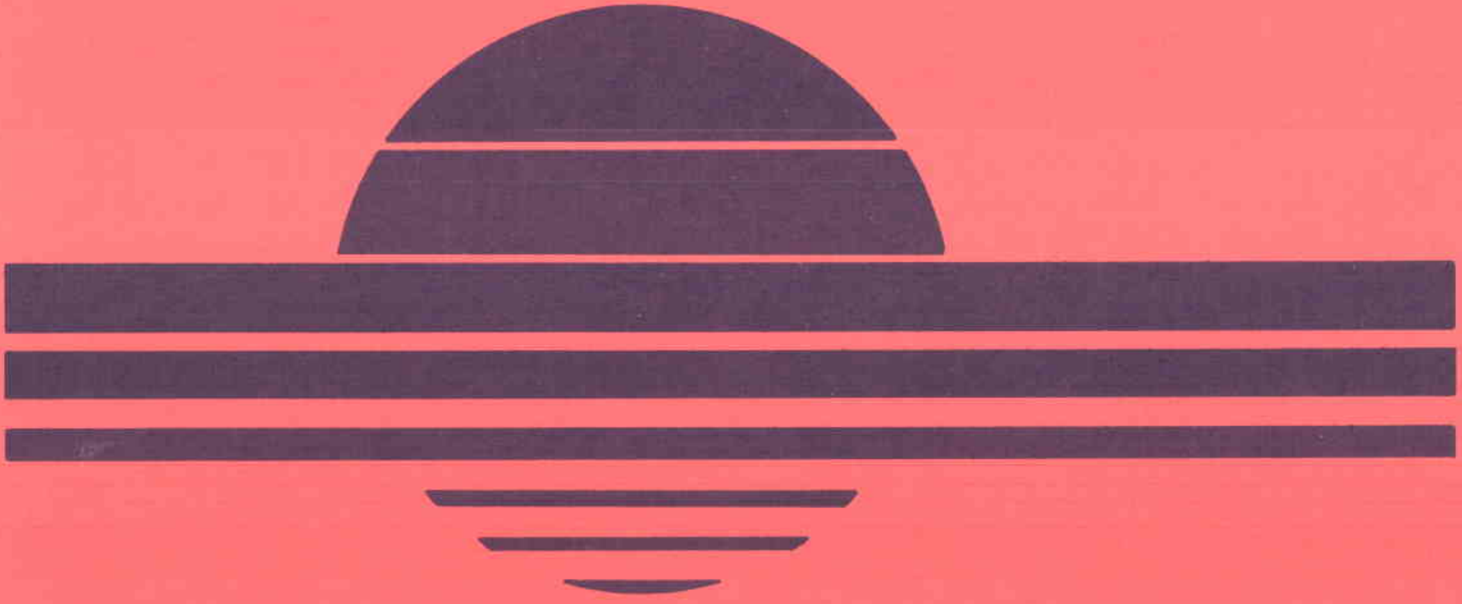
DOE/ET-0062

SOLAR ENERGY

A STATUS REPORT



U.S. Department of Energy

JUNE 1978

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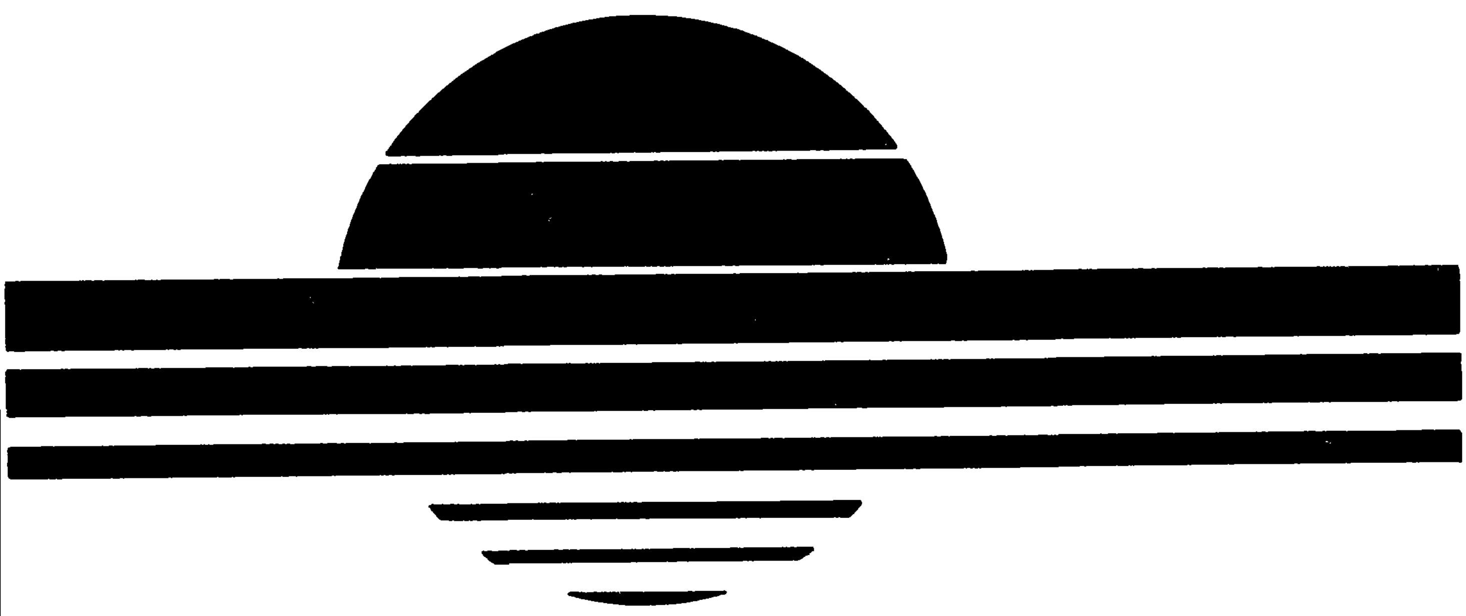

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PREFACE

President Carter, in his address at the Solar Energy Research Institute on Sun Day 1978, cited a recent study of solar energy potential conducted by the Council on Environment Quality. In this study, it was estimated that one-fourth of our energy demands could be met by solar energy by the turn of the century and more than one-half by the year 2020. The President stated, "we must continue to make progress toward these goals." In that same address, the President also ordered a Domestic Policy Review of solar energy for the purpose of developing "an overall solar strategy for speeding the use of solar technologies." This review is to be completed by September 1, 1978, and is the responsibility of a cabinet level Solar Energy Policy Committee chaired by Secretary Schlesinger of the Department of Energy.

A series of regional forums is planned to respond to the need for broad national involvement in the Policy Review. Participation is being invited from a national cross section including the general public, Congressional members, representatives of state and local government, industry, labor utilities, and consumer and public interest groups.

In anticipation of this review, the Department of Energy (DOE) has prepared this document to present an overview of the current status and potential of solar energy, and to solicit comments on the broad range of issues which the public feels should be considered by the Solar Energy Policy Committee. In addition, this document describes various public, industrial, and government-funded studies and developments. Its primary emphasis is on programs and policies directly associated with the Department of Energy. While this document is not exhaustive, the DOE feels it can help provide a starting point for this Policy Review.

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INTRODUCTION

The national security and economic problems posed by increasing U.S. dependence on imported fuels established a clear need for the rapid development and use of alternative domestic energy sources. Solar energy has the potential to provide a significant part of the nation's energy requirements. Recent trends in the development of solar technologies have pointed toward declining costs, improved performance, and broader public acceptance. These trends suggest that now is a useful time to review the direction of solar energy development in the United States and to develop a national solar strategy.

Energy policy decisions made today will have a profound effect on the eventual application of solar energy and the pattern of overall energy use for years to come. It is essential to understand the contribution that solar energy can make to the nation's energy supply. It is also important to understand the social, economic, environmental, as well as other impacts that an expanded use of solar energy will produce. The Domestic Policy Review of Solar Energy is designed to generate initial answers to these questions.

Background

The energy problem that now faces the United States, which is expected to intensify in the 1980's, results from the divergence between its historically increasing energy demand and its decreasing domestic production of oil and natural gas. To solve its long term energy problem, the nation must undergo a major transition from dependence on oil and gas to dependence on renewable and inexhaustible energy supplies.

Historically, the United States has depended on technological progress to solve many of its problems. There is hope that technological developments will provide long-term solutions to the energy problem. However, in the energy field, technologies often develop slowly. America has experienced two major energy transitions in the past, but in very different circumstances (see Figure 1). After the Civil War, wood, waterwheels, and windmills largely gave way to coal. Although these resources were abundant, technological progress made it feasible and economic to use coal for railroad transportation, for industrial process heat, and for home heating. As a result, coal supplied more than half of the United States energy needs from about 1885 to about 1940. In the period following World War II, the pattern of energy consumption changed significantly: natural gas increased from 14 percent to 39 percent of the total energy consumption, while coal dropped from 51 percent to 24 percent.

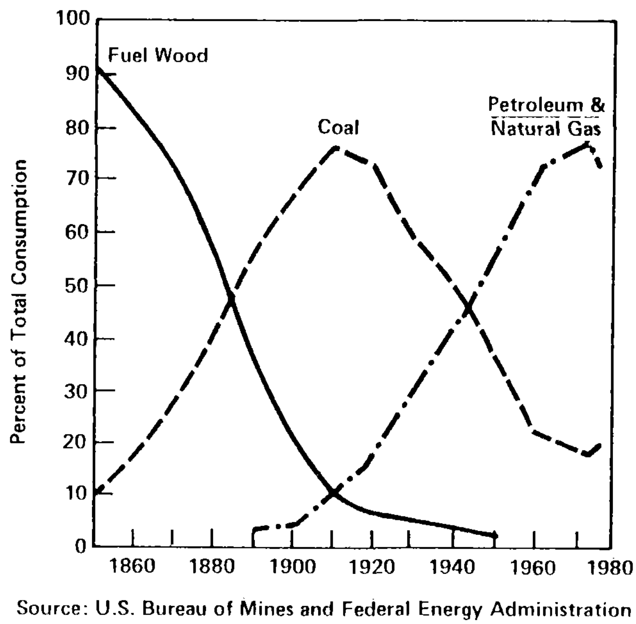


Figure 1. United States Fuel Use Patterns

These changes of about 25 percentage points occurred during a period when there was relatively little concern about availability of energy supplies. During the 1950's, the relative contribution of coal continued to decline and oil and natural gas became America's dominant energy sources. This second transition resulted from technological progress, as well as the lower cost, cleanliness, and ease of handling of oil and natural gas.

The National Energy Plan[1] states that the coming energy transition can be made in stages. In the short term, from now until 1985, the United States can reduce its rate of energy demand growth in general and for oil in particular, reallocate natural gas to high priority uses, increase the use of abundant conventional energy sources, and build up the Strategic Petroleum Reserve to protect against another interruption of foreign oil supply. During this period the U.S. can also begin to adjust its stock of capital goods to consume energy more efficiently.

[1] Executive Office of the President, The National Energy Plan (Washington, D.C., Government Printing Office), 1977.

After the year 2000, America's hope for energy to sustain a healthy economy rests, in large measure, on the development of renewable and essentially inexhaustible sources of energy. Principal among these renewable sources is solar energy, which has the potential to meet a significant share of the U.S. energy needs with minimal environmental impacts.

Solar Energy

Solar energy takes many forms. It can be tapped through innovative architectural design, it can be gathered by collectors for heating and cooling, it can be concentrated for intermediate and high temperature applications, it can be converted directly into electricity, and can also be utilized indirectly in the form of wind, falling water, various forms of biomass including forest products, and ocean temperature gradients (Figure 2).

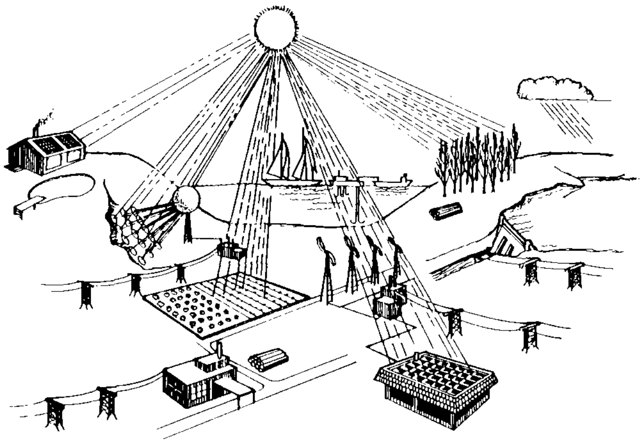


Figure 2. Solar Energy Conversion Processes

The amount of solar energy that reaches the earth's surface in 2 weeks is equivalent to the energy in all known fossil fuel reserves. Nevertheless, use of this abundant energy source at present is very modest. In the U.S., indirect solar sources (hydropower, combustion of biomass) account for only 5 percent of the national energy supply. Worldwide, the figure is about 15 to 20 percent.

However, efforts are beginning to develop the broad range of solar applications. Some technologies, such as passive solar design, combustion of biomass, and active solar hot water and space heating, are economic in many regions now. Others, such as biomass conversion to liquid and gaseous fuels, and solar technologies for generating electricity, require further technical development, but hold great promise for the future. Each of these technologies is discussed in detail in Appendix A, which also discusses current DOE program plans for renewable energy technologies.

STRATEGIC SETTING

BACKGROUND

Prior to 1974, Federal budget for solar energy represented a low-level effort in basic and applied research that was oriented towards very long-term technology development and implementation. This appeared to be an appropriate strategy at the time because energy prices were low compared to solar energy costs, security of supply was not a major issue, and energy-related environmental concerns were still emerging.

The recent growth in the solar budget is shown in Figure 3. From $1.2 million in 1971 the budget is expected to increase to more than $500 million in 1979. This budget growth reflects greater emphasis on solar energy and a revision in basic program strategy. Prior to the centralization of Federal energy responsibilities in DOE, the Energy Research and Development Administration (ERDA), and the Federal Energy Administration (FEA) pursued separate but integrated solar strategies. FEA, responding to a near-term energy focus in its charter, maintained a limited solar effort aimed at market incentives for heating and cooling. ERDA, on the other hand, carried out the principal solar research, development and demonstration effort. The primary goal of the Research, Development and Demonstration (RD&D) program was to stimulate and work with industry to develop and introduce economically competitive, environmentally acceptable, and operationally safe solar energy systems to meet a significant fraction of the national energy requirements at the earliest possible date. The strategy was to lower cost and improve reliability to the point where natural economic forces would achieve expeditious commercialization. This Federal strategy has the following elements:

a. To define all feasible opportunities for displacing critical exhaustible resources such as oil and natural gas, and provide an early institutional and economic environment favorable to the adoption of solar systems;
b. To support research and development by industry that will lead to cost-effective solar systems;
c. To reduce solar system costs to levels competitive with costs of conventional systems;
d. To examine total costs of energy sources, both economic and noneconomic;
e. To accelerate market development through procurement and demonstration programs that stimulate establishment of a manufacturing, distribution, and servicing capability;
f. To perform studies on major policy issues relating to utilization of solar energy, and recommend new policy initiatives.

