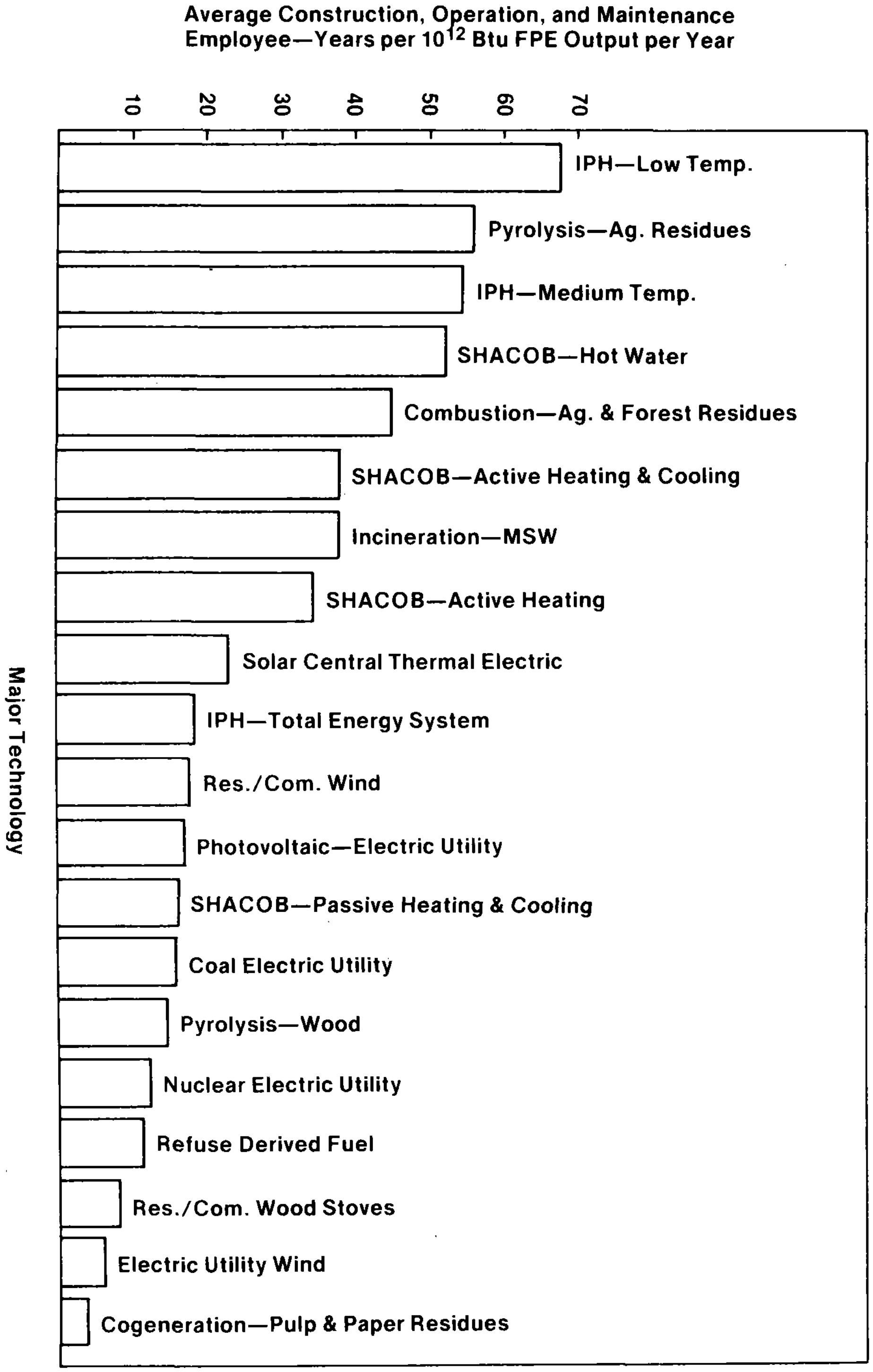

Figure 7.2
Combined On-Site and Fuel System
Employment Intensities

TABLE 7.5
National Energy Employment Summary

	Year 2000, 10^{12} Btu (FFE)							
System Type	*Low Solar Case (6Q)*	*High Solar Case (14Q)*	*Difference*	*Change in Number of Scaled Systems*	*Number of Counties Affected*	*Total 1976–2000 Const/Op/Main Employee/Yr Differential*	*Average 1996–2000 Const/Op/Main Employee-Yr. Differential*	*Employment Intensity: Average Const/Op/Main Emp.-Yr/10^{12} Btu (EFE)/Yr.*
Conventional Electric Plants	44706.3	40120.0	4586.3	−98[a]	−90[a]	−520,440	−52,040	
Coal	23895.5	21208.1	−2687.4	−67[a]	−63[a]	−269,820	−26,980	63
Oil and Gas	4844.9	4830.4	−14.5	—	—	—	—	9.7
Nuclear	15965.9	14081.5	−1884.4	−31[a]	−31[a]	−250,620	−25,060	6.0
Coal Mining	(46296.7)	(42116.1)	(−4180.6)	—	?	−248,000	−28,900	8.9
Uranium Mining, etc.	—	—	—	—	−50	−40,040	−6,510	6.0
Solar Electric Utilities	800.3	2959.5	2159.2			761,300	113,470	
Wind	601.5	1484.5	883.0	22,506	1000	122,300	18,510	6.8
Photovoltaic	99.4	232.3	132.9	62	−50	77,680	8,440	17.1
Central Thermal	99.4	1242.7	1143.3	302	−200	561,320	86,520	22.7
Biomass	2811.9	5385.1	2873.2			750,910	70,710	
Refuse Derived Fuel	89.5	251.4	161.9	15	15	35,070	1,860	10.9
Incineration—MSW	89.8	247.1	157.3	127	110	101,800	10,090	38.4
Combustion—Ag./For. Residues	101.9	1085.7	983.8	5,886	−450	497,120	40,650	44.8
Cogeneration–Pulp & Paper Residues	2311.9	2599.7	287.8	46	−35	9,440	500	2.3
Anaerobic Digestion—Sludge	32.0	32.0	0	0	0	0	0	38.4
Pyrolysis—MSW	20.0	74.9	54.9	2	2	6,430	1,260	6.2
Anaerobic Digestion—Manure	66.9	66.9	0	0	0	0	0	48.1
Pyrolysis—Ag. Residue	99.9	327.8	227.9	1,945	−178	46,700	7,670	56.0
Pryolysis—Wood	0	699.8	699.8	178	−150	54,350	8,680	14.1
Solar Process Heat	1032.7	2065.8	1033.1			732,160	66,390	
IPH—Total Energy Systems	308.4	617.2	308.8	4,656	−500	141,240	17,030	19.0
IPH—Low Temperature	113.2	226.1	112.9	921,760	−1500	88,260	10,570	67.5
IPH—Medium Temperature	611.1	1222.5	611.4	2,617	−500	502,680	38,790	53.8
Residential/Commercial	1386.3	3769.7	2383.4			1,550,850	142,750	
Active Heating	416.2	959.3	543.1	5,852,554	−3070	452,160	35,710	34.0
Active Heating & Cooling	142.0	330.8	188.8	1,568,127	−3070	185,790	16,700	38.8
Passive Heating & Cooling	200.0	999.9	799.9	8,503,913	−3070	393,870	42,810	16.1
Hot Water	341.0	709.9	368.9	13,087,953	−3070	361,960	29,420	52.1
Wind	53.2	418.2	365.0	1,353,792	−2500	137,500	15,930	18.3
Photovoltaic	33.9	51.7	17.8	126,512	−2000	9.700	1,400	33.7
Wood Stoves	200.0	299.9	99.9	623,000	−2500	9,870	780	8.0
Net National Totals	50,737.5	54,300.1	3562.6			2,986,760	305,870	

[a]As estimated and sited by the SEAS model.

and industrial coal boilers is fairly simple, but assigning county-level locations to these projections is not. Rather than attempt such an assignment, only broad generalizations about the local effects of mining and fuel preparation systems will be made.

By 2000, some 29,000 miners are likely to be required annually to provide coal for the industrial boilers and the 45,000 MW of coal electric systems under question, and some 6,500 employees to mine, extract, refine, enrich, and transport the fuel for the 32,000 MW of nuclear electric plants. While these additions to the fuel system labor force would not be numerically overwhelming, there are likely to be locations where concentrations of new employment will create significant local impacts. Especially vulnerable will be the rural western counties in Wyoming, Colorado, and Utah where large new mines will open. Most eastern mines, on the other hand, will probably experience only moderate employment increments at existing locations. New uranium refining and enrichment capacity may also lead to local employment concentrations, but whether these will cause significant local impacts will depend on their location. Overall, coal mining is projected to occur in more than 330 of the nation' approximately 3070 counties (approximately 10.8 percent), and uranium-related activities in some fift counties. The relatively low number of counties involved means that few counties benefit from increase fuel system employment: those that do are more likel to suffer "boom town" damages.

Solar Electric Utility Systems. About 3 quads o fossil-fuel-equivalent (FFE) energy (approximately quad of electricity) are produced by large wind, photovoltaic, and central thermal electric utility system in the high solar scenario, versus 0.8 quads in the lo solar case. The differences between the scenarios ar 22,506 1-MW wind systems, 62 100-MW photovoltai systems, and 302 100-MW central thermal (powe tower) systems. The county-level location of these systems cannot be determined at present, though they ca be expected where the solar or wind resource is greates and comparative electric system economics are favorable. The Southwest, Rocky Mountain, and Southeas regions appear to be the most likely recipients for pho tovoltaic and central thermal systems: the Coastal, Moutain, and Great Plains regions are best for wind systems.