The DOE has separated solar energy programs into solar technology development and solar applications. Table 1 shows the solar program split for the fiscal budgets of 1977, 1978, and the proposed 1979 budget.

Support for DOE solar programs is provided by the Solar Energy Research Institute (SERI) and by four Regional Solar Energy Centers. SERI was established by the Solar Energy Research, Development and Demonstration Act of 1974 and began operations in 1977. It supports research, development and demonstration of solar energy technologies which have a high potential for commercialization. The primary mission of the Regional Solar Energy Centers is to assist states and local municipalities as well as the general public working with DOE to commercialize their solar energy approach, to identify markets, and to support demonstration activities.

During fiscal year 1978, DOE began a pilot regional program of grants for appropriate technology. The purpose was to encourage individuals and small businesses to prove the feasibility of new, small-scale technologies that conserve depletable resources or use renewable energy resources. The program started as a pilot effort in one region of the country. The intent was to distribute $500,000 in small grants (less than $20,000). Over 1100 proposals were received and are being evaluated. Plans are now underway to expand this program nationwide with funding increased to $5 million.

STRATEGIC STUDIES

A number of strategic studies for solar energy deployment have been developed. The results often differ because the basic assumptions, methods, and goals of the studies are different. Nevertheless, there is a general consensus among energy analysts that conventional energy resources such as oil, gas, coal, and uranium are physically limited and, except for coal, are approaching exhaustion, albeit at different rates. Where there is disagreement, it centers on the estimated economically recoverable limits of the various resources. Some analysts argue that the combined oil and gas resource base is sufficiently large to

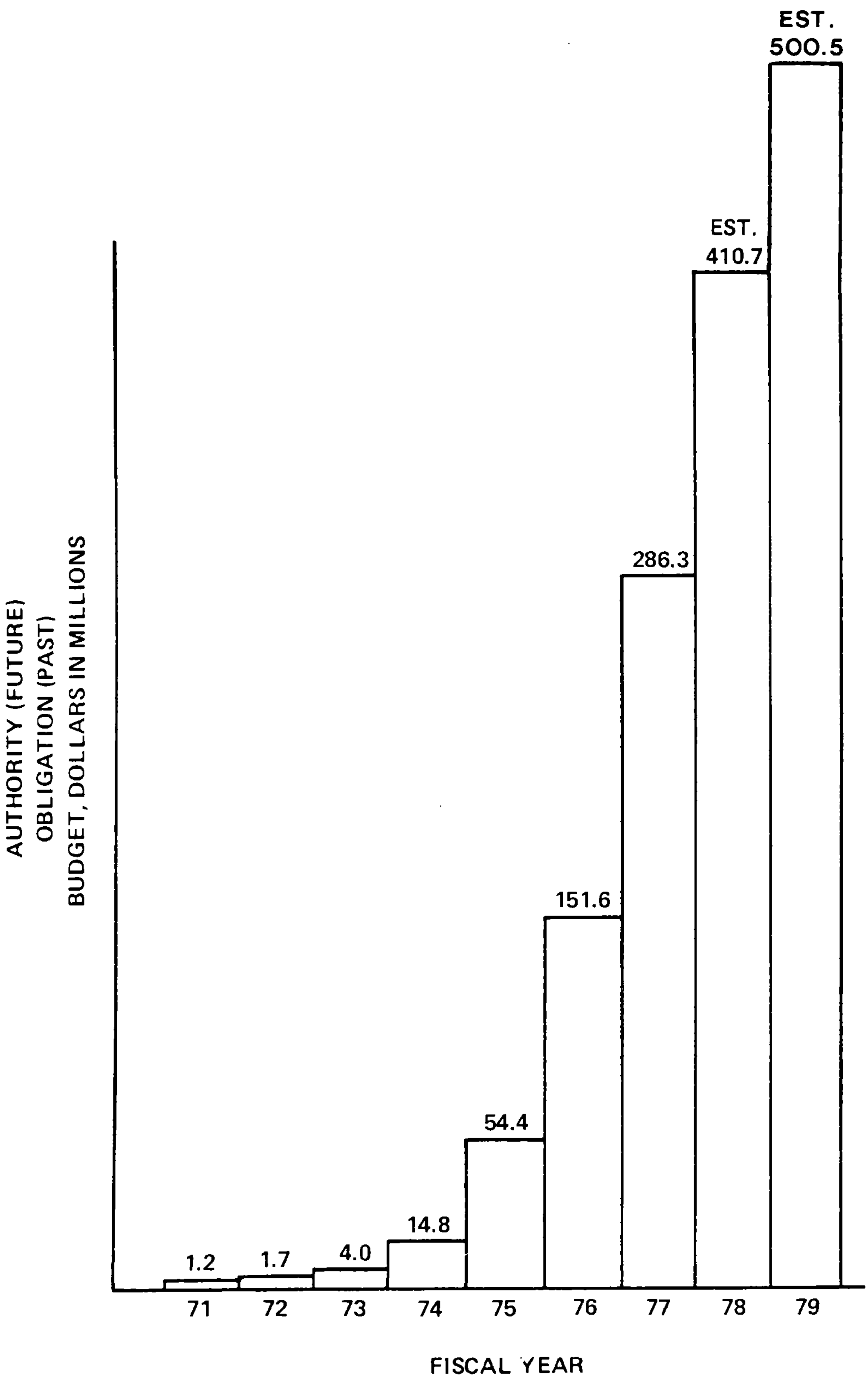


Figure 3. Solar Energy Budget Growth

Table 1. Solar Energy Programs and Budgets

I. SOLAR APPLICATIONS

SUBACTIVITY	BUDGET AUTHORITY (DOLLARS IN MILLIONS) ACTUAL FY 1977	ESTIMATE FY 1978	ESTIMATE FY 1979
A. MARKET DEVELOPMENT	2.6	4.4	5.7
PLANNING	1.6	1.4	2.7
*ENVIRONMENTAL & RESOURCE ASSESSMENT	–	–	–
TECHNOLOGY TRANSFER	–	2.0	2.0
BARRIER & INCENTIVES	1.0	1.0	1.0
B. SOLAR HEATING & COOLING OF BUILDINGS	90.6	115.9	95.8
RESEARCH & DEVELOPMENT	14.9	18.5	22.1
SUPPORTING DEVELOPMENT	12.0	11.0	11.0
DEMONSTRATIONS:			
COMMERCIAL	38.2	38.4	24.5
RESIDENTIAL	23.8	26.0	11.5
FEDERAL BUILDINGS	0	20.0	25.7
PLANT & CAPITAL EQUIPMENT	1.7	2.0	1.0
C. AGRICULTURE & INDUSTRIAL PROCESS HEAT	8.5	10.3	11.0
AGRICULTURE	2.4	2.8	3.0
INDUSTRIAL	6.1	7.5	8.0
SUBTOTAL: SOLAR APPLICATIONS	101.7	130.6	112.5

II. SOLAR TECHNOLOGY

SUBACTIVITY	BUDGET AUTHORITY (DOLLARS IN MILLIONS) ACTUAL FY 1977	ESTIMATE FY 1978	ESTIMATE FY 1979
A. SOLAR ELECTRIC	160.5	253.3	250.0
SOLAR THERMAL	66.6	104.1	100.0
PHOTOVOLTAICS	54.9	76.5	76.1
WIND	24.4	36.7	40.7
OCEAN THERMAL	14.6	36.0	33.2
B. FUELS FROM BIOMASS	9.5	20.8	26.9
ANAEROBIC DIGESTION	1.6	1.6	2.2
FERMENTATION	1.3	3.5	3.6
THERMOCHEMICAL	2.8	6.8	12.0
PRODUCTION & COLLECTION	2.9	7.2	7.6
SUPPORT	0.9	1.7	1.5
C. TECHNOLOGY SUPPORT & UTILIZATION	14.6	6.0	11.1
*ENVIRONMENTAL & RESOURCE ASSESSMENT	6.2	6.0	6.5
SATELLITE POWER SYSTEMS	0.5	2.3**	4.6
TECHNOLOGY TRANSFER	5.3	–	–
SERI (START UP)	2.6	***	***
SUBTOTAL: SOLAR TECHNOLOGY	184.6	280.1	288.0
DOE SOLAR TOTAL	286.3	410.7	400.5 ****

NOTES: *ENVIRONMENTAL & RESOURCE ASSESSMENT IS A JOINT EFFORT BETWEEN SOLAR APPLICATIONS AND SOLAR TECHNOLOGY WITH FUNDING REFLECTED UNDER SOLAR TECHNOLOGY

**NOT ADDITIVE – FUNDS SUPPLIED BY NASA.

***PROGRAM COSTS INCLUDED UNDER TECHNICAL PROGRAMS – $10M FY 78 AND $25M IN FY 77.

****FY 79 Budget Estimate does not reflect the $100 million proposed increase as announced by President Carter on May 3, 1978.

preclude the need to accelerate the energy contributions of solar and other inexhaustible resources. Other analysts suggest that our oil and gas resource bases are depleting rapidly and will be virtually exhausted by the turn of the century. Some suggest that coal reserves are very extensive and could indefinitely delay the need for widespread dependence on solar technologies. Still other analysts argue that coal, while abundant, should not assume a larger energy role because of adverse environmental and climatological effects. Similar issues are raised regarding the limitations on nuclear power, due either to environmental concerns or uncertainty surrounding the availability of advanced reactors.

Many strategic studies are based primarily on economic considerations, assuming little or no change in consumers' tastes, or in policies affecting the pricing of conventional fuels and solar energy technologies. To varying degrees, the studies are based on assumptions regarding the extent to which Federal research and development programs are successful in reducing the cost of Federal technologies. Most of the economic models have the capability for estimating the energy impact of Federal economic policies such as solar tax credits.

Public preferences for energy technologies are not determined by market forces and Federal programs alone. Concern over the "side effects" of technological development has become a significant factor in the public decision-making process. As a result, technologies must be screened against a set of environmental and social concerns which can limit the range of possible choices, and which are not fully reflected in energy market prices. These concerns fall into three broad categories:

a. Environmental: Effects on the physical environment; human health and safety; requirements for land, water, and other nonfuel resources; and effects on climate.
b. Social: Potential for catastrophic occurrences; impacts on national security and employment; changes in lifestyle.
c. Political: Degree of preceived individual control over the development and use of energy technologies, institutional and regulatory constraints, research and development priorities, and state/local government roles.

Difficulties experienced by conventional energy supply technologies in addressing some of these concerns have led, in part, to the growing public support for solar energy.

Several recent studies provide a useful starting point for development of a national solar strategy. The Council on Environmental Quality (CEQ)[1] has just completed a report which concludes that solar energy could contribute up to 25 percent of the nation's energy needs by the turn of the century. The report goes on to suggest that this goal could be achieved by a strategy that includes: a) major conservation efforts; b) increased financial and tax incentives, large Federal buys and removal of institutional barriers; c) emphasis on decentralized energy systems; d) fossil and nuclear energy prices increased to replacement cost levels; and e) vigorous government marketing and promotion of solar systems.

At Congressional direction, the Office of Technology Assessment (OTA) has assessed the potential for small-scale and direct solar energy.[2] OTA's basic finding is that this form of solar energy must be considered a serious future energy supply option. A strategy examined by the OTA report includes: a) reducing the cost of producing or purchasing solar equipment by incentives to purchasers, Federal purchases, incentives to manufacturers, and development of performance standards; b) increased solar R&D; c) removal of barriers; and d) foreign assistance programs involving solar energy.

A CONAES[3] panel report considered both a high and a low solar penetration scenario. The low solar case (less than 5 percent solar in 2000, excluding hydro and biomass combustion) is typical of most studies relying on conventional economic models. It assumed that solar systems would be more expensive than conventional systems, except for space and water heating and a few agricultural applications. This assumption was set in a strategic framework that was characterized by: a) the creation of the industrial and institutional base for conventional fuels to significantly enhance near or mid term supplies and b) developing back-up options based on conventional fuels that can be deployed rapidly. The CONAES high solar energy penetration case estimated a solar contribution of 10 percent in the year 2000 (excluding existing hydro and biomass use), based on mandated use of solar energy in many applications.

In another analysis, Hayes suggests that five-sixths of the world's energy budget could be met with solar technologies by the year 2025.[4] This analysis stresses the importance of solar technologies as substitutes for fossil fuels, primarily because of the possible irreversible climatological effects of increased CO_2 in the earth's atmosphere. This analysis rests on a strategy that includes: a) substantial emphasis on passive solar heating and cooling of new buildings, with active solar as a supplemental measure; b) the use of renewable fuels derived from biomass; and c) the use of wind, hydro, and photovoltaics for electricity.

[1]Council on Environmental Quality, "Solar Energy: Progress and Promise," April 1978.
[2]Office of Technology Assessment, "Application of Solar Technology to Today's Energy Needs," May 1978.
[3]National Academy of Sciences Committee on Nuclear and Alternative Energy Systems, Final Report of the Solar Resource Group, February 1977.
[4]Denis Hayes, "The Solar Energy Timetable," Worldwatch Institute, May 1977.

The complex interactions between energy systems, economic, and social criteria have been raised in Lovins' work "Soft Energy Paths."[1] His strategic approach emphasizes the social and political criteria that shape energy system choices. It also emphasizes the importance of economic factors that account for the total social, environmental, and other structural costs that are frequently absent or not fully represented in present energy market prices. It suggests that a strategy to internalize these costs would result in the majority of U.S. energy needs being supplied by solar within 50 years.

Many studies have addressed the potential impact of solar energy. A summary of 11 of the studies which are most frequently referenced is presented in Table 2. This tabulation shows the primary energy in quads and in percentage of the total national energy demand that can be replaced by solar energy in the years 1985, 2000, and 2020. A description of each of these studies, as well as the assumptions and some of the limitations of the projections, is discussed fully in Appendix B.

Table 3 provides a range of the projected impacts for nine solar technologies in the year 2000, as evaluated by these 11 studies. A discussion of the factors contributing to these projections, as well as the estimated impacts of each of the nine solar technologies in 1985 and 2020, also are listed in Appendix B.

Both tables illustrate the wide variations in the projected impact of solar energy. This variance results primarily from the differences made in such key assumptions as: a) population and energy demand trends; b) projected availability and price of conventional energy supplies; c) projected costs of the various solar alternatives; d) the impact of conservation; and e) changes in living patterns. One purpose of this Domestic Policy Review is to clarify the uncertainty surrounding many of these fundamental assumptions, in order to provide a firmer base from which to develop a realistic solar energy strategy.

DEVELOPMENT OF A NATIONAL SOLAR ENERGY STRATEGY

The development of a solar energy strategy must take place within the framework of the nation's total energy strategy. It must be consistent with the key energy policies and must be designed to achieve its objectives. In the National Energy Plan, the President set forth three overriding energy objectives for the nation:

1. An immediate objective that will become even more important in the future is to reduce dependence on foreign oil and vulnerability to supply interruptions.
2. In the medium term, to keep U.S. imports sufficiently low to weather the period when world oil production approaches its capacity limitations.
3. In the long term, to have renewable and essentially inexhaustible sources of energy for sustained economic growth.