Moderate local concentrations of employment can be expected from the photovoltaic and central thermal systems. They require a large number of employees per Btu of energy delivered, and they are likely to be clustered. However, they are much smaller (100 MWe) than conventional plants, and can be built sequentially in multiunit arrays which can spread construction employment over time and provide for greater workforce and community stability than the boom/bust employment associated with constructing a single large generating unit. The extensive land requirements of these solar electric systems encourages location in rural areas where land is cheaper. However, these systems do not have the pollution or safety problems which will keep new coal and nuclear plants at a considerable distance from population centers. Therefore, solar alternatives may be rural, but need not be remote from the population center served. The combination of these factors leads to the expectation of fewer and less severe concentrations of employment in impact-prone counties than would be experienced with the projected conventional electric systems.

Biomass Systems. In terms of employment impacts, the most significant biomass systems are those which generate process heat or low-Btu gas and char by burning or pyrolyzing wood and agricultural and forest residues. The primary labor requirement is not for construction of the system, as is the case for virtually all other solar systems, but for its operation, including the collection, transportation, and preparation of the energy feedstock. Though some 50,000 annual employee-years in some 650 counties would be required to operate these systems in the high solar scenario, an individual system requires only about 7 employee-years annually to provide the residues and operate the conversion equipment. An average county is projected to have eleven of these systems, or seventy-seven employees, but even this increase will likely be drawn out over a number of years, resulting in negligible annual population increases. The location of biomass systems is likely to be highly resource-oriented and scattered throughout crop and forest regions.

Solar Systems for Heating and Cooling of Buildings and Industrial Process Heat. These systems are by far the most numerous and widespread of any energy system projected by the TASE scenarios. The high solar scenario includes some 10 million residential/commercial (R/C) active heating systems; some 2.7 million R/C active heating and cooling systems; about 25 million hot water systems; almost 11 million passive solar systems; and almost 2 million industrial process heat systems. These system totals are all more than double the number required by the low solar scenario. The following generalizations can be made about the employment differences between the TASE scenarios for these systems.

- To build, operate, and maintain the differential systems would require a cumulative total of over 2 million employee-years from 1976 to 2000.
- The average employment differential from 1996 to 2000 is 190,000 employee-years per year.
- Averaged over the nation's 3070 counties, these employment differentials come to about sixty-two employees per county during the last five years of the scenario, and 692 total employee-years per county over the full study period.
- Areas with more new construction (residential, commercial, and industrial), more abundant solar energy, and higher conventional energy costs can expect higher levels of solar installations.
- Because they are relatively small, their construction requirements per system are low, and they are likely to be widely dispersed in time and space, these units will avoid the social damages associated with the construction of some conventional energy facilities.
- Though often manufactured by large national firms, installation and maintenance of these systems is likely to be performed by small local construction and heating contractors. This should also increase employment stability and distribution.

Materials Resource Impacts

The accelerated deployment of solar energy technologies will require significant amounts of materials, which could possibly impact the demand for industrial materials and the U.S. industrial capacity to supply those materials. These impacts could in turn, affect the cost of the solar energy technologies and could restrain the rate of solar energy deployment.

This section represents a first step in determining the materials constraints to solar energy development postulated in the TASE High Solar Cases during the period 1975-2000. This section focuses on the year 2000 projections by comparing the materials required for TASE model solar energy systems to industrial production levels (1974) for selected materials. The materials intensiveness is also briefly examined by comparing the materials required for solar energy technologies with selected nonrenewable technologies.

Materials Requirements for TASE Model Solar Energy Systems

The amount of materials required to construct and operate the model solar energy system were determined by multiplying the materials coefficient (tons/10^{12} Btu) by the energy supply projections (10^{12} Btu) given in the high scenario. This resulted in the total demand for materials by solar energy technologies.

These materials requirements were aggregated by materials type. A list of those materials most in demand is shown in Table 7.6. Included are steel, concrete, glass, aluminum, copper, and titanium. There are gaps in the information regarding the TASE technology characterizations that make the data in these tables incomplete. For instance, the material and amounts are unspecified for some systems: commercial photovoltaic conversion, incineration of municipal solid waste, direct combustion of cotton residues, agricultural wood stoves, methanol from wood, solar total energy systems, etc. When materials are listed, they are sometimes labeled in such a way as to make it difficult to break them down into components, i.e., pipes, valves and fittings, structural products, wood products. Some materials are not completely specified. What *kind* of plastic? There is also no mention of alternative systems that might be used, such as gallium arsenide or cadmium sulfide for photovoltaic systems. The technology data base does not take into account new materials applications, or replacement of deteriorated or failed materials and system components. These problems notwithstanding, the technology data base does lead us to some conclusions regarding materials resources.

Materials Availability

On a national basis, major markets for solar systems could have a serious impact on industries which compete for the basic materials which are utilized by these systems, i.e., copper, glass, steel and aluminum. On the local level, there could be increased pressures on price and supply for concrete and glass.

TABLE 7.6
Total Materials Requirements For Solar Energy Technologies

	(10^6 MT)				*% of 1974*
	1985	*1990*	*2000*	*1974 Materials Production*	*Production Required in year 2000*
Steel	.97	2.7	9.4	132	7
Glass	.18	.50	1.7	20	8.5
Copper	.04	.08	.24	1.5	16
Concrete	.16	.77	69.2	417	16
Aluminum	.03	.16	.39	4.4	8
Chrome /Titanium	—	.0002	.0054	1.3	1

Many factors must be considered in determining future availability of materials: domestic production and capacity; slowdown of U.S. production and lower costs of imports; foreign dependence on certain materials and minerals; depletion of mineral resources; advances in technologies of manmade materials, etc. Initially, we examined the domestic production and capacity needed to supply the key materials.

The trend in the past few years has been for the U.S. to turn more and more to imports to fill its raw materials requirements, and indications are that the percentage of imports will continue to increase in the future. Steel production, for instance (according to the American Iron and Steel Institute), is expected to decline 5 percent next year. At the same time, steel imports are increasing to fill the gaps in domestic demand. If the U.S. continues its materials imports, it does so at the price of increased dependence on foreign sources of supply and to elements beyond its control: foreign strikes, transportation stoppages, punitive or coervice bargaining, political instability of foreign regions. Copper, lead, zinc, and bauxite are examples of those resources for which we depend on foreign resources and, thus, they could present a potential problem.

Solar energy technologies are substantially more materials intensive than conventional energy technologies. Biomass technologies are more operating residue intensive and are slightly more materials intensive than conventional energy technologies. Figure 7.3 illustrates the relative materials intensity for selected solar, biomass and conventional energy systems. The materials listing are not complete but do allow the reader to compare the materials requirements for selected systems producing the same output. Table 7.6 also lists the 1974 production of selected key materials used in the manufacture of solar and biomass technologies as a percentage of the 1974 production levels. The 1974 product level includes only flat glass.

This analysis is by no means complete. The TASE technology characterization data base should be updated to fill known gaps in data. Additional efforts should be put into the examination of industry trends, focusing on those industries which have experienced either recent growth and declines, and major shifts in the change of their buyer markets (i.e., auto industry steel demand).

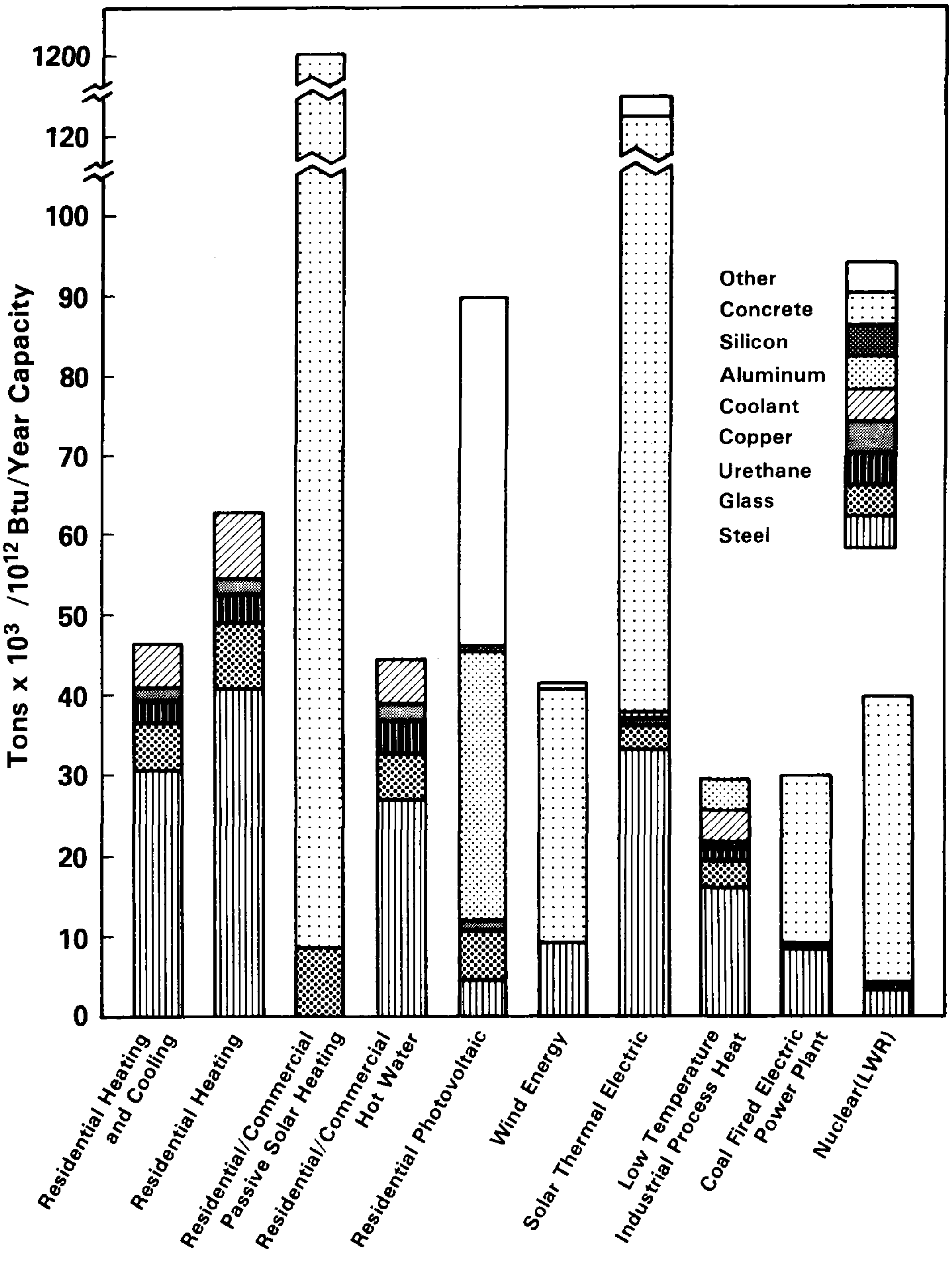

Figure 7.3
Relative Materials Intensiveness of Selected Energy Technologies

Chapter 8

Institutional Framework

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Chapter 8

INSTITUTIONAL FRAMEWORK

Introduction

This chapter identifies the institutional and social issues resulting from deployment of solar-based energy systems.

The materials in this section are not scenario-dependent and thus the findings are not intended to provide an integrated assessment of the potential institutional and social impacts resulting from accelerated deployment of solar energy systems. Rather, they represent a range of possible employment, land use, institutional and social consequences of large-scale commercialization of solar technologies. Since each study appears elsewhere as a separate report, the reader can find a more extensive discussion from these documents.

Summary and Conclusions

Several conclusions can be drawn from the various socioeconomic studies. First, the largest market for industrial solar technology installation is likely to be retrofitting existing plants because of the slow turnover rate in this sector. Second, although there are many institutional barriers to the commercialization of community energy systems, few appear unresolvable. The most challenging may be the problem of expanding the use of cogeneration and municipal solid waste utilization, while at the same time maintaining or improving ambient air quality. Financial subsidies required to make community energy systems competitive, with the exception of photovoltaics, are also not extraordinary. Finally, several categories of social impacts resulting from widespread solar energy use have been identified and correlated to various policy initiatives. Roles have been suggested for DOE in implementing the policies that will maximize public good while minimizing public cost in a transition to extensive use of solar energy.

Institutional Barriers to Commercial Development of Community Energy Systems

The purpose of this study was to identify the barriers that groups and individuals will face when attempting to commercialize community energy systems. The energy systems studied were: municipal solid waste (MSW) ; wind; industrial cogeneration; and residential photovoltaic. Three particular classes of barriers were investigated: 1) those within the organization attempting the commercialization; 2) those that arise from attempts to link the community system with an electric utility; and 3) those that impede the flow of investment capital into community energy systems.

The major conclusions of this study are discussed in terms of organizational, interface and financial barriers.

Organizational Barriers

The need exists for financial assistance to communities to cover the prebonding costs in the development of municipal solid waste (MSW) facilities. These costs may total several million dollars, an amount that few communities have as readily available fiscal resources. Funding of this magnitude generally requires that short-term bonds be issued, notes be secured, or that general revenue resources be increased through taxes. Any action on the part of the community to raise the necessary prebonding funds internally to the community would result in long lead times and would delay the development of the MSW project.

Municipalities may also require the assistance of state or county government to ensure an adequate supply of municipal solid waste to fuel the MSW facility. Economies of scale of construction and operation may dictate a facility that requires waste from more than one community to make the project economically viable. The state or county could establish wasteshed areas for each MSW project.

Public information, educational programs and technical assistance should be made available to local industry to assist them in accelerating the development of cogeneration systems.

Residential homeowners, developers, and the building trades are likely to possess the knowledge and skills necessary to install photovoltaic systems. The development of standardized, mass produced photovoltaic systems will be needed if significant amounts of energy are expected to be supplied by this technology. Since it is not likely that industry will undertake this venture on its own the federal government, electric utility industry or the involvement of some other brokering firm will be necessary to help underwrite its introduction and use.

Interface Barriers

The issues involved in the interfacing of community energy systems with electric utilities have received considerable attention since the passage of the Public Utilities Regulatory Policies Act of 1978. Much progress has been made in terms of developing regulations and purchase prices that make the sale of energy and capacity to utilities an attractive proposition. The Federal Energy Regulatory Commission and a number of state public utility commissions have been very effective in this regard.

Many interfacing issues and regulations remain in a state of flux, and further are quite possible. Most of the recently developed policies were structured with the "firm" types of community energy systems—cogeneration and MSW—in mind. The applicability of these regulations for nonfirm systems such as wind and photovoltaics is uncertain, although it is clear that different provisions will be required in some policies, such as those governing payment for capacity cost.

Several issues appear to be of significant concern in the immediate future.

> First, how reliable must a small power facility be to receive capacity payments? Related to this question are two other issues. Must the power be available during certain periods, and how should capacity payments be made for nonfirm power (at what rate and under what regulations)? Should these small facilities be dispatchable so that the system owner can maximize the capacity payments from the utility?
>
> Second, the level of control that the utility has over a private developer's plans for a new community energy system is also an important issue. Can the utility demand special system protection equipment or other special facilities and if they can, who will decide whether demands for such equipment are reasonable?
>
> Third, there are possible difficulties for cogenerators to obtain exemptions to the Power Plant and Industrial Fuel Use Act of 1978 in order to burn natural gas. An issue is whether the congenerators should pay the same prices and hold the same priority for natural gas that electric utilities do.
>
> Last, who will pay for necessary emissions offsets for new cogeneration and MSW facilities?

Each of these issues will ultimately be decided in a manner conducive to further commercialization of community energy systems. The regulatory process may be slower than some would wish, but little experience exists with interfacing technologies other than cogeneration. It would be unwise to impose regulatory changes whose effects could upset the smooth operation of the large utilities upon which society relies rather heavily. Moreover, rapid changes in the structure of the electricity industry might be unacceptable to political power forces in state legislatures and Congress.

Financial Barriers

The central difficulties that developers of community energy systems face in obtaining sufficient investment capital are (1) the perceived risk of the new technologies; and (2) their relatively high cost compared to the historical cost of conventional power generating facilities. The recent cost increases for fossil fuels have made community energy systems much more competitive, although in most cases fossil fuel power plants still produce cheaper power. However, over the long term, it is clear that fossil fuel supplies will diminish and rise in price. Thus, commercialization of alternatives must be accelerated now, and for this reason, various political bodies are willing to provide public subsidies to accomplish it.

Municipal Solid Wastes. The major financing barriers to the development of municipal solid waste plants are the need to offer higher interest rates to bondholders because of project risk and the possibility of unexpected costs stemming from new emissions control regulations. Federal or state governments could provide guarantees to bondholders, and thus reduce the project risk; or they could provide grants that would directly reduce project cost. Either would make financing an MSW project more feasible, but neither option has yet been enacted anywhere.

Wind. The major financing barrier for wind developers is the lack of startup capital. This problem may be overcome through loans from the Small Business Administration, but the analysis given previously suggests that the funds currently available may be inadequate for this purpose.

Industrial Cogeneration. Cogeneration has received less than maximum investment in the past because its return on investment was considered too low. Because fuel prices have doubled during the past year, this situation has changed. Cogeneration now offers attractive returns and no additional subsidies for it are proposed. However, if tight credit should prevail in the future, the provision of low-interest loans in place of currently available tax credits might be useful.

Residential Photovoltaics. The central barrier to photovoltaics is system cost. If rooftop photovoltaic systems are to become competitive, they will require substantial subsidies in the form of low-interest, extended-term loans, as well as tax credits. The cost per kilowatt-hour or photovoltaic electricity subsidized may run as much as thirty times the cost per kilowatt-hour of cogeneration subsidized, even assuming the DOE's 1985 goal of 50 cents per watt of solar cells is achieved. Of course, an important reason for accepting high photooltaic subsidies is the fact that cogeneration potenial—as well as that of virtually every other source—s limited.

Social Impacts of DPR Policy Initiatives

This section focuses on an investigation of the ikely social impacts of the DPR policy initiatives and dentifies the salient social impacts likely to occur if the policy initiatives are enacted. The investigations also identify the institutional framework for mitigating the impacts. The reader can find a more extensive discussion covering these issues from the Solar Energy Research Institute (SERI) report on the subject.