The plan also defines five strategic guidelines for achieving these objectives:

1. Conservation and fuel efficiency.
2. Rational pricing and production policies.
3. Reasonable certainty and stability in government policies.
4. Substitution of abundant energy resources for those in short supply.
5. Development of nonconventional technologies for the future.

These objectives, guidelines, and the present status of Federal solar programs provide a starting point for this review. Development of a national solar strategy will occur in the context of a complete national energy strategy reflecting broad national concerns, ans will recognize the characteristics and capabilities of other energy forms to contribute to national objectives. The Federal role has emphasized supporting the RD&D required to bring solar technologies to commercial viability. To date, most of the dollars invested in solar research have been allocated from the Federal budget. However, state governments are also beginning to support RD&D in solar energy as well as economic measures to accelerate the use of solar energy. In addition, industry is showing increasing willingness to cost-share in the development of solar energy systems. As solar technologies near commercial readiness, the Federal government needs to assess the nature and amount of support that is needed to make solar energy available in the marketplace.

All of these considerations provide the strategic setting for the Domestic Policy Review.

The review is a response to: 1) a new set of energy realities experienced by the United States; 2) increasing public concern with the social and political (non economic) and environmental characteristics of energy supply systems, and 3) the new technological opportunities that exist for use of solar energy. The past few years have been dynamic ones in terms of Federal support for solar RD&D, solar technological development, and public interest in, and attitudes toward solar energy. Although many solar technologies are not economically competitive with conventional fuels today, it is clear that solar energy is an important op-

[1]Amory Lovins, Soft Energy Paths–Toward a Durable Peace, Ballinger Publishing Co., Cambridge, Mass., 1977.

Table 2. Summary of Projected Solar Impacts

QUADS DISPLACED
(Primary)

Scenario	1985			2000			2020		
	Total	Solar (1)	Percent	Total	Solar (1)	Percent	Total	Solar (1)	Percent
Mitre SPURR NEP	86	.20	.2	115	6.0	8.0	189	35.4	18.7
Mitre SPURR RTS	85	.09	.1	113	5.0	4.4	188	24.7	13.1
SRI-Reference Case	99	2.0	2.0	145	6.0	4.1	198	11.0	5.6
SRI-Solar Emphasis Case	99	5.0	5.0	148	15.0	10.1	204	44.	22.
SRI-Low Demand Case	79	2.0	2.5	89	7.0	7.9	102	14.	13.7
Solar Working Group -									
with Behavioral Lag	90	.4	.4	115	8.1	7.0	140	19.1	13.6
without Behavioral Lag	90	2.5	2.7	115	8.8	7.7	140	19.5	13.9
MOPPS	94.6	1.2	1.3	117.3	2.8	2.4	-	-	-
IERPS	-	-	-	132.5	5.8	4.3	195.5	29.5	15.0
Lovins (2)	95	5.	5.3	108	40	37.0	76.	70	92.0
NSF/NASA	117	.4	.4	177	11.8	6.6	300	109.	36.0
Project Indep-B.A.U.	120	.8	.7	180	10.8	6.0	-	-	-
- Accelerated Solar	120	1.4	1.2	180	38.8	21.3	-	-	-
CONAES - High Solar	98	3.0	3.0	146	14.0	9.6	-	-	-
- Low Solar	98	0.0	.0	146	0.1	.1	-	-	-
ERDA-49	100	.8	.8	150	10.	6.7	180	45.0	24.1
CEQ-April 1978 (3)	-	-	-	100	24.5	24.5	105	45.0	43.0

(1) Solar components exclude hydropower. Some studies also exclude the current biomass consumption.
(2) Includes all soft technologies.
(3) Mid range of CEQ estimates for each technology.

Table 3. 2000 Impacts for Nine Solar Technologies
(Quads-Primary Energy)

Solar Technology[1/]	Mitre SPURR NEP	Mitre SPURR RTS	SRI Ref.	SRI Sol. Emph.	SRI Low Dem.	SWG w/B.L.	SWG wo/B.L.	MOPPS	IERPS	NSF/ NASA	CONAES High Sol.	CONAES Low Sol.	Proj. Ind. BAU	Proj. Ind. Acc. Sol.	ERDA 49	CEQ (mid point)
Heating and Cooling of Buildings	1.60	.90	5.0	9.0	6.0	4.0	4.1	.71	.95	2.10	4.25	.00	2.30	3.5	2.00	3.0
Agricultural and Industrial Process Heat	1.60	.90	0.0	0.0	0.0	0.0	0.0	.02	2.27	—	2.67	.00	—	—	1.00	3.5
Total Energy Systems	—	—	—	—	—	—	—	.06	.15	—	.50	.00	—	—	—	—
Photovoltaics	.04	.15	—	—	—	0.	0.	.11	.27	1.50	1.10[2/]	.00	1.50	7.0	1.88	5.0
Wind	1.70	2.20	—	—	—	2.0	2.3	.10	.31	.76	1.40	.00	4.00	5.0	1.25	6.0
Solar Thermal Electric	.30	.22	—	—	—	0.	0.	.10	.24	.76	.20[2/]	.00	.60	1.3	1.25	1.0
Ocean Thermal Energy Conservation	.01	.01	—	—	—	0.	0.	.03	.04	.76	.40[2/]	.00	1.70	7.0	.67	2.0
Satellite Power Systems	—	—	—	—	—	—	—	—	.21	.76	—	—	—	—	—	—
(Solar Electric)	(2.95)	(2.60)	(0.0)	(1.0)	(0.0)	(2.0)	(2.3)	(.33)	(1.22)	(4.54)	(3.10)	(0.00)	(7.80)	(20.3)	(5.05)	(14.0)
Biomass	.40	.10	1.0	5.0	1.0	2.1	2.4	1.66	1.16	5.12	3.50	.10	.70	15.0	3.00	4.0
Total Solar	5.65	4.48	6.0	15.0	7.0	8.1	8.8	2.79	5.75	11.76	14.02	.10	10.80	38.8	11.05	24.5

1/Excludes hydropower

2/The impact of photovoltaic, solar thermal electric and OTEC shown in summary of CONAES Solar Resource Group report was allocated in proportion to the larger impact shown in the detailed report.

tion for the future, and that there is need for a national solar strategy to bring the benefits of this energy source to the American people on a timely basis. The Domestic Policy Review is the first step in developing and implementing a strategy to speed the use of solar energy.

DOMESTIC POLICY REVIEW

The specific purpose of the Solar Policy Review as defined by the Issues Definition Memorandum issued by the White House Domestic Policy Staff on May 16 (Appendix C) is "to provide the President with:

a. A sound analysis of the contribution which solar energy can make to U.S. and international energy problems, both in the short and in the longer term;
b. A thorough review of the current Federal solar programs to determine whether they, taken as a whole, represent an optimal program for bringing solar technologies into widespread use on an accelerated timetable; and
c. Recommendations for an overall solar strategy to pull together Federal, state, and private efforts to accelerate the use of solar technologies."

The Policy Review will be directed by a cabinet-level Solar Energy Policy Committee, chaired by the Secretary of Energy. This Committee will provide overall guidance to the review, direct the activities of several interagency panels, and prepare a response to the Domestic Policy Staff by August 15, 1978. The Domestic Policy Staff will then prepare a Decision Memorandum with policy options and recommendations, for submission to the President on September 1, 1978.

KEY ISSUES

The development and use of solar energy systems raises a series of issues that deserve broad public review. Many of these issues are key to developing a national solar strategy, and defining the appropriate Federal role in each area will be a major focus of the Solar Policy Review.

Specifically, the Policy Review will:

1. Examine each of the major areas of solar energy use (industry, buildings, agriculture, transportation) and each solar technology (heating and cooling, thermal electric, intermediate temperature-systems, photovoltaics, biomass, wind, hydropower, and ocean thermal) to determine technical or scientific needs relating to their expanded uses, both short term and long term.

Key issues include:

- What are reasonable goals for the use of solar energy?
- What sectors of society and industry are most in need of solar energy and can most readily adopt solar energy to end uses?
- What solar technologies can be expected to provide significant amounts of energy to these sectors and in what time frame?
- Are the key technical issues being properly addressed?

2. Review current Federal research, development, and demonstration programs for solar technologies to determine whether they are structured appropriately to address the priorities and needs identified in paragraph 1.

Key issues include:

- Are current programs sufficiently broad in scope?
- Is the emphasis on cost reduction properly placed?
- Is the level of system demonstration proper?
- Is the overall level of funding and its distributions among the various technologies appropriate?
- Is there an appropriate level of public and industry involvement in the program?

3. Identify the institutional, economic, and environmental factors relating to the introduction and use of solar technologies and development of Federal policy options and strategies for dealing with barriers or problems identified.

Key issues include:

- What effect do current policies designed to enhance solar development have on energy pricing, taxation, utility regulation, patents and licenses, building codes, sun rights, trade practices, and consumer protection?
- To what extent is lack of information delaying use of solar energy? What kind of information and training would best assist different groups in using solar energy?
- What should be done to assist groups uniquely impacted by high energy costs, such as the poor, in solar energy utilization?
- What institutional arrangements are most compatible with accelerated solar energy use? To what extent should utilities and other energy companies be involved?
- Should a Solar Development Bank be established?
- What impacts will accelerated solar energy use have on employment, on industry, on different types of consumers, on units of state and local government?
- How do renewable energy systems compare environmentally to other energy sources?

4. Evaluate the appropriate Federal role in the commercialization of solar energy, including the particular contributions which the various Federal agencies can make to the commercialization process.

Key issues include:

- Are current Federal efforts oriented too strongly toward technology development rather than commercialization, regulation, market or incentives?
- Should government-owned utilities such as Tennessee Valley Authority be used to "showcase" solar energy? How?
- How can Federal procurement practices contribute to accelerated use of solar energy and development of a competitive industry infrastructure?

5. Examine the potential for and impacts of using solar technologies abroad.

Key issues include:

- Are solar technologies likely to be import or export items for the U.S.?

- How does the export of solar designs and solar technologies fit into our international assistance programs?
- Can a large international market supply the needed production volume and assist in bringing down prices of solar units?
- What are the foreign policy implications of widespread solar energy use abroad?

6. Review issues relating to the regional diversity of solar resources, to the matching of solar equipment to end-use requirements, and to the integration of solar technology with the existing energy supply system.

Key issues include:

- What roles can and should Federal power agencies play in the demonstration and technical evaluation of integrated solar/conventional electric energy systems?
- What are the social and regional implications of decentralization of energy supply?
- Which regions are best adapted to early use of each solar technology?
- How important are storage and interregional power grid connections to widespread use of solar energy?

These issues, and others will be addressed by the public and representatives of industry, state and local governments, and other organizations at 11 regional solar energy forums during June 1978. Through such public involvement the Domestic Policy Review should be responsive to the growing national interest in solar energy.

APPENDIX A. SOLAR TECHNOLOGIES

INTRODUCTION

This Appendix describes a number of solar energy technologies and the role of the Department of Energy in their development. While there are many Federal, state and local programs, and private business activities that affect use of solar energy, this discussion is limited to Department of Energy programs.

The solar technologies are diverse and at different stages of development. Several are cost competitive today and only require that institutional barriers to their use be resolved. Most others have been proved technically feasible and require engineering effort to reduce cost and improve performance. A few technologies are sufficiently novel that their technical feasibility remains to be demonstrated. The cost and performance goal provided for each technology reflects its state of development. The goals have been established at a level that will permit the technology to be competitive in the market place. Achievement of those goals requires significant technological breakthroughs, the exact timing of which is difficult to predict. In addition, market acceptance of some technologies requires resolution of significant institutional barriers.

The following sections present a summary of the various solar technologies. The data presented includes:

1. A brief description of each technology, how it works and what equipment is involved;
2. The energy market the technology can best serve;
3. The status of the Federal program including accomplishments, program thrust, and economic goals;
4. The status of the industry involvement and support of each technology;
5. Regional aspects including those areas where the technology has the greatest potential impact; and
6. Environmental aspects or concerns.

PASSIVE SOLAR SYSTEMS

Description

Passive solar systems are ones in which the thermal flow of energy for heating and cooling of buildings is by natural means (convection, conduction, and radiation), as opposed to active systems which use compressors, pumps, fans, etc., to transfer energy. The building is designed to take maximum advantage of the sun's energy to heat the building in the winter and provide cooling and ventilation in the summer without requiring external energy. Passive or natural energy conscious design is typified by large areas of south facing glass, massive structural elements such as thick concrete walls or floors, and energy conserving insulation techniques. Other applications include utilizing the earth or environment as an energy source or sink to heat and/or cool the building (i.e., wind, evaporation, night-sky radiation).

The major features and advantages of passive solar systems are:

a. They tend to cost less than active solar systems for the same total energy delivered to the building and, in some cases, cost is no more than conventional building design (e.g., south facing windows);
b. Although the techniques are different, the materials are often the same as those for other building construction and can be installed without any special skills;
c. There is a minimum likelihood of operational malfunction; and
d. Few aspects require certification of equipment.

Markets

Innovative architects and engineers have developed various techniques for using passive solar and their work can be seen in several hundred modern passive solar buildings that now exist in the country. The potential market is quite large; space heating and cooling currently accounts for a major part of U.S. energy demand. Candidates for passive solar include new buildings (residential and commercial) and a noteable fraction of existing buildings.

Passive solar heating is also being used in agricultural applications (e.g., grain drying and shelter heating).

Program Status

The Department of Energy has an on-going program to develop passive solar technologies. Currently, 24 building experiments and 15 test cells have been built, instrumented, and are providing data. Various design tools and handbooks, including three computer programs, are being developed to assist designers and researchers.

The DOE Solar Demonstration Program has funded the construction of approximately 50 passive solar buildings or about 1 percent of the total number of solar demonstration units built with DOE funding.

The major barrier to accelerated adoption of passive solar technologies seems to be a lack of awareness and understanding of passive solar systems by architects, builders and consumers. To address this probelm, DOE is sponsoring a series of passive solar design and build competitions to stimulate the use of innovative passive solar practices.

The potential for widespread use of solar is high because many simple approaches are working and are cost-effective in every part of the country today. Many states have enacted tax credit legislation including passive solar, thereby making it more of a viable energy option. Passive solar systems can supply from 25 percent to 80 percent of a buildings space heating and cooling energy needs. Data from buildings in New Mexico, New Jersey, and California show fuel bills under $100 for the entire heating season and well below those of neighbors.

Industry Status

Passive solar does not require the development of a new industry, only the development of commercially available components and assembled systems through the building construction industry. However, there is a need for education and orientation of architects and builders, and user groups.

Regional Aspects

Passive techniques are now in use in every region of the nation principally on a custom-built basis. Passive houses may be seen in Vermont as well as California and New Mexico. Passive sun spaces (e.g., greenhouses and atriums) have been integrated into existing dwellings in Seattle, Denver, and Princeton, for example. There are virtually no regional limitations to use of passive solar systems.