The objective of this investigation was to identify salient social impacts likely to occur if proposed policy nitiatives are enacted to achieve 20 percent solar energy use by 2000. The Domestic Policy Review (DPR) Response Memorandum Option II Policy Initiatives for solar energy were selected to guide the investigation of likely social impacts (Table 8.1).

In this study, social impacts refer to the changes in society that may occur as a consequence of implementing the DPR Option II policy initiatives. Social changes are shown in the attitudes and behavior of individuals, social groups, organizations, communities, and society. Social changes are dynamic and complex, and may not be immediately evident. While established social values may vary from group to group, the acceptance of a technology and its performance are unquestionably affected by the values of the users. Social changes are difficult to quantify and predict because values are constantly changing.

Study Approach

An inductive strategy was employed to identify and specify social changes. The first activity was to identify known social effects applicable to the development and deployment of energy technologies. This was accomplished through a literature review.

The second activity was to formulate a set of social categories by which to organize social changes. Fourteen categories were identified inductively by noting conceptual similarities among social changes:

1. financial aspects of solar energy decision-making
2. behavior related to energy use
3. land use
4. political institutions
5. impacts on the economy
6. information and education
7. social acceptability
8. consumer demand/protection
9. health and safety impacts
10. employment impacts
11. aesthetics
12. quality of social life
13. impacts on industry
14. international implications

TABLE 8.1
DPR PROPOSED POLICY INITIATIVE
(Maximum Practical Scenario)

	Option II
Residential	
Passive Solar	Tax credit for energy-efficient construction.
Financing	Establish a Solar Development Bank to provide subsidized and unsubsidized residential loans and guarantees.
Low-Income	Two 4-year, $10 million programs to enhance solar use by the poor. Set goals for solar use in HUD housing assistance programs.
Consumer Protection	Enhance existing voluntary testing and certification program; reguire standardized solar product information; develop warranty reinsurance program, if needed.
Tax Credit	Extend investment tax credit to leased property.
Industrial	30 percent tax credit or expansing for solar process heat equipment.
Utility	Enable REA to allocate loans to solar energy systems by modifying REA Act or establishing a Rural Energy Development Fund. Request state public utility commissions to encourage conservation and solar (presidential letter).
Government	
Federal	Require all new civilian Federal facilities to use passive solar design and cost effective active solar systems. Have DOE fund solar costs above cost-effective limit? Demonstrate active systems in highly visible Federal buildings.
State and Local	Give higher priority to energy planning in State Energy Management Programs.

The third activity was to correlate the sets of DPR Option II Policy Initiatives and social change categories to determine the likely effects of each initiative. Each of the nine initiatives was analyzed independently.

Major Findings

Several general issues of particular importance to DOE permeate the findings.

Timing of policy implementation is crucial. From experience with the Energy Tax Act, it has been established that delay in implementing tax incentives, for example, can have disastrous effects on the solar industry.

Incentives for solar energy, in general, can enhance social acceptance of solar energy merely by being put in place by regulatory agencies.

Energy issues can generate new political alliances among existing and emerging special interest groups at local, state, regional and federal levels. DOE must therefore cooperate with other federal agencies that have expertise in these areas, or they must participate in federal programs that may include an energy element.

After taking social impacts into account, some alternative programs are possible.

Utilities

1) Rural Electric Administration (REA) Loan Program
    - Assist in setting guidelines or a loan program, both in establishing the appropriate level of load subsidy and in developing a loan application evaluation format. Contribute funding to REA Loan Program.
    - *Social Impact:* Implies that higher subsidies would be available, making solar energy technologies accessible to a larger range of income groups.
2) Water and Power Resources Service and Army Corps of Engineers: Mission Expanded.
    - Provide technical assistance to the two agencies whose focus has been centralized power generation.

Federal Buildings

1) Work with Office of Management and Budget
    - Provide technical assistance to evaluate cost effectiveness of proposed solar installations.
2) Work with other federal agencies
    - Provide technical assistance to federal agencies that are designing solar applications for specific buildings, whether new or retrofit.

Tax Credit

1) Tax credit for energy efficient construction
    - Cooperate with the National Bureau of Standards to establish building performance standards for passive solar construction.
2) Tax credit to solar equipment leasing companies
    - Establish level of tax credit.
    - *Social Impact:* By itself, this policy is an insufficient incentive to encourage the use of solar energy on rented property. While helpful for owner-occupied property, tenant-landlord relations can be a substantial barrier to using leased solar equipment on rental property.
3) Expanded investment tax credit for industrial and agricultural process heat equipment
    - Assist Internal Revenue Service in establishing eligibility for expanded investment tax credit.

State Energy Management Planning

1) Requires states to develop energy management plans
    - Provide technical assistance to states in energy planning.
    - Provide funding to states for developing energy management plans.
    - *Social Impact:* Requiring state energy management plans for federal funding could seriously constrain local energy planning and projects. More progressive states in energy planning will tend to benefit most from a program such as that outlined in the DPR. The majority of states will require substantial time and financial resources to develop energy plans, possible delaying or terminating local energy activities in those states.

APPENDIX 1

A Technology Assessment of Solar Energy Systems: Assessment of Solar Energy Within a Community; Summary of Three Community Level Studies

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I. Introduction

The Office of the Assistant Secretary for Environment* of the Department of Energy through its Division of Technology Assessments initiated in fiscal 1979 a comprehensive project relating to the extensive use of solar energy technologies. The project, entitled "Technology Assessment of Solar Energy (TASE) systems," will determine the long-range environmental and socioeconomic impacts of solar energy systems.

The primary objective of the TASE Project is to determine the range of potential consequences to the environment and to public health and safety resulting from widespread implementation of major solar resource technologies in accordance with the national estimates set by DOE for the year 2000. The results of the project are intended to assist DOE policymakers in determining the optimum course for solar energy deployment considering public benefits and environmental and socioeconomic impacts.

The overall focus of the TASE Project is to provide impact analysis of various solar technologies at the national, regional and subregional levels. To perform these computations, the Strategic Environmental Assessment Simulation (SEAS) model will be utilized to compare environmental residuals and economic factors resulting from the Domestic Policy Review (DPR) solar base case scenario (year 2000) to the DPR maximum practical scenario (year 2000) and to a base year (1975). Since impacts at the local or community level are inaccessible through a SEAS computation, a series of community-level studies were initiated. Furthermore, since the community level impacts (e.g., land use and institutional requirements) may be greater than state, regional or national impacts with regard to decentralized technologies, these studies are an important continuation to the national level impact assessment.

The community level studies are divided into three task areas: (1) *community impact analysis*, (2) *threshold impact analysis* and (3) *solar city end-state analysis*. The overall purpose of the studies is to investigate the impacts of various solar-based energy systems on the community environment and its physical and social structure. Further, the studies identify issues and constraints to local and regional deployment of decentralized solar technologies. The integrated organization of the studies has been coordinated by Lawrence Berkeley Laboratory. Each of the studies was designed and conducted, for the most part, by outside investigators. The community impact analysis was carried out by a research team from the University of California, Berkeley, and resulted in a report, "Community-Level Environmental Impacts of Decentralized Solar Technologies." The threshold impact analysis conducted by a team from SRI, International (formerly Stanford Research Institute) was issued as a report, "Community Impediments to Implementation of Solar Energy." The end-state analysis was undertaken by the Urban Innovations Group of the University of California, Los Angeles. Its final report was entitled "Three Solar Urban Futures."

The objective of this report is to describe the basic assumptions, methods and findings of each community-level study. The report is organized into the following sections: conclusions, study assumptions and definitions, community-level scenario development and a summary of each task area. Because each of the community studies appears elsewhere as a separate report, this appendix is intended to provide a summary of the major findings and the relationship of these results to the Phase II activities of the TASE project.

II. Conclusions

Several general conclusions emerge from the individual community-level studies. Even though each task area used a different study methodology and format, the results provide some generalized trends that should enrich the overall TASE analysis. The conclusions are related to the scenario and study assumptions and should be viewed as illustration opportunities and impacts and not as projections of a likely urban future.

Land Use Impacts

The first general conclusion is that a community can meet the on-site energy demands assumed by the scenario in all but the most dense land-use sectors (e.g., central business district). In the residential sector, however, this may require removal of 15 to 35 percent of the tree canopy. Further, it may be required that greater than 80 percent of the total area in the industrial sector and about 50 percent of the available commercial parking area be covered with solar collectors.

Community Expansion

Secondly, decentralized solar technologies can produce substantially greater amounts of on-site energy supply than was prescribed by the scenario. Greater solar development can be realized by using "shared neighborhood systems" and by employing passive design in all new buildings. As evidenced in the hypothetical "solar city" (Future 3), a community may become energy self-sufficient if 650 acres of photovoltaic arrays are addded in the commercial sector and 2800 acres of on-site collectors are augmented to the industrial sector.

Institutional Impacts

A third conclusion is that various institutional impediments produce time delays in achieving acceptance of solar technologies within the community structure.

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*Presently Assistant Secretary for Environmental Protection, Safety & Emergency Preparedness.

Most important among those barriers are the acceptance and adoption of solar by residential and commercial building industries, the legal issues of solar access, easements and use of public lands for solar technology installations, and the aesthetic concerns of the public and planning agencies. In order to meet the levels of on-site solar collection that are described in this study, these impediments must be removed.

Building and Urban Design

A fourth general conclusion is that passively designed buildings in future residential, commercial and industrial sectors need not look different from existing versions that consume up to 25 times more energy. However, the overall appearance of a community with a high level of solar development (e.g., large collector areas and tree removal.), may be quite different based on current urban design and aesthetic criteria.

Community-Level Planning

Finally, there are great opportunities for implementing decentralized solar technologies within a community. The implementation, however, will require the integration of urban and energy planning at the local level in order to avoid potential aesthetic, institutional and land use impacts.

III. Study Assumptions and Definitions

To place the analyses of the community-level studies in the proper context, it is necessary to clearly delineate the basic assumptions made by the three task areas. Understanding the assumptions made by the working groups allows proper evaluation of the study results and conclusions. In Table 1, the basic study assumptions are briefly outlined; a discussion of each assumption in more detail follows.

Table A.1
Basic Study Assumptions for the Community-Level Studies

1) Coordinate efforts with the national technology assessment of solar energy (TASE).
2) Use DOE national energy scenarios as a framework for the studies
3) Adapt national energy scenarios to form a community-level scenarios.
4) Use solar technologies, applications and technology characterizations from TASE Phase I.
5) Emphasize decentralized solar technologies.
6) Emphasize analysis of impacts from various solar scenarios rather than emphasizing implementation methods and feasibility.
7) Assume the solar systems are cost competitive with those they replace.
8) Assume no radical changes in lifestyles and institutions.
9) Assume present trends in city form (urban morphology) will continue.
10) Assume the national average land use mix for the prototype communities.

Coordination of Community Level Studies to the TASE Project: Assumptions 1 through 4

The importance of the first four assumptions lies in defining the relationship of the community-level studies to the work being done by the other laboratories for the National Technology Assessment of Solar Energy (TASE) Project. The use of the Department of Energy national energy scenarios will ensure consistency and allow for more reasonable comparisons of the results of the community-level studies with the rest of the TASE efforts. In this respect, assumption 4 concerning the solar technologies and their application and characterizations is particularly important; it delineates the very definition of what constitutes "solar." The purpose of these assumptions was to ensure at the outset of the community-level studies that the utility of work would be increased by the coordination with TASE.

Decentralized Solar Technologies: Assumptions 5 through 7:

The distinctive and innovative nature of the community-level studies is expressed in assumptions 5 through 7. The majority of research in the past has emphasized centralized technologies of the conventional types as well as the feasibility of various combinations of fuel types and sources to meet projected energy demands. The focus of the community-level studies goes beyond this. Even after the feasibility (both technically and in terms of supplies of materials needed to produce solar energy) has been assured, the question remains of how social and environmental problems will interfere with widespread implementation of various decentralized solar technologies. These studies addressed the question of what the impacts of solar scenarios are rather than dealing with technical problems on "how to implement" problems. These assumptions are important and demonstrate that the results of the community-level studies address important problems that exist but have not yet been analyzed.

Special Assumption 8 through 10

The remaining three assumptions (8 through 10) are working assumptions which deal with the practical approach of the three task groups. Assumptions 8 and 9 ensure that the basic continuation of the status quo is considered. Although some drastic or radical changes may be expected to occur, for example, if the price of oil would increase sharply over a short period of time or if some other "energy crisis" were to occur, it is still important to consider the impediments to solar that exist in present society. The resistance to change should not be underestimated. By assuming no radical changes in lifestyle will necessarily happen, the working groups can gain insight into a realistic and probable future. Assumption 10 again provided the tasks with a common starting point which will aid the intercomparison of the results of the three task groups.

In addition to the basic study assumptions, several terms are used in the community-level studies with specific meanings. Decentralized solar technologies" have been defined to include those technologies which can be implemented within communtiy boundaries and are not part of the utility grid.

The following technologies were considered:

—solar heating and cooling (space heating, hot water and air conditioning for residential and commercial buildings)
—photovoltaics (electricity for residential, commercial and industrial buildings)
—wind energy conversion (electricity)
—industrial and agricultural process heat (from biomass and solar thermal conversion)
—biomass conversion (heat for residential and commercial buildings and industrial processes)

The inherent focus of these studies raises the question, "What is meant by community?" Clearly, different aspects of "community" would be relevant to different phases and types of analysis. After discussion in the early joint meetings, it was agreed that each task would need to outline its own definition of community in the context of the work to be accomplished.

IV. Community-Level Energy Scenario Development

Existing energy scenarios, and in particular the interim DPR scenarios available August 1978, could not be precisely allocated to the community level. DPR scenarios describe only the national energy supply and are not directly comparable to the energy flows in a single community. In addition, the community-level studies could not use an *a priori* characterization of the absolute amount of energy flowing through a community or subcommunity element as this was to be, in a large part, a product of the land use patterns, architectural design, and institutional actions defined in the individual tasks. Rather these studies needed as a starting point a description of the *mix* of energy resources used to supply a community.

In order to tie the community level studies as closely as possible to the TASE program, the energy information used by the studies was based on the available DPR scenarios and the TASE technology characterizations. Further, it became clear that the identification of institutional and land-use impacts would be enhanced by the use of a high level of decentralized solar technologies. It was therefore decided to use the interim DPR scenario which allowed the greatest relative contribution of solar technologies as the basic model for the community energy supply mix. The version of the DPR scenarios available in August/September 1978 which met this goal was the $32 per barrel "maximum solar" scenario.

The solar energy supply for each sector (residential, commercial and industrial) was disaggregated into specific TASE technologies by information provided by the DPR staff and available TASE analyses. The resulting picture of sector-by-sector energy supply was converted from the amount of energy contributed by each technology into percent contribution of each technology to the sector's energy needs. This information was grouped into centralized (e.g., central grid) and decentralized technologies. Only the decentralized technologies were listed by their individual contribution. Central technologies were listed collectively as the amount of energy entering a community through this grid. In essence, the community-level scenario was built from the "bottom up" using the national totals as a boundary condition. The resulting community-level scenario is shown in Tables 2, 3, and 4. More important than the specific numbers in this scenario are the following underlying principles.

1) The scenario represents the national average of each sector. Thus, it describes a national average community and not any specific community.
2) The scenario includes contributions from all decentralized technologies. Certainly no one community will use all of these possible supply options.

Table A.2
Residential Energy Mix Scenario

Category	*Total* %
1. *Space heating/cooling, hot water (non-electric)*	
a. *On-Site Solar*	
• solar thermal	23.04
• passive design	6.14
• biomass (wood)	3.52
b. *Other*	
• oil	2.27
• gas	10.60
• synthetic fuel	0.74
SUBTOTAL	46.31
2. *Electric*	
a. *On-Site Solar*	
• wind	1.15
• solar thermal	0.22
• photovoltaics	2.42
b. *Utility Grid*	
• space heating/cooling, hot water	29.87
• other electric	20.03
SUBTOTAL	53.69
TOTAL	100.0
Approximate percent of residential energy provided by decentralized solar energy technologies	36.5

Table A.3
Commercial Energy Mix Scenario

Category	*Total* %
1. *Space heating/cooling, hot water (non-electric)*	
a. *On-Site Solar*	
• solar thermal	10.74
• passive design	2.15
• biomass (wood)	0.45
b. *Other*	
• oil	4.35
• gas	20.61
• synthetic fuel	0.41
SUBTOTAL	38.71
2. *Electric*	
a. *On-Site Solar*	
• wind	1.61
• solar thermal	0.50
• photovoltaics	3.37
b. *Utility Grid*	
• space heating/cooling, hot water	33.37
• other electric	22.44
SUBTOTAL	61.29
TOTAL	100.0
Approximate percent of residential energy provided by decentralized solar energy technologies	18.8

3) The intent of the scenario is not to constrain the design options and impact investigations of each project. Rather the scenario provides a guide for the general level of decentralized solar energy which should be included in the design of each community and its component parts.
4) Technologies sited outside the community (e.g., most biomass and wind systems) are deemphasized since they will not directly impact the community.
5) The transportation sector has been excluded since the DPR scenarios did not provide for solar energy in that sector.

V. Community Impact Analysis*

The objective of this study is to examine the physical, spatial and land-use-related impacts of decentralized solar technologies applied at the community level by the year 2000. The results of the study are intended to provide a basis for evaluating the way in which a shift toward reliance on decentralized energy technologies may eventually alter community form. This project has been conducted in parallel with two related efforts: a study of end-state community design and an analysis of institutional impediments to widespread solar technology implementation.

Table A.4
Industrial Energy Mix Scenario

Category	*Total* %
1. *Process Heat*	
a. *On-Site Solar*	
• solar thermal	12.42
• biomass	9.23
• synthetic fuel	0.0
b. *Other*	
• oil	2.13
• gas	13.84
• coal	6.75
• synthetic fuel	1.12
• central electric	1.42
SUBTOTAL	46.91
2. *Other Energy Requirements*	
a. *On-Site Solar*	
• wind electric	0.26
• solar thermal electric	0.40
• photovoltaics	0.25
• synthetic fuel	1.03
b. Other	
• oil	2.13
• oil	2.13
• gas	13.13
• coal	13.13
• synthetic fuel	2.00
• central electric	20.75
SUBTOTAL	53.08
TOTAL	100.0
Approximate percent of industrial energy provided by decentralized solar energy technologies	23.5

The project assumes that in many physical respects, communities in the year 2000 will resemble parts of cities as they exist today and that the level and types of solar technologies identified by the maximum solar scenario of the DPR will be used. For the purposes of this study, a land-use impact is related to competition for space and, more specifically, to insufficient collector area on site to achieve a particular level of solar penetration.