Environmental

Passive solar heating and cooling systems pose no serious environmental concerns.

ACTIVE SOLAR HEATING, COOLING, AND HOT WATER HEATING

Description

A wide variety of equipment to capture solar energy and use it for space and water heating is readily available. The three major components for solar heating and hot water systems are the solar collector, the energy storage, and the distribution pipes or ducts. Solar cooling systems include an additional component for energy conditioning such as a chiller or a heat pump. Sunshine is collected by absorber panels and pumped to storage, conditioned if required, and distributed by a heat transfer fluid or by air. Most of these systems are controlled by thermostats. Several heat transfer fluids are used ranging from glycol (antifreeze) to potable water.

Active systems are usually used in conjunction with conventional systems which serve as a backup to the solar equipment. Equipment sizing of both collectors and storage systems is quite important, both in terms of system cost and the potential contribution of solar for a particular structure.

At present the various solar cooling technologies are in different stages of development. No manufacturer yet produces and markets a solar system that provides space cooling, either alone or for combined heating and cooling functions, but several are developing prototype systems. The relatively few solar cooling systems being installed in residential and commercial buildings are custom built from available components.

Solar water heating and combined water and space heating systems are being purchased and installed today. Solar water heating is already cost competitive with electric water heating in some parts of the country. Solar space heating has not generally reached cost competitiveness with other home heating options. Installed cost depends on the region of the country and the specifics of the installation including any "do it yourself" labor and insulation. Typical costs for 1978 and projected costs for 1985 for residential installations are:

Residential Solar Applications

(Commercially Installed)

Component	Hot Water		Hot Water and Space Heating	
	1978	1985	1978	1985
Collector Cost $/sq. ft	15 to 30	8 to 20	15 to 30	8 to 20
Collector Size (approximately)	50 sq. ft	50 sq. ft	300 to 400 sq. ft	200 to 400 sq. ft
Total System Cost (1978 $'s) (Solar provides 50 to 80 percent of total energy)	1600 to 2500	1000 to 1500	8000 to 13,000	4000 to 10,000

Markets

Active solar equipment can be used on almost all types of structures. Both new construction and retrofit markets exist for active systems. Housing units are now being built at about 2 million units per year. The existing residential housing inventory amounts to some 79 million units (single and multi-family units), and the national goal is to install solar systems on 2.5 million homes by 1985. Presently, active systems are closer to commercial viability for new construction because of site specific problems associated with retrofit in existing buildings.

Present Status

The current R&D program is structured to develop solar applications by demonstration of systems. The R&D program stresses continued component and systems development to improve efficiency, reliability, and cost effectiveness. The National Energy Act now pending before Congress would provide tax credits covering 30 percent of the first $1,500, and 20 percent of the next $8,500, for a maximum of $2,150 for residential users. Together with 10 percent additional investment tax credits for commercial users, this program is expected to provide $1 billion worth of incentives over a 7-year period to accelerate commercialization of solar energy.

The general objective of the research and development program is to assist in improving energy components and systems and reducing their costs. Specific objectives are to identify potentially cost-effective systems for building, heating and cooling applications, and to provide the emerging solar industry with the materials, components, information, and methodology needed for designing, producing, and installing these systems.

DOE's solar heating and cooling demonstration program covers both residential and commercial markets, however, HUD administers the residential demonstration program for DOE. In response to the Solar Heating and Cooling Demonstration Act (PL-93-409) there have been four annual purchase cycle in the HUD residential demonstration program. This has resulted in about 330 residential projects involving over 5,000 dwelling units. The fourth cycle, now underway, already has attracted 520 grant applications.

In commercial demonstrations, there are 108 projects from two cycles with cycle three underway. Twenty-two other commercial projects were initiated prior to the first cycle. An example shown in Figure 4, is the Shenandoah Project in Georgia. The 11,213 square feet of collectors drive a heating, hot water, and cooling system.

Other demonstration activities have included 40 Federal government buildings projects with ten agencies and departments of the government. The National Energy Plan calls for up to $100 million worth of solar equipment to be

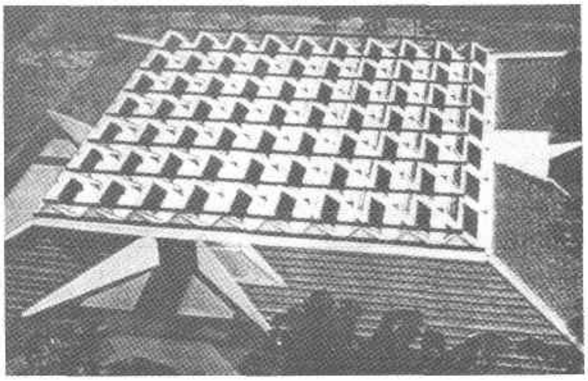


Figure 4. Shenandoah Community Center

installed on Federal buildings during the next 3 years. Over 160 residential and commercial projects are now operational, involving about 1426 units. When the multi-cycle procurements under PL 93-409 are completed there will be approximately 17,000 residential units and 250 commercial demonstrations of solar heating and cooling. The 1977 status map of units is shown in Figure 5.

It is estimated that there are now approximately 50,000 solar installations of various types in the nation.

The HUD Intermediate Minimum Property Standards for solar water and space heating systems have been developed and adopted (effective July 30, 1977) to supplement the existing HUD/FHA Minimum Property Standards. Interim performance criteria for both residential and commercial systems have been published for use in the demonstration program.

A program for the accreditation of laboratories to test solar collectors based on the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) consensus test standard is underway.

Industry Status

In only 3 years, the solar industry has grown to a sales volume of approximately $200 million per year. The total area of solar collectors manufactured each year has been doubling every 9 months to a current annual rate of approximately 5 million square feet. The industry now has several trade associations, and several widely circulated journals exist.

In addition to HUD Minimum Property Standards, an industry certification and labeling program for solar collectors will be operational early in 1979. Initial studies have been completed on model building code provisions for solar installations. Such codes are now being developed. DOE has recently proposed a $5 million job training program for installers of solar heating equipment, to be initiated through labor unions, trade associations, and community colleges during 1979.

Regional Aspects

Regional prices and availability of competing fuels are the key factors in evaluating the potential applications of the systems being developed. To provide the capability to address these factors, the solar heating and cooling programs are developing appropriate systems design and application guidelines.

State and local legislation can significantly affect the adoption of solar systems. In fact, 22 states have already taken some action to provide tax incentives for the use of solar energy.

Environmental Aspects

There are no major environmental issues related to active solar heating and cooling systems. However, a concern with solar hot water systems is potential contamination of potable water by various heat transfer fluids. This problem has been solved technically through the use of double wall heat exchangers to keep heat transfer fluids separate from potable water. There is a slight penalty in system performance and cost.

AGRICULTURAL AND INDUSTRIAL PROCESS HEAT APPLICATIONS

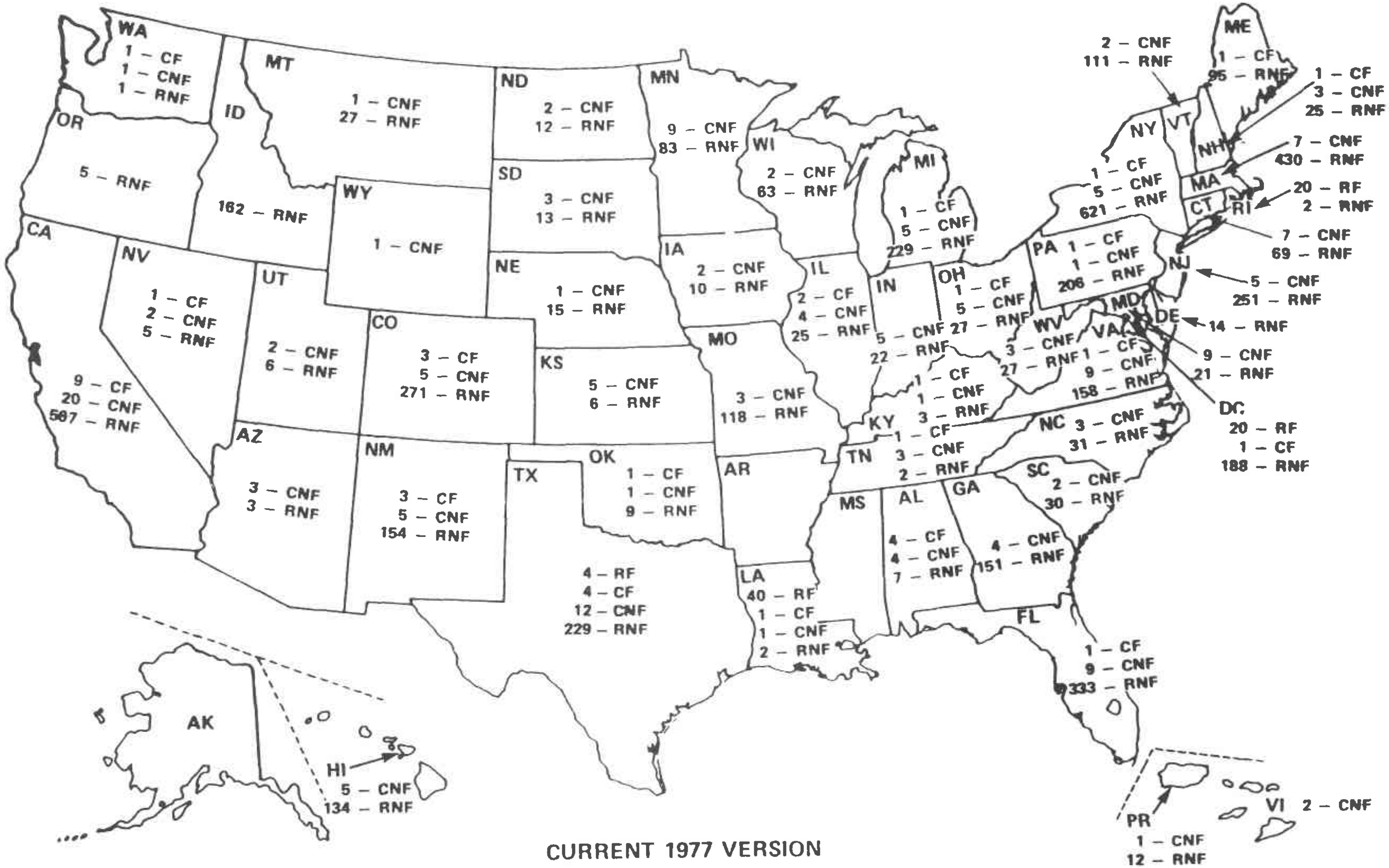
Description

Agricultural and Industrial Process Heat (AIPH) applications use a broad range of solar collectors to produce hot air, hot water and steam at a variety of temperatures suitable for industrial and farming operations. The collector types include greenhouses, simple farmer-fabricated collectors, several types of flat plate collectors, shallow solar ponds, stratified solar ponds, and many types of concentrating collectors. Heat from these collectors is injected into the process directly or through heat exchangers, with or without storage, and with or without conventional back-up, depending upon the system design.

Markets

Applications include food processing, grain drying, crop drying, heating of livestock shelters and greenhouses. Agriculture now consumes about 2 percent (1.5 quads per year) of total U.S. energy, principally in the form of Liquified Petroleum Gas (LPG) for low temperature applications.

Industry's share of total U.S. energy consumption is about 40 percent (30 quads), with the major share derived from fossile fuels. Industrial process heat requirements account for nearly 29 percent of the nation's energy consumption. About one-half of this energy is used at temperatures within the range achieved by solar collectors now under development. Ten industries have been identified as the principal users of over 80 percent of the energy used in the industrial sector.



CNF – COMMERCIAL NON-FEDERAL PROJECTS
CF – COMMERCIAL FEDERAL PROJECTS
RNF – RESIDENTIAL NON-FEDERAL PROJECT UNITS
RF – RESIDENTIAL FEDERAL PROJECT UNITS

Figure 5. Distribution of Solar Heating & Cooling Demonstration

Program Status

Many of the system components for agricultural applications are adaptations of heating and cooling components developed in DOE's Heating and Cooling of Buildings Development Program. Other low-cost devices are being designed using on-site labor and inexpensive, readily available materials. The combination of proven technology, inexpensive materials, and rising fuel costs should make the agricultural applications economically attractive within the next few years. Exposure of these low-cost solar systems to the agricultural community has been initiated through cost-shared demonstrations in the heating of commercial greenhouses and the heating of livestock shelters (Figure 6).

The U.S. Department of Agriculture (USDA) , through the Science and Education Administration (SEA) is sponsoring experiments and prototype systems development. The program now consists of 49 projects in 29 states under a variety of climatic conditions. These projects include:

a. Agricultural food processing;
b. Grain drying;
c. Crop drying (peanuts, forage, and tobacco);
d. Heating of livestock shelters; and
e. Heating of greenhouses.

Much of the energy required by industry is in the form of process hot water, hot air for drying and dehydration, and relatively low temperature steam. Solar energy conversion equipment and technology are already available for such industrial applications. DOE is sponsoring a series of projects to demonstrate the industrial application of state-of-the-art solar systems in a variety of industrial processes. Four of these systems have been dedicated and are now operational, and seven are under construction and will become operational within a year. Four experimental high-temperature (550°F) projects are to be initiated in 1978 and three to six large scale demonstration projects in 1979. Figure 7 shows the locations of existing agricultural and industrial projects.