Land-Use Types

Six land-use types representative of those found in most U.S. cities are analyzed according to solar penetration levels identified in the DPR maximum solar scenario for the year 2000. The scenario is translated into shares of end-use demand in the residential, commercial and industrial sectors. These proportions become the scenario goals to be met by the use of decentralized solar energy systems. The percentage of total solar energy demand is assumed to be 36.5 percent, 18.8 percent and 23.5 percent in the residential, commercial and industrial sectors respectively. The community-level scenario stipulated that a certain percentage of the total demand be met by on-site collection

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*Summary of "Community-Level Environmental Impacts of Decentralized Solar Technologies," Robert H. Twiss, Patricia L. Smith, Scott T. McCreary, and Allan E. Gatzke, 1979.

e.g., photovoltaic and thermal collectors) and by pasive design. This on-site solar goal is 31.9 percent (resdential), 16.8 percent (commercial) and 13.1 percent industrial).

The land-use types evaluated in this study may be hought of as energy sensitive land-use patterns. Paterns studied are single-family detached dwellings and nultiple-family row house apartments in the residenial sector; strip commercial development, warehousng and central business district in the commercial secor; and central-city facilities in the industrial sector. These land-use types vary with respect to end-use denand and density characteristics which influence on-site solar supply. Table 5 identifies the energy demand and density for the land-use types considered in this study.

Solar Supply System

Six different solar energy supply systems ranging from thermal collectors with current output and short-term storage (i.e., two to three days) to cogenerating photovoltaic arrays with long-term storage (i.e., between seasons) are examined. Each of these technologies has a theoretical potential to meet any given mix of end-use demands based on its output of thermal and electrical energy. Table 6 lists the theoretical potential of the selected technology systems. Characteristics of the technology that determine its potential are the storage capacity, quality of energy produced and system efficiency. These factors define the proportion of demand for each land-use type that can be met if the required amount of collector area is available.

Methodology

The method for analysis consists of determining the maximum on-site collector area for each land-use type in the residential, commercial and industrial sectors. This determination includes an evaluation of passive (south wall) design potential and measurements of the available unshaded collector area from aerial photographs. The evaluation of solar potential of each individual parcel is augmented with an estimation of several alternative schemes for sharing collector area among parcels in the neighborhood. The study area as a whole is analyzed to determine the physical impacts likely to occur when achieving the scenario goal and to identify community characteristics of the natural and built environment which affect the ability of the study area to rely on decentralized solar energy technologies. Finally, the percentage of the parcel's total on-site energy demand that can be provided by each technology using the available collector is determined.

Table A.5
ENERGY-SENSITIVE LAND-USE TYPES

Sector[1]	*Density Of Case Study Areas*[2,3]	*Energy Demand/ Gross Acre*[4]
Residential: SFD Single Family Detached Dwellings	8 d.u./acre	$.03 \times 10^{10}$ BTU
Residential: MFD Row House Apartments (multiple family)	31 d.u./acre	$.79 \times 10^{10}$ BTU
Commercial: STRIP Strip commercial development	F.A.R. = 2.3	$.13 \times 10^{10}$ BTU
Commercial: WH Warehousing	F.A.R. = 4.6	$.11 \times 10^{10}$ BTU
Commercial: CBD Central business district	F.A.R. = 6.7	1.00×10^{10} BTU
Industrial: In the industrial sector, central city facilities identified as adaptable to solar energy use by Battelle and ITC (1977) were selected for case study.		

Notes:

[1] These land-use types occur in all large metropolitan areas and comprise most of the residential and commercial land area. The single case study examples of the energy-sensitive land-use types were drawn from three cities in the United States: Denver, Baltimore, and Minneapolis.

[2] d.u. = dwelling unit

[3] F.A.R. = floor area ratio (i.e., ratio floor area to parcel area).

[4] See Report for calculations.

Table A.6
POTENTIAL OF SIX TECHNOLOGY SYSTEMS TO MEET ENERGY END USE DEMANDS

Technology	*Short-term storage*	*Long-term storage*
Thermal collectors with performance comparable to currently available	1. 70% heat 80% hot water 70% cooling[1]	4. 100% heat 100% hot water 100% cooling[1]
Thermal collectors with a 33 percent increase in efficiency and using planar reflectors to increase output 50 percent (50 percent reduction in collector area)	2. 70% heat 80% hot water 70% cooling[1]	5. 100% heat 100% hot water 100% cooling[1]
Cogenerating photovoltaics with 80 percent the output of current photovoltaics and 80 percent the output of current thermal collectors	3. 70% heat 80% hot water 100% cooling 100% power	6. 100% heat 100% hot water 100% cooling 100% power

Notes:

[1] Use of solar thermal air conditioning is assumed only for the commercial sector.

Results

The results of the study are the following.

- Assuming a typical land-use mix of the land-use types studied, a community can achieve the DPR maximum solar goals for the year 2000 using on-site technologies with current performance. Table 7 contains the percent of total energy demand for each land-use type that can be provided by the direct solar technologies.
- Of the individual land-use types, only the commercial central business district cannot achieve the scenario goal on-site. The deficit in the central business district, however, can be more than offset by the ability of other land-use types to achieve a greater level of solar development.
- In the residential sector, low density detached single-family development (i.e., urban sprawl) is not required in order to meet the solar scenario.
- Detached single-family development can achieve greater independence from conventional energy sources than denser residential patterns only by using cogenerating photovoltaic systems with long-term storage.
- Central-city industrial locations would require use of other renewable sources (e.g., cogeneration, wood or municipal residues) in addition to direct solar technologies to meet the solar scenario.
- Decentralized solar technologies can produce substantially greater amounts of on-site energy supply than the DPR scenario projects. The increased levels are limited by the quality and availability of energy supplied by a given technology and by the demand for that particular quality of energy within each land-use sector (see Table 8.)
- Communities will be required to take one or more of the following actions in order to produce increased levels of on-site energy:
  - —select technologies which maximize output of both thermal and electrical energy including use of long-term storage and cogenerating systems;
  - —implement shared energy systems in which a number of individual energy collectors are combined with a single storage facility;
  - —transfer surplus thermal and electrical energy to land-use types deficient in on-site solar potential; and
  - —control land development patterns through land-use regulations to eliminate environmental characteristics that constrain on-site collection.
- Environmental characteristics of a community which reduce available collector area include:

—vegetation
—street configuration
—lot configuration
—density
—roof configuration
—adjacent buildings

Table 9 shows the environmental characteristics which act as limiting factors in the case study areas.

- Environmental characteristics of a community which acted as limiting factors can be elimi-

TABLE A.7
PERCENT OF TOTAL ENERGY DEMAND PROVIDED BY ON-SITE SOLAR COLLECTION FOR FIVE LAND-USE TYPES

	TECHNOLOGY *(with Rooftop Collectors)*	*LAND USE TYPES*				
		Residential		*Commercial*		
		SFD	*MFD*	*STRIP*	*CBD*	*WH*
SHORT-TERM STORAGE	1. Thermal Collectors w/Existing Output	36.5[3]	33.0[5]	32.0	3.6	56.0
	2. Thermal Collectors w/Improved Output	36.5[4]	44.0[5]	43.0	7.2	56.0
	3. Cogenerating Photovoltaics	59.6[5]	62.0[5]	35.0	6.2	78.0
LONG-TERM STORAGE	4. Thermal Collectors w/Existing Output	55.1	46.0[5]	27.0	3.3	65.0
	5. Thermal Collectors w/Improved Output	55.1	66.0[5]	48.0	6.7	79.0
	6. Congenerating Photovoltaics	79.5[5]	61.0	57.0	9.1	93.0
	Scenario Goal[1]	36.5		18.8		
	On-Site Solar Collection Goal[2]	31.9		16.8		

NOTES:

1. Scenario goal for all solar technologies.
2. Photovoltaic and thermal collectors; also assumes some passive design.
3. Assumes removal of up to 35 percent of the tree canopy.
4. Assumes removal of 15–20 percent of the tree canopy.
5. Includes other areas of parcel in addition to rooftops.

TABLE A.8

PERCENT OF TOTAL ENERGY DEMAND MET BY EACH SOLAR TECHNOLOGY ASSUMING UNLIMITED COLLECTOR AREA

	TECHNOLOGY (with Unlimited Collector Area)	*LAND USE TYPES*				
		Residential		*Commercial*		
		SFD	*MFD*	*STRIP*	*CBD*	*WH*
SHORT-TERM STORAGE	1. Thermal Collectors w/Existing Output	40	44[3]	43	39[4]	56
	2. Thermal Collectors w/Improved Output	40	44	43	39[4]	56
	3. Cogenerating Photovoltaics	85	86[3]	86	86[4]	87
LONG-TERM STORAGE	4. Thermal Collectors w/Existing Output	55	66[5]	61	56[4]	79
	5. Thermal Collectors w/Improved Output	55	66	61	56[4]	79
	6. Cogenerating Photovoltaics	99	99[3]	49	99[4]	99
	Scenario Goal[1]	36.5		18.8		
	On-Site Solar Collection Goal[2]	31.9		16.8		

NOTES:

1. Scenario goal for all solar technologies.
2. Photovoltaic and thermal collectors; also assumes some passive design.
3. Ability to meet this level is limited by various environmental factors.
4. Ability to meet this level would require major changes in physical form.

nated by use of shared energy supply systems and long-term storage.