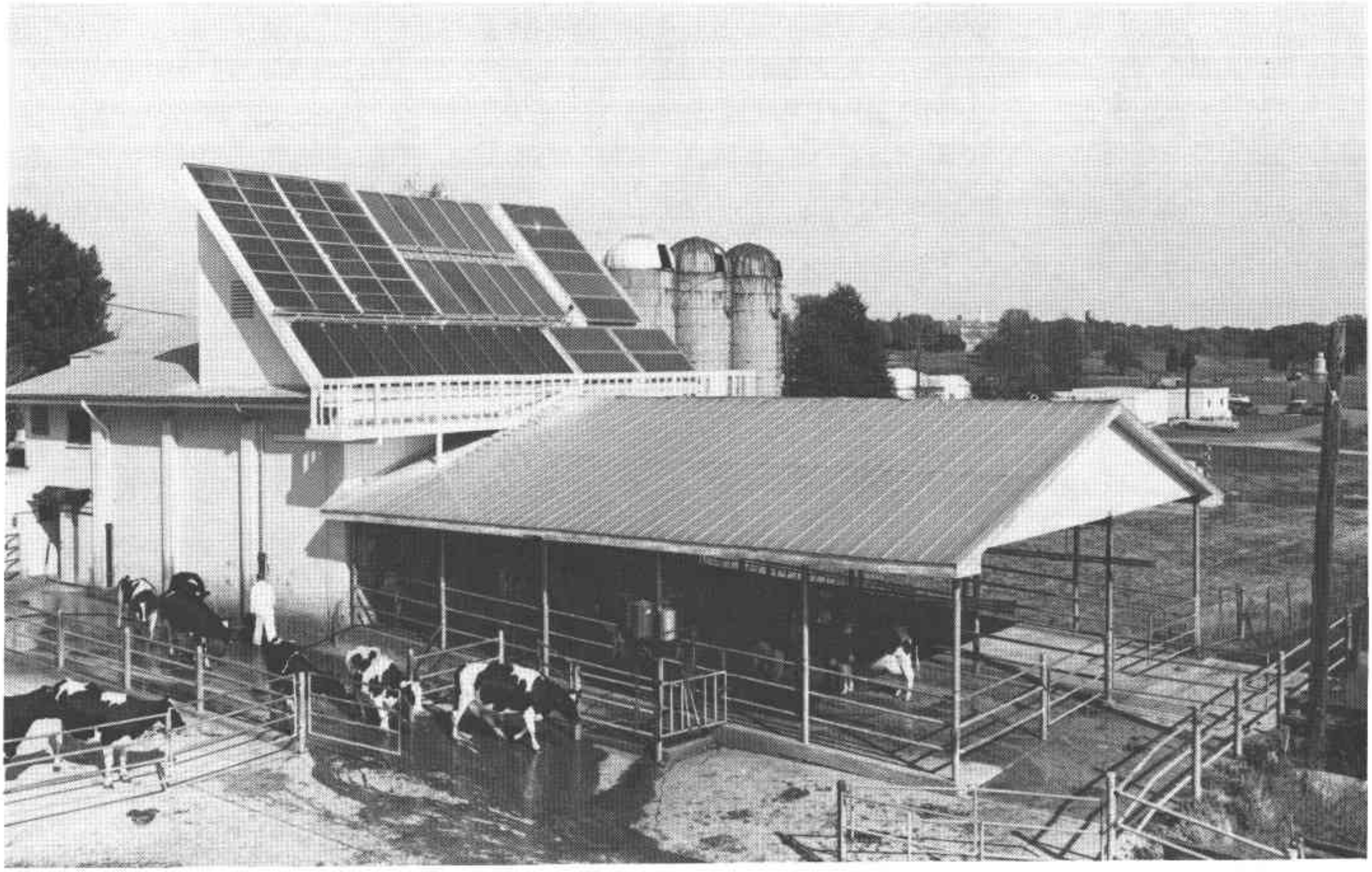


Figure 6. Experimental Solar Heating System for a Dairy Barn. USDA Genetics and Management Laboratory, Beltsville, Maryland.

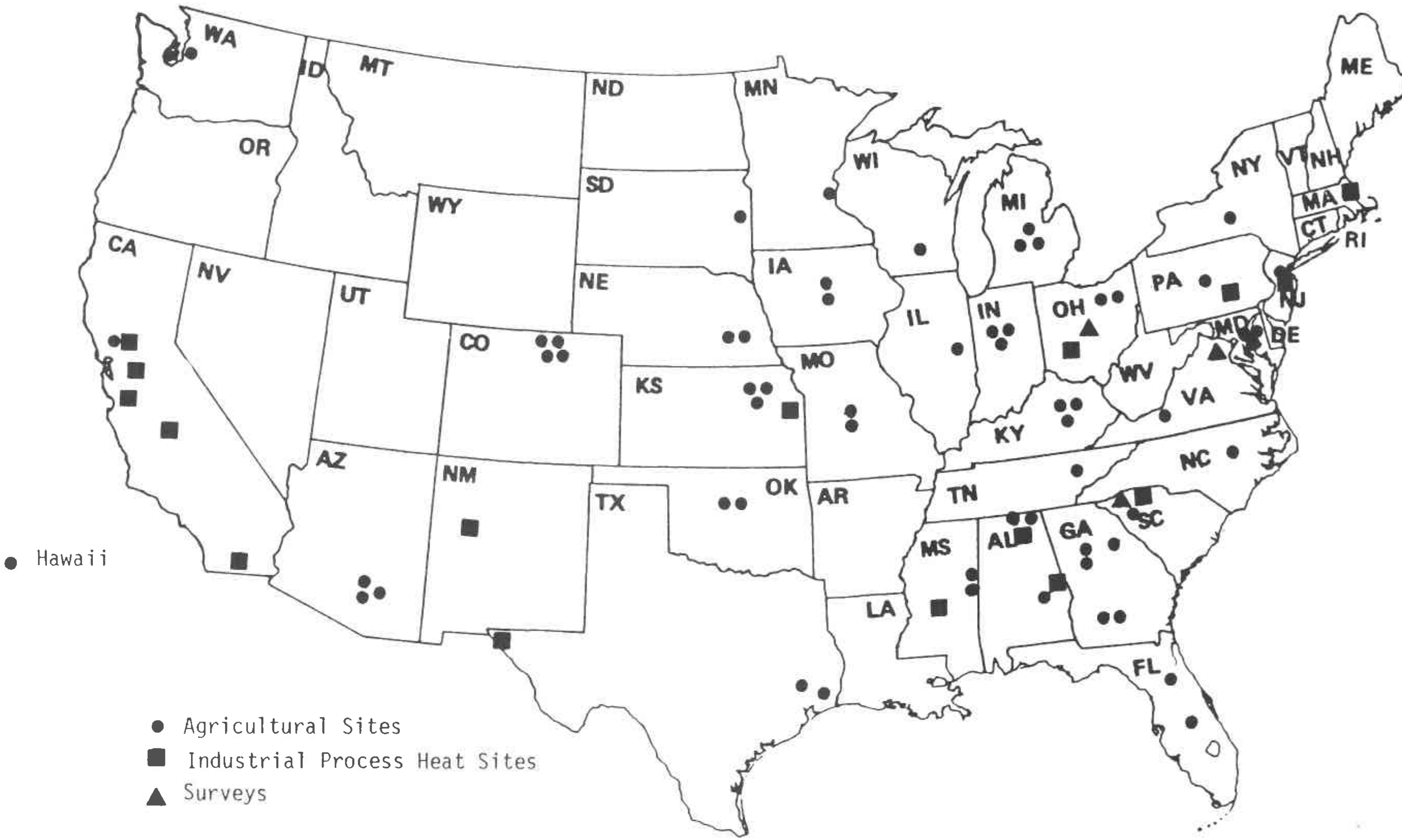


Figure 7. Location of Agricultural and Industrial Process Heat Projects

Economics is the key factor in bringing systems to a high degree of use. Program costs goals for agriculture and industrial systems are:

Component Cost	1978	1985	2000
Collector Cost ($/sq. ft)	10 to 30	8 to 20	7.00
System Cost ($/sq. ft)	20 to 60	15 to 20.00	10.00
Energy Cost ($/MBtu)	10 to 12	6 to 8.00	4.00
Annual Output (Btu/sq. ft)	300,000	330,000	400,000

Industry Status

Agriculture and industrial process heat systems utilize most of the same industrial base as residential and commercial solar heating and cooling systems. As such, an industry is beginning to be established; however, high temperature concentrating collectors are currently made in small experimental quantities. Mass production of large, modular collectors is necessary to meet the above cost goals.

Regional Aspects

Greatest utilization of solar energy for process heat is expected in the West (Arizona, New Mexico, California), where solar insolation is the highest and in the West South Central region of the nation (Texas, Oklahoma, Arkansas and Louisiana), followed by the East North Central (Michigan, Illinois, Ohio, Indiana, Wisconsin) and South Atlantic regions. Other regions are likely to show smaller but significant amounts of solar process heat consumption.

Environmental Aspects

The principal environmental question raised by AIPH applications is the land use requirement for industrial systems. The large amounts of energy required, coupled with the location of most industries in built-up areas, results in potentially severe constraints on industrial solar process heat development in retrofit situations from competing land use requirements. Process heat systems also pose a number of potential problems similar to those of solar heating and cooling systems. Examples are the release of toxic gases during overheat and fire, and accidental release of working fluids into local waterways and sewage systems. Potential contamination of livestock and food products is a concern for process heat systems.

SOLAR THERMAL POWER SYSTEMS

Description

Solar thermal power systems involve direct conversion of solar energy to thermal energy, and subsequent conversion of the thermal energy to mechanical energy in a turbine. The mechanical output of the turbine can be used to generate electricity.

Present solar thermal power systems are of two types: those using a central receiver system and those using a distributed receiver system. Both systems collect and concentrate the direct (rather than the diffuse) component of sunlight and utilize it to heat working fluids such as high pressure water, steam, hydrocarbon oils, molten salts, and liquid metals.

In the central receiver configuration a large field of dual-axis tracking mirrors (heliostats) intercept and redirect sunlight toward a single large tower-mounted receiver which contains the circulating working fluid. Current designs can achieve working fluid temperatures in excess of 600°C. High temperature thermal energy storage can be used to smooth the output of such plants over the daily solar cycle.

A distributed receiver system concentrates sunlight and converts it to a heat at a large number of individual collector modules. The collector module consists of a mirror (single or segmented) in a trough or disk configuration. The mirror redirects and concentrates the sun's rays onto a receiver/absorber unit located at the focus of the mirror. The internally circulating working fluid is heated and then pumped through a pipe network to a boiler or heat exchanger.

Markets

The solar thermal power program is aimed at three major applications:

a. Large-scale centralized electric power generation;
b. Smaller-scale dispersed applications for electric power generation; and
c. Smaller-scale on-site total energy applications involving both electricity and heat production.

Program Status

The thrust of the current DOE program is toward applications with a potential of early market penetration that are compatible with first-generation intermediate and high-temperature concentrating collector technology. It is anticipated that designs for heliostats and trough-type collectors suitable for mass production will be available within 1 to 2 years.

A 5 megawatt (MW) Solar Thermal Test Facility in Albuquerque, New Mexico has recently been completed (Figure 8). It can test and evaluate all major central receiver subsystems and components including receivers, heliostats, and high-temperature thermal storage systems. This facility will be available to foreign governments and to private firms who wish to test components. Detailed engineering design has been initiated on a 10 MWe central receiver experimental module that is scheduled to operate in a utility grid in Barstow, California in 1981. This plant will be jointly funded by DOE, and the Southern California Edison Company and the Los Angeles Department of Water and Power.

A Total Energy Test Facility at the Sandia Laboratories in Albuquerque, New Mexico (see Figure 9) is now operational. Its purpose is to evaluate subsystem component designs under different operating conditions. Testing total energy systems at Fort Hood, Texas and Shanandoah, Georgia will be completed in September of 1980.

The small-scale electric power generation program has two principal targets: irrigation systems and community-size systems. A 25 HP irrigation pump is currently operating and a 200 HP system will be completed in Coolidge, Arizona in FY 1979.

Neither central receiver nor dispersed collector systems are commercially available today. If either system were to be built with currently available components the cost would be $7,000 to $10,000 per kW-pk.

Heliostat cost is critical to the economic competitiveness of solar thermal power systems. Achievement of the DOE program cost goal of 7 dollars per square foot of reflector surface implies solar thermal power systems with the following characteristics:

1990 Installations

Component	Electric Utility	Small Community Systems
Capital Cost ($/kW-pk)	1200	1000
Energy Cost (cents/kWh)	6 to 8	6 to 8
Unit Size (MWe)	50 to 300	1 to 10
Capacity Factor (includes energy storage)	.45	.45

With anticipated increases in the cost of oil and gas, an energy cost of 6 to 8 cents/kWh could be competitive in some regions of the country during the 1990's.

Industry Status

A number of companies offer intermediate temperature distributed receiver collectors at prices that range from $20 to $40 per square foot installed. Eight potential major heliostat suppliers have been identified and most have received assistance from DOE in developing and testing prototype hardware. Several electric utilities in the southwestern U.S. are actively interested in solar thermal power plant technology for both capacity additions and retrofit (repowering) of existing oil and gas-fired units. These utilities are providing a significant level of cost sharing in the early experimental projects.

Regional Aspects

Solar thermal electric technology is expected to first penetrate utility and dispersed applications markets in the southwestern U.S. where sunlight conditions are optional Expanded market penetration beyond the Southwest is expected to follow, based on cost reductions and performance improvements that are expected from the development of advanced technology.

Environmental Aspects

Stray reflections from heliostats are expected to be the major health and safety issues associated with solar thermal power systems. A study is also planned to analyze hazards associated with heliostat manufacture, transport, and installation, and to develop control procedures as needed. Additional studies will assess ecological impacts on flora, fauna, and hydrology, and assess potential effects on local climates.

PHOTOVOLTAIC

Description

Photovoltaic cells convert sunlight directly into electricity through the use of semiconductor materials such as silicon, cadmium sulfide, and gallium arsenide. The principles involved are well known, primarily through experience gained in the space program. Photovoltaic cells are grouped into modules called arrays which are combined in a total system that includes equipment to convert the direct current power generated by the arrays to conventional A.C.

Figure 8. Solar Thermal Test Facility

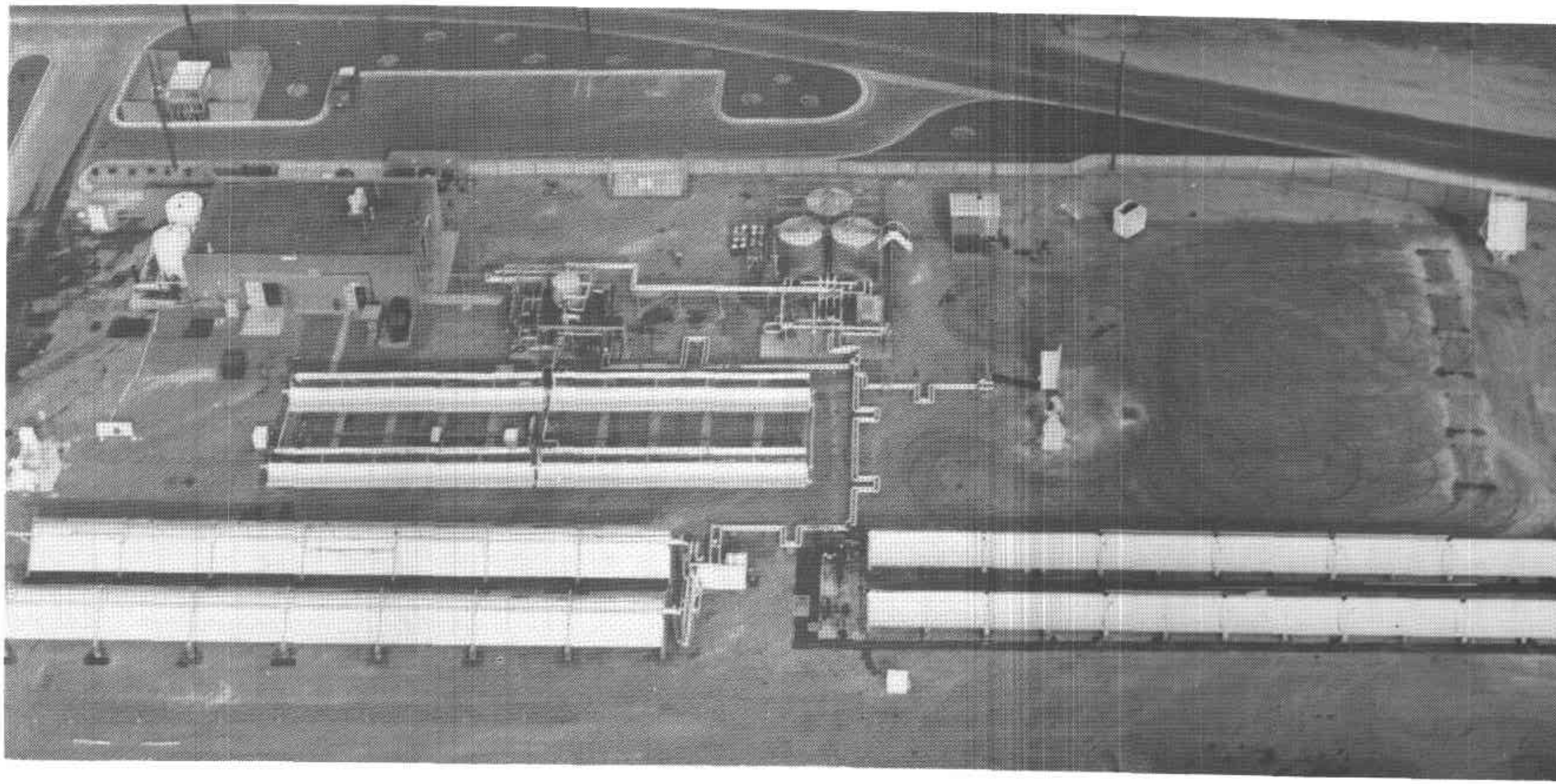


Figure 9. Total Energy System Test Facility

equipment to interface with the electric utility grid, and energy storage systems. A schematic diagram of such a system is shown in Figure 10.