- Environmental characteristics of the community limit on-site collectors primarily in the higher density land-use types (i.e., multiple family residential and central business district).
- Demand for water to meet thermal storage requirements although an impact with each technology is insignificant relative to total water consumption within the community.
- Potentially significant secondary impacts may occur from the disposal of hazardous wastes associated with the working fluids.
- Visual intrusion of solar collectors will be more significant in the central business district, central-city industrial locations, and in high density residential areas than in low density commercial or residential types.
- Meeting the scenario goal in the single-family dwelling case, using on-site thermal collectors, will require the removal of 15 to 35 percent of the tree canopy.

Summary

In summary, the implementation of decentralized solar technology systems to meet the DPR maximum solar goals for the year 2000 will not produce significant physical impacts using even direct thermal technologies with current performance. All but the most dense commercial development (i.e., central business district) can achieve the solar scenario goal without a transfer of surplus thermal and electrical energy from other land-use types. In addition, these technologies can replace substantially greater amounts of on-site energy demand when communities follow various courses of action.

The results of this analysis illustrate that there are identifiable environmental characteristics that individually or collectively limit the community's ability to meet end-use demand. In cases where these characteristics limit on-site collection, their influence decreases when a large number of individual installations are combined into a district system. Implementation of district systems, however, will introduce a new set of considerations involving the integration of future energy planning goals into the broader social and institutional setting.

VI. Threshold Impact Analysis*

Introduction

The main objective of the analysis is to examine the ability of communities and their institutions to progressively absorb changes incurred by adapting to an energy system consisting primarily of dispersed solar technologies. Specifically, the goal is to identify likely institutional community-level impediments to the widespread implementation of solar technologies by the year 2000, and particularly to focus on those impediments causing projected delays of 3 to 5 years or more in deploying any of the solar technologies.

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*Summary of "Community Impediments to Implementation of Solar Energy," Marilyn Duffey-Armstrong and Joe E. Armstrong, 1979.

TABLE A.9
ENVIRONMENTAL CHARACTERISTICS WHICH LIMIT ON-SITE ENERGY SUPPLY[1]

	Energy Supply System Characteristics					
	Individual/ Short-Term Storage			*Shared/ Long-Term Storage*		
NATURAL[3]	*Passive So. Wall*	*Roof*	*Roof*[2] *+ Site*	*(Parcels) Block*	*Study Area*	*Beyond Study Area*
Latitude						
Climate						
Topography						
Obstruction of solar access by vegetation	SFD Strip CBD	SFD	SFD			
BUILT						
Street pattern: Orientation	SFD WH	CBD	CDB	CBD	CBD	
Street pattern: Lot configuration	SFD					
Density: Available collector area relative to required collector area	SFD CBD	MFD CBD	MFD Strip CBD	CBD	CBD	
Density: Building location relative to lot lines	SFD		NFD			
Roof configuration: Area and orientation		SFD				
Obstruction of solar access by buildings	SFD, MFD Strip CBD	MFD CBD	MFD CBD	CBD	CBD	

SFD: Single Family Dwelling (detached)
MFD: Multiple Family Dwelling
Strip: Strip commercial development
WH: Warehousing
CBD: Central business district

1. Blank space indicates that no land use type is limited.
2. Site: Area on parcel not occupied by structures.
3. Latitude, climate and topography which are potential limiting factors did not constrain solar energy supply in the selected land use types.

Methodology

The methodology adopted for the study consists of:

(1) The preparation of a national-level background description of the seven institutional sectors judged most pertinent to solar technology implementation: utilities, finance, community planning, construction, environmental protection, special consumer groups, and legal and insurance interests.

(2) The formulation of a hypothetical city (prototypical city) of 100,000 population, in which a prorated national average of the DPR maximum solar technology scenario for the year 2000 is depicted. Solar technology implementation in the prototypical city includes projected sizes and configurations for each type of technology and approximate magnitudes of the residential, commercial, and industrial solar panel coverages to meet the assigned shares of heat and electrical loads for the city (see Table 10).

(3) The conduct of two one-day workshops with representatives from the seven institutional sectors, each of whom had knowledge of and experience in solar implementation, for the express purpose of identifying the specific difficulties their institutions have with each of the solar technologies.

(4) The conduct of several telephone interviews and site visits to obtain further inputs from geographically dispersed institutional representatives.

Results Presented as Time Delays

The results of the study are presented in two formats. In the first, the findings are organized by the

Table A.10
YEAR 2000
PROTOTYPICAL CITY SOLAR TECHNOLOGY SUMMARY

	Residential	*Commercial*	*Industrial*	*Total City*
Area Acres*	4,000 acres	490 acres	590 acres	11,150
Total solar panel coverage	43% of residences equipped for 70% efficiency	274 acres	466 acres	740 acres + residential
Required Solar Technology Units**				
Wind Energy System Conversion	95(100-kW)	47(200-kW)	5(1-MW)	147
Solar thermal electric	10 (100-kW)	94 16 (100-kW)	4 (1-MW) (or 2 1-MW)	30
Photovoltaic	101 (100-kW)	101 (100-kW)	2 (1-MW)	204
Total Installations	206	164	11	381

* This total includes the 5,110 acres devoted to infrastructure and open space.
**Figures in parentheses indicate generating capacity per unit.

time frames of delays in solar implementation caused by the inherent difficulties a national energy policy would encounter in changing the way a given institution responds to specific solar technologies. Delay categories of 10 years or more, 6 to 8 years, and 3 to 5 years were selected; all were assigned under the assumption that a strong national policy promoting adoption of solar technologies would be in effect.

An assumption is also made that no major U.S. crisis occurs and that institutions will behave in their customary modes of doing buisness. The associations with time frames represent best judgments from the analysis of the past, present, and projected future practices of the institutions involved, and implies the delays that should be expected after effective national-level policies been implemented.

The following three institutional impediments are categorized as the most intractable since delays in achieving acceptance of the solar technologies at a level considered in this study can be expected to be *10 or more years*

- Time delays are perceived in the acceptance and adoption of solar technologies by the residential and commercial building industries. The amorphous nature of the building industry, consisting of numerous relatively independent entities, the lack of vertical integration of the entities, and the personal contact method of doing business all result in time delays of adoption of new technologies and practices.
- Widespread solar technology adoption within a community is unlikely to receive public acceptance until the due process of public hearings, commissions and local planning activities can evolve solar installation designs and siting procedures compatible with local aesthetic standards.
- Legal issues of solar access, easements, use of public lands, and urban infilling all pose significant impediments to achieving the solar goal assumed in this analysis.

Three other institutional barriers, although considered major ones, are judged to be more amenable to policy influence than the previous set. Accordingly, the following have been assigned to the *6 to 8 year impediment* category

- In the near term, financing is a major deterrent to solar implementation, which can be eliminated if national policy firmly supports solar technology. The desired stimulus can take one or both of two thrusts: stimulate market demand for solar with various monetary incentives to the user—rapid depreciation, tax credits, subsidies, and so on—or take a more direct approach by providing government loan guarantees.
- If the solar technologies are to be implementd to the maximum solar scenario of the year 2000, utilities will have to be directly involved in installing, maintaining and controlling residential solar systems. This involvement, which will likely stimulate public resistance, is potentially a major barrier.
- Cooperative/neighborhood-scale installation offer an excellent opportunity to overcome or avoid many of the economic barriers to on-site energy generation and storage. There is little precedent, however, for existing institutional structures to permit or encourage such options to be exercised. Even in new construction arrangements for metering individual use, maintenance and interaction with utilities and local

building codes make shared installations extremely difficult to implement.

The *3 to 5 year category* contains 11 identified impediments. Their assignment to this category was not meant to diminish their potential magnitude or importance; rather, it reflects that they are judged to be readily amenable to change through nationl energy policy. If these issues are not resolved, however, many of the 3 to 5-year impediments could emerge as longer term barriers to wide-spread solar technology implementaiton. The 3 to 5-year impediments are: warranties, professional liability insurance, solar technology standards, utility interface, retrofit markets; utility plans for future capacity, averaging factor for small-scale distribution systems, assistance to local planning and code officials, local planning initiatives, lifestyle changes and maintenance of a viable solar industry.

Results Presented as Community-Level Difficulties

The second presentation format for the study findings constitutes a description of the difficulties, at the community level, associated with implementing each solar technology. Residential and commercial space and water heating are currently the only solar technologies generally installed around the country, and these still represent a very small fraction of the total potential market. Although both the general public and institutions usually support the adoption of these technologies, the implementation rates necessary to reach the goal for the year 2000—on the order of one million new installations and, additionally, and million retrofits per year—are very unlikely to occur without a strong federal policy to speed the process. An underlying concern with all of the solar technologies is the extent to which utilities will be willing and permitted to participate in the installation, maintenance, and control of the equipment.

Other solar technologies—particularly those of a larger scale, such as wind energy conversion, biomass conversion, photovoltaics, and solar thermal—have their own peculiar sets of problems resulting in institutional impediments and implementation delays. These problems include financing, siting, environmental hazards, legal and regulatory issues, and gaining the cooperation of planning agencies and local utilities.