Markets

Today photovoltaic systems are used to provide electric power in spacecraft and satellites. This power is extremely expensive: $12 to 30 per peak Watt for arrays. If the cost of photovoltaic arrays are reduced to $2 per peak Watt, it is expected that photovoltaic systems would become competitive in remote applications hwere the cost of running a connecting power line to a utility grid is prohibitive. These applications include corrosion protection for highway bridges, communications relay stations located on mountain tops (see Figure 11), and electric power for recreational vehicles, campsites and cabins.

In addition to the U.S. market, there is a much larger market in the Less Developed Countries (LDC) for power in remote villages where the alternatives to photovoltaic systems is generation of very high cost power from diesel or gasoline generators fueled by imported oil. Wind systems might be competitive in this market as well.

With subsequent reduction in array costs, photovoltaic systems could be attractive for dispersed power generation in residential and commercial applications as either the primary source of power, or a supplement to buying power from the utility grid. Because arrays are modular and can be assembled in multi-megawatt blocks, photovoltaic systems are also potentially suitable for peak and intermediate electric power generation.

These systems can be included in a total energy system in which the solar cells are cooled by a fluid which is then used in a manner similar to an active solar heating system.

Program Status

The objectives of the DOE program are to stimulate the development of the technology required to produce low cost, reliable photovoltaic systems, and to stimulate the necessary industrial manufacturing capability.

These objectives are pursued by a two step approach:

- High risk research and development program seeking cost reduction in arrays through new materials, improved manufacturing techniques, and advanced array concepts.
- Development of a near-term market demand through a series of private sector photovoltaic applications in which the government shares the cost with the user.

The current program goals are to reduce the cost of solar arrays to $2/Wp of electric capacity by 1982, $0.50/Wp by 1986, and $0.10 to $0.30/Wp by 1990.

Single-crystal silicon flate-plate arrays have received much of the research support to date. Concentrating systems, which use cheaper lenses to focus sunlight into a smaller area of cell, have been receiving increased emphasis. It is anticipated that concentrators will be the first option to reach the $1.00 to $2.00/Wp array cost.

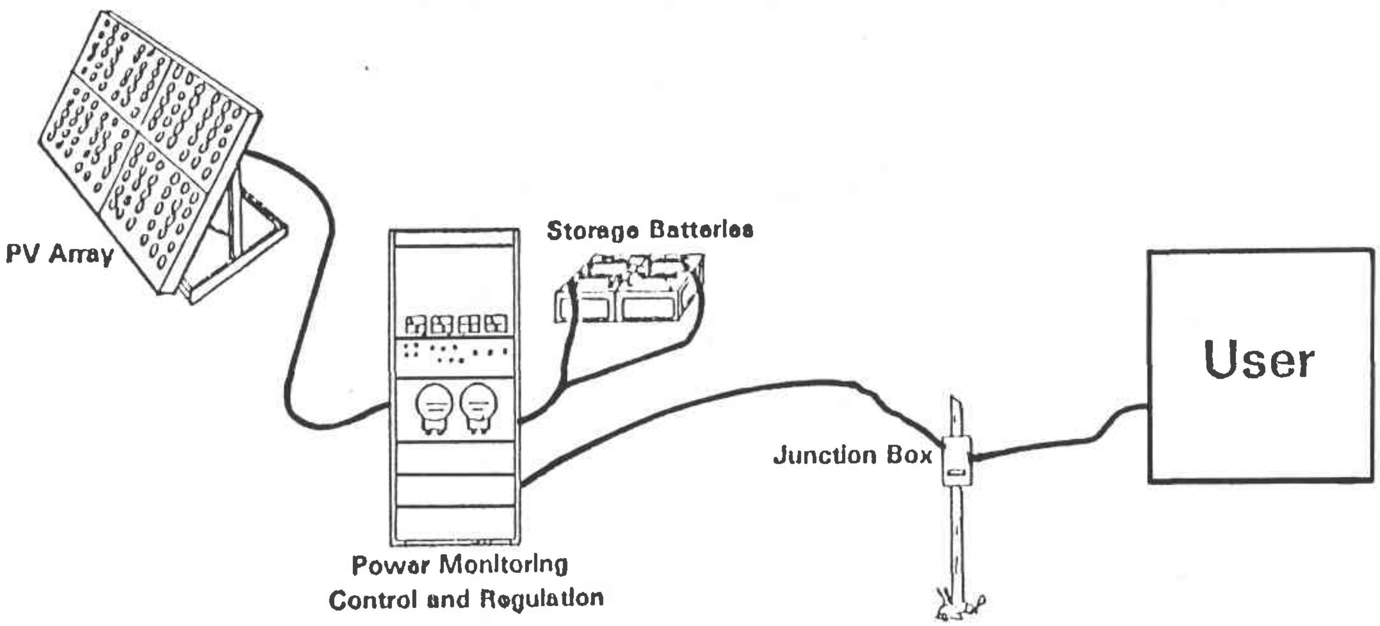


Figure 10. Photovoltaic System for Dispersed Application

Figure 11. Remote Site Photovoltaic Array

Recent program changes emphasize silicon and gallium arsenide concentrator systems and high-risk thin films and amorphous materials. Thin film photovoltaics are an attractive alternative to single-crystal silicon in the longer term, particularly cadmium sulfide and gallium arsenide. These advanced concepts have the potential of achieving costs in the range of $.10 to $.30/Wp by 1990.

Photovoltaic systems can be purchased today. Based on array costs of $13 to 16 per peak Watt, total system costs are estimated to be $20 to 25 per peak Watt for residential applications (3 to 4 kW-pk) and $20 to 25 per peak Watt for electric utility applications (10 MW-pk). As array costs are reduced, estimated systems cost for typical photovoltaic applications are expected to be:

Environmental Aspects

Photovoltaic systems produce no pollutants or major adverse impacts during normal use. The principal environmental concerns involve worker exposure to toxic substances during manufacture. Of the materials currently under development or consideration silicon has the greatest potential for early application. The National Institute of Occupational and Health Safety (NIOHS) has begun studies to quantify the levels of exposure to these toxic substances. Health effect studies are scheduled. Additional studies are planned to determine health effects of exposure to other semiconductor materials, including cadmium sulfide and gallium arsenide.

Specifications	Residential Application		Electric Utility
	1986	1990	1990
Array Cost ($/W-pk)	0.50	0.10 to 0.30	0.10 to 0.30
System Cost ($kW-pk)	1000 to 1500	less than 1000	800 to 1000
Energy Cost[1] (cents/kWh)	5 to 7	less than 5	4 to 6
Capacity Factor[1]	.20	.20	.26

[1]Location dependent – most favorable in the Southwest.

Industry Status

Photovoltaic demand is met by a small photovoltaic industry ($25 million annual sales), consisting of ten manufacturers of single-crystal silicon solar arrays and two pilot production lines for Cadmium Sulfide (CdS) arrays. These manufacturers are primarily the leaders in the semiconductor field, with off-line operation for photovoltaic production. No large automated manufacturing facilities exist. The total 1977 world production was about 750 peak kilowatts.

Regional Aspects

Photovoltaic systems lend themselves readily to all parts of the country for application. The need for energy storage and total system costs will vary depending on the intensity and availability of sunlight.

In addition, the release of gaseous residuals from silicon and advanced materials, and the production of solid wastes containing leachates, require the use of controls. Research in both areas is scheduled.

WIND ENERGY SYSTEMS

Description

Wind energy has long been used for water pumping and generating electricity. Modern wind machines also perform these functions in on-site applications and may also generate electricity for distribution through a utility grid.

The energy output of a wind turbine is principally a function of wind velocity at the site and rotor diameter of the machine, with the power rating (i.e., generator size) determining peak power.

Markets

DOE is pursuing development and demonstration of small machines (5 to 10 kWe) which could be utilized by an individual rural home, farm, or ranch and intermediate sized machines (100 to 200 kWe) used by towns and rural electric cooperatives.

Wind systems of 1 to 3 MWe size for integration with electric power systemc can be used individually or in clusters. These larger systems could also be grouped into clusters or "farms" to provide substantial blocks of power for larger utilities. Lower energy costs are achieveable by increasing unit size.

The wind resource base is very large: 10 to 20 quads of electrical power, according to recent estimates.

Program Status

A Federal program is underway that includes the development of high performance, low-cost wind systems covering a variety of sizes. The primary technical challenges are achievement of high reliability and lost cost. DOE has established a test center for small machines at Rocky Flats, Colorado, and has several machines currently under test (see Figure 12).

The Federal small wind machine program presently has nine systems under development. These systems are in the 1 kWe, 8 kWe, and 40 kWe class, and will be tested in 1979.

Large wind turbines in the range of 200 kW (100 to 125 ft-diameter) to 3 MW (200 to 300 ft-diameter) are being designed to feed electricity directly into existing power grids. The National Aeronautics and Space Administration (NASA) is providing technical program management for the development of large horizontal axis wind turbines. The primary application is in the utility industry, with the smaller units applicable to small communities, agriculture, and potentially some remote industries. Multiple units, either collected in "farms" or dispersed across the users network, would be used to obtain higher power levels. Technical feasibility of individual machines up to 125 ft has been shown, and remote, unattended, automatic operation has been demonstrated. In utility operations, wind systems would provide additional generating capacity where wind is sufficiently reliable and would also work in a fuel saver mode in which energy from conventional units is displaced by wind when wind is available.

The Mod-0 (125 ft-diameter/100 kW) is currently being used as a test facility for evaluation of new engineering concepts; the Mod 0A-1 (125 ft/200 kW) has recently started test operations with the Clayton, New Mexico Utility (see Figure 13). Second and third Mod 0A units are to be installed this year at other sites. The Mod-1 (200 ft-diameter/2 MW) is being fabricated and will be tested in FY 1979 while the Mod-2 (300 ft-diameter/3 MW) is in the preliminary design phase. Second generation system design projects for 100 ft (Mod-4) and 200 ft (Mod-3) models will start in late 1978.

No major feasibility questions are involved. For utility operations, some technical issues to be resolved include dynamic behavior, utility interface, and control. The primary challenge is obtaining high performance and reliability at low cost. Cost is expected to decrease for four reasons:

a. Development of advanced concepts.
b. Mass production efficiencies.
c. Size (estimates predict economies of scale up to blade diameters of 300 to 400 ft).
d. Competition among manufacturers.

The cost goals for the wind program are illustrated in the typical wind machine costs shown below. Small machines are commercially available today. The costs for mature units are based on mass production and establishment of a competitive manufacturing industry.

Small Wind Machine

Specifications	Currently Available		Advanced (1985 Design)	
	Initial Unit	Mature Unit	Initial Unit	Mature Unit
Capital Cost ($/kW)	2000	1300	1200	750
Energy Cost (cents/kWh)[1]	10 to 20	5 to 10	4 to 8	2 to 4
Size (kW)	1		8	
Minimum Wind Speed (Average, mph)	14		12	

[1] Excludes demand charges which small users might be required to pay for electric utility backup power.

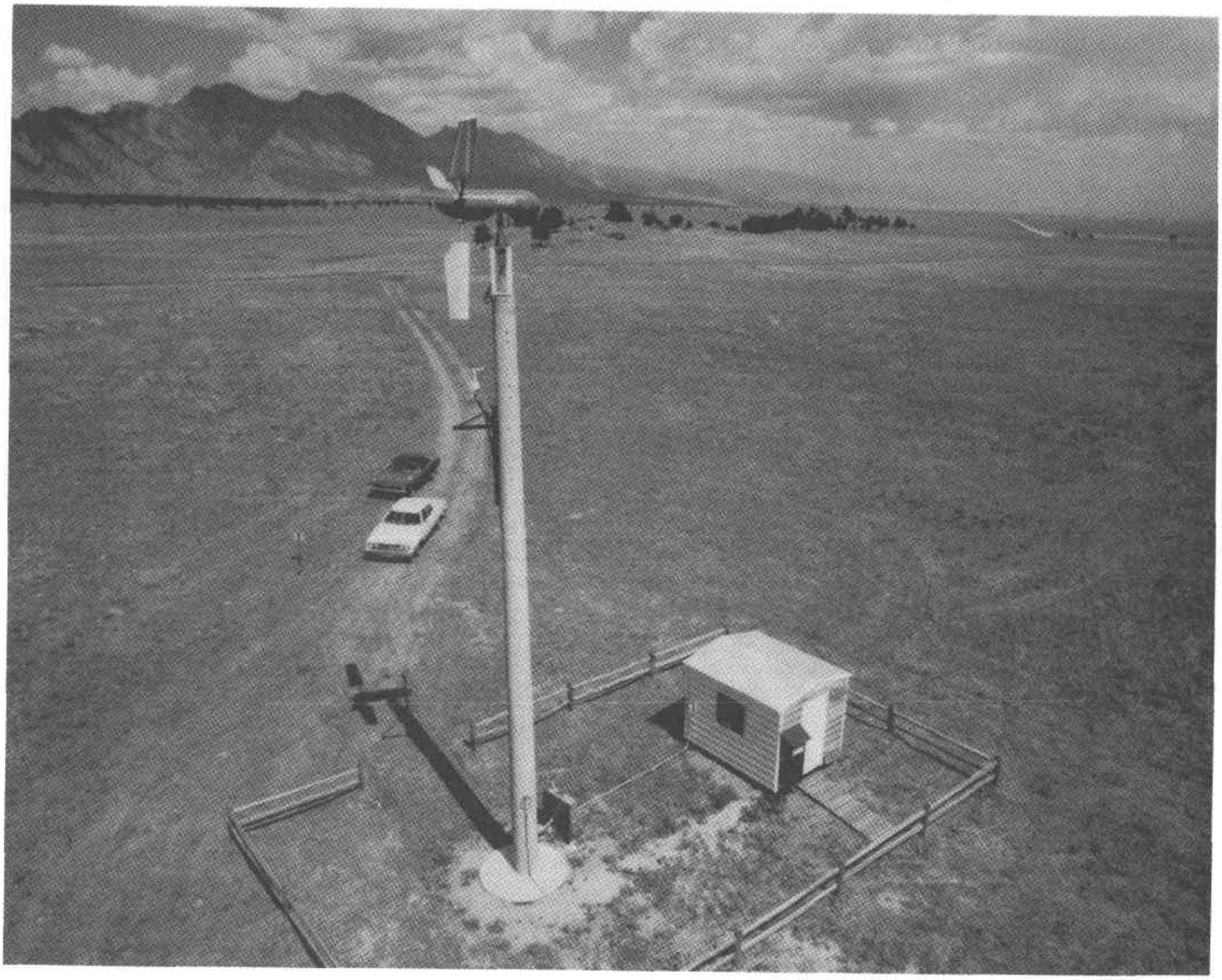


Figure 12. Test Center for Small Machines at Rocky Flats, Colorado
(1 of 12 Test Cells Shown)

Figure 13. Clayton, New Mexico MOD 0A Installation

Large Wind Machines

Specifications	Mod 2 (1980)		Advanced (1985 Design)	
	First Unit	Mature Unit	First Unit	Mature Unit
Capital Cost ($/kW)	1500	750	600 to 900	400 to 600
Energy Cost (cents/kWh)	7	3	2 to 3	1 to 2
Size (MW)	2		2 to 4	
Wind Speed (Average, mph)	14		14	

Industry Status

A significant wind industry existed in the U.S. from 1850 to 1930, but went into decline with the arrival of the REA and low-cost central power. There are probably 50 to 100 units/year sold now, principally in the 1 to 6 kW range (excluding fractional kW battery chargers and water pumpers). These are dominated by three foreign manufacturers. U.S. industry consists of two groups: 10 to 15 very small companies trying to develop and sell their small systems and about 5 large companies are conducting research and development work and assessing market potential. At present there is little industry infrastructure, particularly in the sales, distribution, and maintenance/field service networks. Availability and cost of product liability insurance also remain potential problems.

Present commercially available systems have shown high failure and maintenance rates, which is surprising in the sense that 1920 to 1930 vintage machines were noted for their longevity and survivability. The current situation is believed due to the limited engineering development, and lack of feedback from the marketplace.

Several large industrial organizations are involved in the present development program and have begun serious consideration of possible product lines. Some utilities have also begun to show a serious interest in wind, particularly those in high fuel cost/high wind areas (65 utilities proposed sites in the last competition for four test machines).

Regional Aspects

The regions with the most desirable wind characteristics include the various islands, Alaska, the Great Plains, the high desert, and the Rockies, with some additional potential in the Great Lakes, New England and coastal areas.

Environmental Aspects

Environmental issues arise in two areas: public and user acceptance, and television interference. Wind systems are unusual and highly visible, and public reaction will depend on aesthetic factors. Wind machines with metal blades can also affect TV reception at distances up to 2 miles.

OCEAN SYSTEMS

Description

Renewable ocean energy resources take several forms, and can be used to generate substantial quantities of electricity and to produce energy-intensive products. Ocean energy system concepts under study and development include Ocean Thermal Energy Conversion (OTEC), salinity gradients, ocean currents, and ocean waves. Wave energy resources are readily accessible to certain parts of the coastal United States, e.g., the Northeast region, but power densities are not comparable to those encountered in Britain. A modest amount of ocean current power is available in the Gulf Stream (Florida current), although much smaller than from currents off Japan. Salinity gradient energy conversion has a promising potential for the continental United States, especially through the use of salt brines and domes, but the required technology is in an early stage of development. In the near term, OTEC appears to be the most promising ocean energy option and it is receiving the greatest emphasis.

OTEC system would use ocean temperature differences between warm surface water and cold water from depth to produce baseload electricity. Typical systems for achieving this conversion may use ammonia as a working fluid, which is evaporated by the warm water, driving a turbogenerator, and which is then condensed by the cold water. Because of the low net energy efficiency of an OTEC system (a few percent), large volumes of warm and cold water must be circulated and extensive areas of heat exchangers are required. OTEC energy would be utilized as electricity conveyed to shore by submarine cable, and in production of energy-intensive products (such as ammonia, aluminum, hydrogen, chlorine) on or near the OTEC platform. Figure 14 is an illustration of a 100 MWe plantship for producing 300 tons of ammonia per day. Power generating OTEC systems would appear similar but would have an electric cable going ashore.

Markets

OTEC-generated baseload electricity would be of most interest to utilities in the southern United States and to those serving Hawaii and Puerto Rico. Also, energy intensive chemicals such as hydrogen, chlorine, ammonia, and aluminum might be produced on OTEC plantships and delivered to port.

Program Status

The DOE OTEC Technology Development Program is aimed at developing and testing OTEC components, subsystems, and complete systems. In particular, candidate heat exchanger designs are being produced and tested in laboratory and core-test (1 MWt) units. OTEC hardware, including a cold-water pipe, will be ocean-tested at 1 MWe (40 MWt) in the OTEC-1 component testing facility starting in 1980. Modular experiments (10 MWe) are planned for 1982 through 1983. These systems are intended to demonstrate operational feasibility, provide test data to help reduce costs, and support the establishment of an industry infrastructure.

The most important OTEC subsystems from a cost standpoint are the heat exchangers. Other OTEC system components include the cold water pipe, that may range from 80 to 110 feet in diameter and 2000 to 3000 feet in depth for a 400 MWe OTEC power plant, and a hull with horizontal dimensions of about 400 feet. For conveying electricity to shore via submarine cable, OTEC power plants will require special anchoring and mooring systems.

OTEC systems are not available today. Considerable engineering development is required on the heat exchanger, cold-water pipe, and submarine cable. DOE cost objectives for production units in the post 1990 time frame are shown below:

	Baseload Electricity
Capital Cost ($/kW)	1500 to 1800
Energy Cost (cents/kWh)	4 to 5
Size (MWe)	100
Capacity Factor	.80 to .85

The goals include $250 to $350 per kilowatt for submarine cable from 50 to 100 miles off the Gulf Coast locations to points such as Tampa and New Orleans. Where cable lengths would be short, for islands such as Hawaii and Puerto Rico, cable cost would be about $125/kW. Since there is no fuel cost, these capital cost goals project an energy cost of between 4 and 5 cents/kWh, including about 0.5 cent/kWh for operation and maintenance cost.

Industry Status

Industrial capabilities required for OTEC development include shipbuilding and large scale heat exchanger design and manufacture. To date, two shipbuilders, several companies with off shore oil drilling capabilities, and several heat exchanger manufacturers are participating in the DOE OTEC program.

Interest in OTEC power has been expressed by several electric utilities including Florida Power and Light, Florida Power, Southern Companies, Middle South Services, and the Puerto Rican Water Resources Authority.

Regional Aspects

OTEC has the potential to supply a significant share of the Gulf Coast and island electricity markets, which is estimated to require an additional 200 GWe of installed capacity by the year 2010. No other major regional impacts are anticipated.

Environmental Aspects

The possible changes in ocean characteristics that can occur in the vicinity of OTEC operations are a significant environmental concern. Because large amounts of cold, deep ocean water will be pumped to near the surface, parameters such as temperature, dissolved oxygen, nutrients, carbonates, turbidity, etc., will be modified by mixing with ambient ocean water in the vicinity of the discharge. There is also concern about contamination of ambient ocean due to heat exchanger corrosion and use of biocides to control buildup of slime in heat exchangers.

HYDROPOWER

Description

Hydropower facilities tap the energy of falling water at dam sites and flowing water in rivers to drive turbines

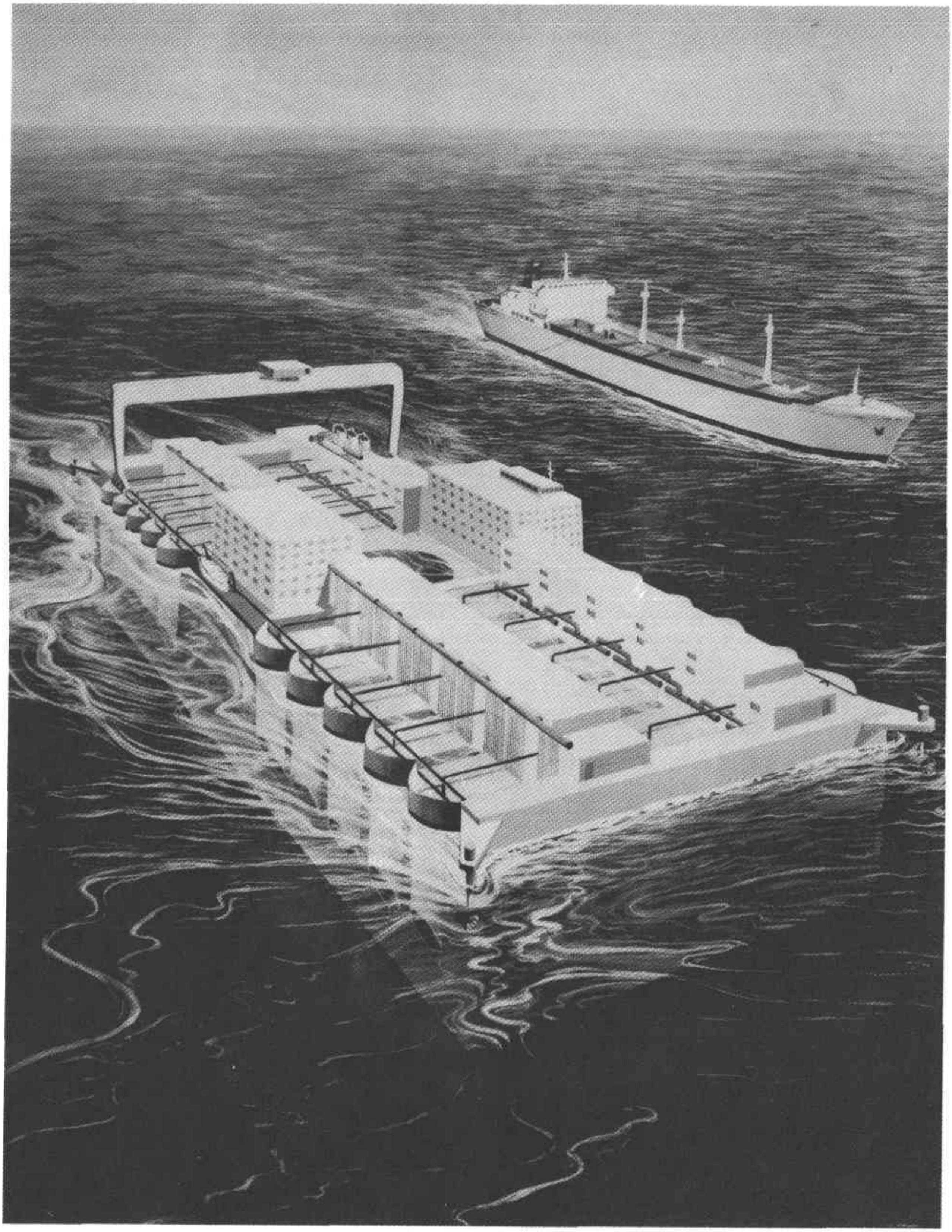


Figure 14. OTEC Floating Plantship

which generate electricity. Such facilities may be large such as found at Niagara Falls and Grand Coulee Dam, or much smaller and fall into the category of low-head hydro.

Conversion of the kinetic energy in the water to electric power requires a dam or divergence structure to effect a differential head or pressure, a conduit (penstock) to direct the water to the turbine and a draft tube to carry the turbine discharge to the downstream channel. A spillway for emergency spillage of larger flood flows is essential. A powerhouse to enclose the mechanical and electrical systems needed for generation, control and distribution of electrical energy is usually located at the base of the dam or divergence structure (see Figure 15).

Markets

Hydroelectric plants now account for about 14 percent of total U.S. electricity generation. Although there have been recent substantial increases in total hydroelectric capacity, most large U.S. hydroelectric sites have now been developed, and major new site development is not expected.

Low-head hydroelectric baseload generation at small dam sites and in rivers is attracting renewed interest, after a period of relative decline. A survey by the Corps of Engineers has identified 50,000 existing small dams that might be retrofitted for hydroelectric generation, and a recent report has estimated U.S. low-head hydro potential at 14,000 MWe.

Five thousand MWe of new low-head hydro capacity could be in place by 1990, and twnety thousand MWe by 2000.

Program Status

The DOE program is primarily aimed at low-head hydro, and the strategy is to develop small, prepackaged turbogenerators to reduce low-head retrofit costs to an average $700 to $1500 per installed kilowatt (corresponding to a generating cost of about 1.5 to 2.5 cents/kWh). By supporting feasibility studies, (authorized in the NEA) or renovation at several hundred sites, the DOE program is also designed to stimulate renovations at other existing dams, creating a market sufficient to support a domestic turbine industry. Projected installed costs range from $300 to $1500/kWe depending on location and whether dams and other facilities are already in place.

A pending provision of the NEA will require utilities to purchase power at nondiscriminatory rates from small producers. This is expected to offset the declining utility interest in small-scale (50 kW to 15 MW) hydro projects.

Industry Status

All present manufacturers of small turbines that would be used at low-head hydro sites are located overseas, where recent demand has been focused. Development of a competitive domestic turbine industry is a primary goal of the DOE program.

Regional Aspects

Small hydro will probably be most attractive in the New England and North Atlantic regions where small hydro could displace expensive oil-fired generation without sacrifice of substantial land areas. DOE is now considering a large number of proposals for site specific feasibility studies, most of which are for sites in New England and the Pacific Northwest.

Environmental Aspects

Since most low-head hydro installations will be run-of-the-river plants, utilizing essentially undisturbed stream flow, with only minor changes in impoundment area and minor fluctuation in water levels, the environmental impacts should be minimal. However, if low-head hydro plants are used to supply peaking power, larger impoundment areas and fluctuations in water level could lead to greater environment impact on a local basis.

FUELS FROM BIOMASS

Description

Biomass resources range from wood and other plants grown specifically for energy purposes, to the more widely available agricultural and forest residues. There are two major technologies for converting biomass into liquid and gaseous fuels:

a. Biochemical conversion, where microbial processes break down the biomass into simple chemicals such as alcohols, which can be separated and purified.

b. Thermochemical conversion, where biomass is heated in the presence of reactive gases to produce fuel gases and oils.

Specific products of biomass conversion are medium Btu gas, high Btu gas, alcohol, fuel oil, petrochemical substitutes, and heat.