Summary

In summary, the study has assembled the complete array of institutional problems expected to emerge when solar technologies are implemented on a national scale. Since this first phase of the TASE study was designed to deal with solar implementation from a national perspective rather than attempting a regional specification, which is the goal of Phase II, the identified impediments will apply to different degrees in various areas of the country. The study has attempted to identify and provide a basic understanding of th institutions that are most likely to be involved wit solar installations, to provide some understanding the complex ways in which they must interrelate achieve a widespread implementation by the year 200 and by so doing, to provide a framework within whic an effective array of national-level policies can be fo mulated and evaluated to achieve national energ goals.

VII. End State Analysis*

Introduction

The goal of the end-state analysis is to examin the structure of a typical community as it would appea in the year 2025 under varying solar growth assum tions. Transition problems to the year 2025 were e plicitly excluded from this study.

A hypothetical city of 100,000 people is assume to undergo changes with time coincident with the a sorption of solar energy technologies into its commu nity structure. A city is analyzed in its end-state afte a period of growth based on three different energy scen arios. Future 1 specifies that approximately 6 percen of the city's demand is met by solar technologies. It based on a "business-as-usual" scenario which conti ues present supply patterns. This scenario depend heavily on fossil fuels imported into the city. Futur 2 is based on an extrapolation of the DPR "maximu solar" scenario for the year 2000 in which about 2 percent of the city's energy supply is supplied by sola technologies. This scenario depends heavily on im ported electricity. Future 3 represents a hypothetica city that is built *de novo* to maximize the use of sola energy collected on-site. These three versions of th hypothetical city are identical in terms of demograp ics (population and land uses), goods and services pr duced and energy demand. Their differences are com pared in terms of physical layout, environmenta quality, socioeconomics, and quality of life.

Methodology

A hypothetical city was designed to reflect th median characteristics of existing U.S. cities. In eac case, the city consists of prototypical building types i its residential, commercial (including institutional and industrial sectors. The terms of the study exclud transportation energy from consideration. In the res idential sector, four different building types are con sidered: a large and small detached residence, a ro house, and apartments. The commercial/institutiona sector is represented by a midrise office building, small strip commercial building, and a one-story sho ping center. Three versions of each prototypical resi

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*Summary of "Three Solar Urban Futures," Murray Milne, Marv Adelson and Ruthanne Corwin, 1979.

ntial and commercial building type are considered: uninsulated version of a kind common before 1979; standard version satisfying the ASHRAE 90-75 En- gy Standards; and a passive version designed for bet- r solar energy performance. End-use demand is com- ted for each building prototype. The prototypes are en aggregated for each version of the hypothetical ty in proportions calculated to match the given en- gy supply scenarios and assumed demographic nstraints.

Industrial sector energy demand is dominated not y building design characteristics, but by requirements r production and process energy of various qualities. he proportion of this demand that can be met by the ven solar technologies is calculated to meet the given ergy supply scenarios for each version of the hypo- etical city.

esults

The results of the study include the following.

- In Futures 1 and 2, the hypothetical city's residential sector can easily meet the on-site energy collection requirements of the given supply scenario. The total residential roof area required for on-site collection 3.3 percent in Future 1 and 20.2 percent in Future 2 (see Table 11).
- In Future 3, the residential sector can be totally energy self-sufficient (i.e., collecting all needed energy on-site) if there is 80.7 percent coverage of the available residential roof area.
- In Futures 1 and 2 the commercial sector can easily meet the on-site solar energy collection requirements. The total available area in the commercial sector covered with collectors will be 3.9 percent for Future 1 and 16.4 percent for Future 2 (see Table 12).
- The commercial sector in the Future 3 city can collect 67 percent of its energy requirement if about 50 percent of available commercial parking area and 100 percent of the available rooftops are covered with collectors.
- The commercial sector can be energy self-sufficient by doubling the area for photovoltaic arrays. This would require an additional 650 acres of land.
- The industrial sector in Futures 1 and 2 can meet on order to meet the scenario requirements 12.3 percent of the industrial land area in Future 1 and 83.7 percent in Future 2 are covered by solar collectors (see Table 13).
- In Future 3, the industrial sector can collect onsite only for 18 percent of its energy needs. If the industrial area is expanded by 2800 acres of additional land, the sector can meet all its moderate temperature energy (250°F to 600°F) needs.
- If the land area of the city is increased 34.5 percent (from 10,000 acres to 13,450 acres), all three sectors of the hypothetical city can be energy self-sufficient. The resulting energy self-sufficient city of 13,450 acres is still less than the median area (14,780 acres) of 23 existing U.S. cities of about the same population.

Table A.11

SUMMARY OF ON-SITE SOLAR ENERGY PENETRATION IN RESIDENTIAL SECTOR OF HYPOTHETICAL CITY IN 2025

Source of Energy Supply	*Future 1*	*Future 2*	*Future 3*
(Btu's × 10^{12})			
Total Residential Supply	4.948		4.078*
Total "Imported" Supply	4.725 (95.5%)	3.383 (66.4%)	0
Total Collected On-Site	0.217 (4.5%)	1.565 (31.6%)	4.078 (100%)
Housing Stock Distribution			
Uninsulated Versions	29.0%	37.9%	0%
Standard Versions	68.8%	67.7%	0%
Passive Design Versions	2.2%	12.6%	100%
Total	100.0%	100.0%	100%
On-Site Collector Areas (square feet)			
Flat Plate Solar Thermal (@250,000 Btu's/sq. ft./year)	572,000	4,564,000	1,852,000
Photovoltaic Collectors (@34,100 Btu's/sq. ft./year)	733,000	3,519,000	34,280,000
Total Collector Area	1,305,000	8,083,000	36,132,000
Total garage, porch and building roof area for collectors**	39,308,000	39,967,000	44,800,000
Percent Coverage	3.3%	20.2%	80.7%

* If all homes in City 3 are assumed to be passively designed, it is not possible to consume the stipulated residential sector energy holding all other variables (such as number of buildings) constant.

** The increase in area from one city to the next reflects additional roof overhang area in passive design buildings.

Table A.12
SUMMARY OF ON-SITE SOLAR ENERGY PENETRATION IN COMMERCIAL SECTOR OF HYPOTHETICAL CITY IN 2025

Source of Energy Supply	*Future 1*	*Future 2*	*Future 3*
(Btu's × 10^{12})			
Total Commercial Supply[1]	3.540	3.540	3.540
Total "Imported" Supply	3.384 (95.6%)	2.949 (83.3%)	0.97 (27.4%)
Total Collected On-Site	0.156 (4.4%)	0.591 (16.7%)	2.114 (59.7%)
Roof-mounted Collectors[2]			
(Acres)			
Flat plate hot water	17	81	35
Photovoltaic	19	68	396
Subtotal	36	149	431
(% of roofs)	(8.4%)	(34.6%)	(100%)
Collectors mounted above parking lots[3]			
Photovoltaic	0	0	249*
Solar Thermal Electric	0	3	0
Subtotal	0	3	249
(% of parking)	(0%)	(0.6%)	(50%)
Total[4]	36	152	680
(% of available area)	(3.9%)	(16.4%)	(73.3%)

[1] If additional 650 acres of on-site collectors are added to the 1000 acres in commercial sector, it can become energy self-sufficient.

[2] Total area available in roof area = 431 acres.

[3] Total area available in parking area = 497 acres.

[4] Total area available in commercial sector = 928 acres.

Table A.13
SUMMARY OF ON-SITE SOLAR ENERGY PENETRATION IN INDUSTRIAL SECTOR OF HYPOTHETICAL CITY IN 2025

Source of Energy Supply	*Future 1*	*Future 2*	*Future 3*
(Btu's × 10^{12})			
Total Industrial Supply	19.90	19.90	19.90
Total "Imported" Supply	18.87 (96.6%)	17.05 (85.7%)	16.28 (81.8%)
Total Collected On Site	0.67 (3.4%)	2.85 (14.3%)	3.62 (18.2%)
On-Site Collected Energy Sources			
(Acres)			
Total Energy (Solar Thermal and Solar Thermal Electric)	47	63	200
Parabolic Trough & Solar Thermal Collectors	27	180	200
Flat Plate Hot Water Collectors	—	216	200
Photovoltaic Collectors	—	43	—
Subtotal On-Site Collection	74	502	600
% of Industrial Land Area Covered by Solar Technologies	12.3%	83.7%	100%

[1] If additional 2800 acres of on-site collectors are added to the 600 acres in the Industrial sector, all energy demands except for high temperature (greater than 600°F) industrial processes can be accommodated.

Summary

It is concluded that these results can be achieved without major shifts in urban form, density, or municipal operations. For example, passive solar residences need not look different from conventional houses, and passive solar space commercial/institutional buildings may be virtually indistinguishable from existing versions that consume up to twenty-five times more energy. The most obvious difference in the physical appearance of the commercial sector in Future 3 will be covered parking areas supporting solar collectors. The industrial sector of the Future 3 city will be the most different in appearance compared to today's city.

On balance, environmental quality is not expect
to be compromised. Two trends are perceived as o
proceeds from Future 1 to Future 3. The first is a d
crease in hazards and pollutants from transporting a
burning fossil or synthetic fuels, and land required f
electrical transmission. Second, an increase in tho
hazards and pollutants is postulated to result from t
use of solar systems. Finally, few socioeconomic, li
style and quality of life consequences are identified
the physical changes introduced, or from the sol
equipment used. It should be noted, however, that
major assumption of the overall study is that trans
tional problems are specifically excluded.

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