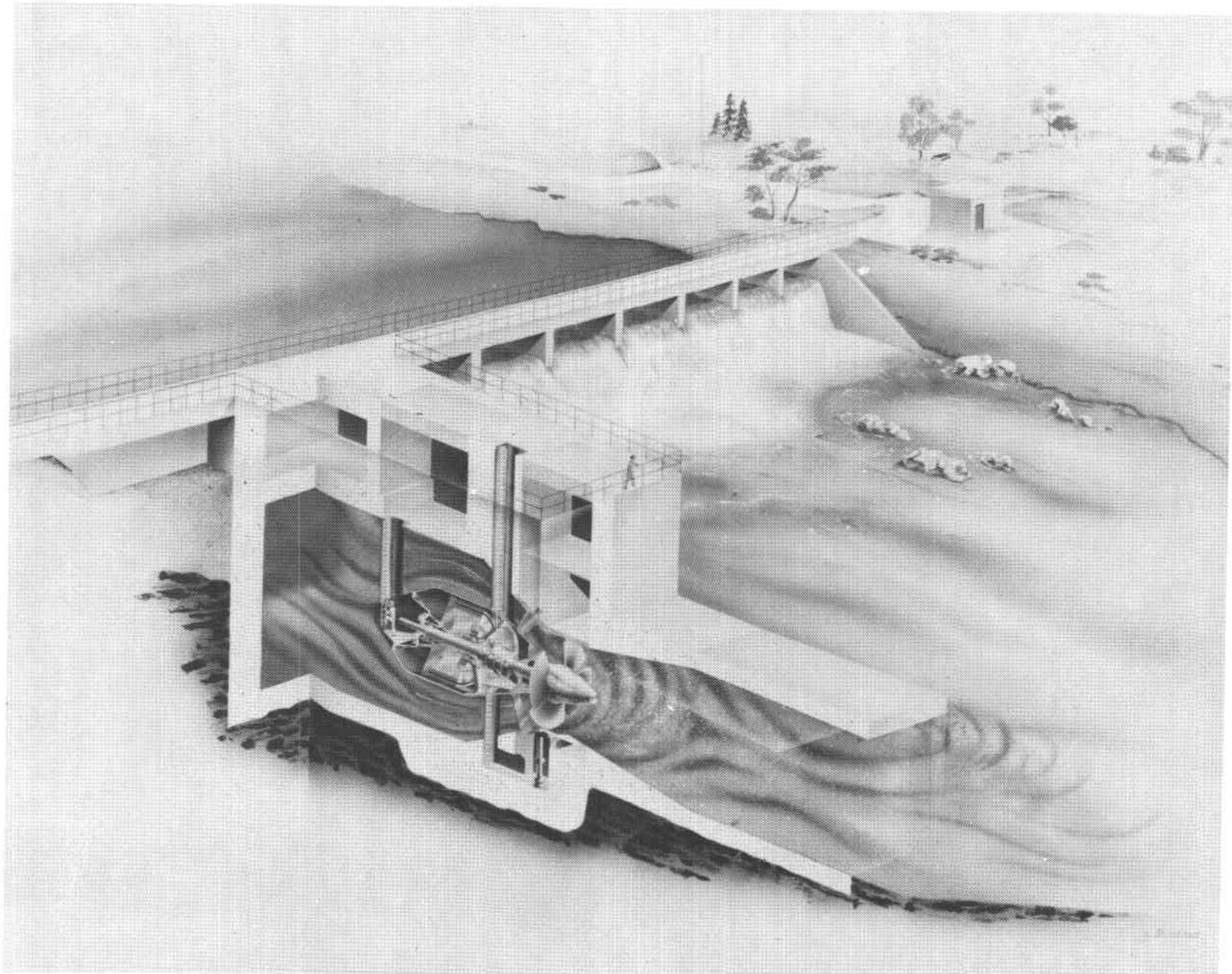


Figure 15. Low-Head Hydro Concept

Markets

The principal markets for biomass are likely to be the supply of liquid and gaseous fuels and direct combustion. Direct combustion of biomass for heat, steam, and electricity is economic today, and contributes 1.3 quads annually, principally in the forest products industry. It appears practical to grow and harvest 4 to 5 quads of energy on silviculture energy farms. This concerted effort would require only 4 percent of the present U.S. forest acreage equivalent. The biomass resource potential is shown in Figure 16.

Program Status

The DOE biomass program has emphasized establishing an assured feedstock supply and developing new, more efficient and economic, conversion technologies. Field production experiments have been established in different climatic areas to provide initial technical and economic baseline data on the production of biomass. A process development unit for making oil from wood by liquefaction (see Figure 17) has been in operation since May 1977. This experimental unit converts 3 tons of wood chips into 6 barrels of oil per day. Gasification is a technology that is also being emphasized, since the production of "syngas" by this process is the first step in making a wide range of derived fuel products. The technology for anaerobic digestion of feedlot manure to produce methane is nearing commercialization. A large-scale experimental facility is under construction on a cattle feedlot in Bartow, Florida, and will process manure from 10,000 head of cattle. Other studies are being conducted on anaerobic digestion from manure for small dairy farms. Laboratory studies are underway on the anaerobic digestion of crop residues. Fermentation to produce ethyl alcohol remains an important part of the program, the main objective now being to reduce the cost of producing sugar feedstocks through the hydrolysis of cellulosic (woody) biomass.

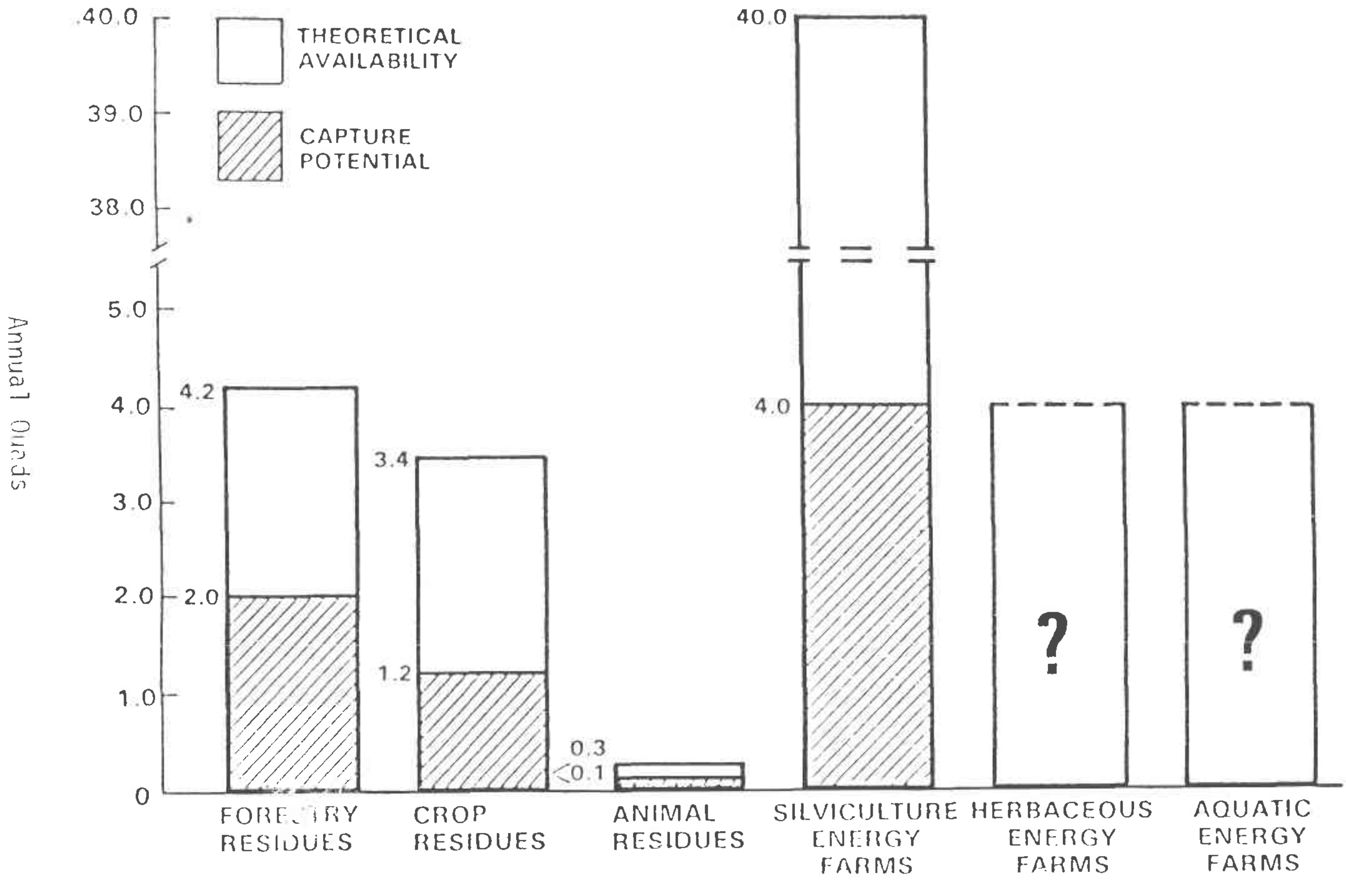


Figure 16. Market Assessment – Supply Potential Biomass Resource Availability

Figure 17. Wood to Oil Process Development Unit

Biomass conversion is basically a decentralized or dispersed technology, or cluster of technologies, because of the dispersed nature of the resource base that must be harvested and transported. Opportunities for economies of scale are limited compared to coal, imposing an economic penalty that must be offset through technological advancement. Quantities of biomass residues do not exist in amounts required for large-scale energy production, and biomass grown on energy farms may remain more expensive than fossil fuels for some time. In the near term, the biomass program emphasizes the deployment of systems that use regionally available forestry and agricultural residues for direct combustion and gasification. These resources will be augmented as soon as practical by biomass from energy farms. Thereafter, liquefaction technology will be introduced to provide fuel oils.

Biomass product costs vary widely, depending on the size of the facility, the type of biomass resource and its cost delivered to the point of use, and the specific product produced. Limited quantities of biomass resources are available now at costs of $.50 to 1.50 per million Btu. Wood chips are currently delivered to the 10 MW electric generating plant in Burlington, Vermont at a maximum cost of $1.25 per million Btu. Electricity from such plants would cost 2 to 4 cents/kWh. Agricultural residues such as cornstalks can be mixed with coal and fired in boilers. Methane can be produced by anaerobic digestion of animal manure at costs of $2 to $4 per million Btu depending on the size of the animal feedlot and the credit assumed for the undigested animal feed recovered.

The NEA contains a 1 cent/gallon motor fuel tax credit for alcohol fuel blends made from biomass. According to cost comparisons performed by the DOE Alcohol Fuels Task Force, this could make gasohol (a 10 percent ethanol blend with gasoline) economically competitive with premium gasoline in a few areas of the nation where ethanol can be produced from relatively inexpensive spoiled grain. Gasohol would not be competitive with regular grades of gasoline, however. Although its energy content per gallon is less than that of gasoline, test results show a 10 percent blend does not significantly reduce gas mileage, and the octane of regular gasoline is boosted to premium levels. The state of Nebraska has recently experimented with ethanol/gasoline blends and found favorable market acceptance, even at prices slightly higher than gasoline. A plan for use in state-owned vehicles is under construction.

Biomass program cost goals are:

Process	Application	Cost (1978$) ($/million Btu)	Date
Production	Cultivation on Energy Farm	1.00 to 1.50	2000
Gasification	Synthetic High Btu Gas		1990 to 2000
	• anaerobic digestion of marine	2 to 4	
	• thermochemical conversion	4 to 6	
Liquefaction	Liquid Fuels		1990 to 2000
	• ethanol	10 to 12	
	• methanol	7	
	• Transportation Fuels	5	

These costs compare to slightly more than $2.00/MMBtu for imported crude oil today, and are slightly lower than the cost of synthetic fuels from coal using present technology.

Industry Status

Industry is advancing on many fronts to utilize the biomass potential. This effort varies from small wood processing units for pelletizing the product to large gas producing facilities. A facility in Guymon, Oklahoma in January, 1978, began producing synthetic natural gas using processed manure from a 75,000 head cattle feedlot.

On the big island of Hawaii, forty percent of the electricity is supplied by the burning of bagasse (sugar cane residue). Utilities in Burlington, Vermont and Eugene, Oregon are using wood as a feedstock for generating steam and electricity. Several industries are installing package boilers to be fired by wood. Small wood gasifiers that retrofit gas fired boilers are being developed but have not yet been extensively marketed.

Regional Aspects

Biomass in various forms can occur throughout the country. Forest residue is available in New England and agriculture residue and spoiled grain are potential Midwest feedstocks. Lumber residue is available in the Northwest and Southeast and bagasse is available in the Southeast as well as in Hawaii. Silviculture energy farms require relatively large tracts of land and are likely to be located in the Southeast.

Environmental Aspects

Production and conversion of biomass will result in relatively few environmental impacts. Direct combustion will require assurance that burning is complete and that particulate matter is contained. The technology for controlling such potential environmental effects is well in hand. Environmental control technologies for other conversion processes have been developed by coal conversion and waste treatment technologies. Excessive use of residues from forestry and agricultural operations could contribute to dust and erosion problems and lower the organic content of the soil. Energy farming in coastal, wetlands, or marginal areas must be undertaken with caution through small-scale test evaluations.

SATELLITE POWER SYSTEMS

Description

Satellite Power Systems (SPS) in stationary orbits above the earth, would capture solar energy, convert it to electricity, and beam energy to earth in microwave form (see Figure 18). This energy would then be converted back to electricity and distributed to users over utility grids. The technology is now in the concept formulation stage, under joint DOE/NASA sponsorship to determine technical, economic, and environmental feasibility. Several different systems are under investigation, including very large photovoltaic arrays and solar thermal power systems.

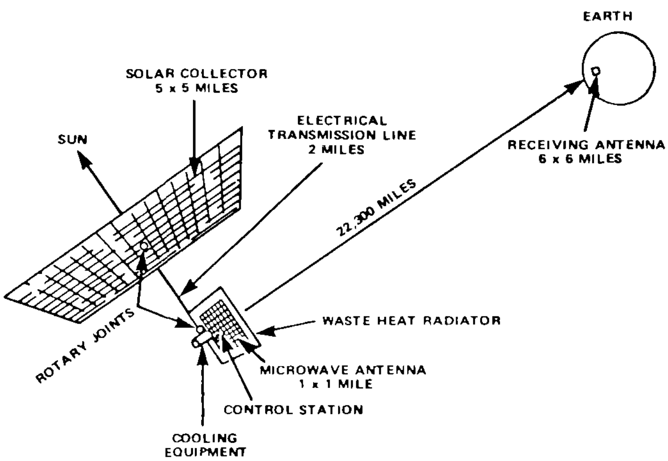


Figure 18. Proposed Satellite Power Station. Designed to Produce 10 Gigawatts of Electricity

Markets

To be practical Satellite Power Systems are generally conceived to generate large amounts of power. Present designs are sized to generate 5000 MWe to 10,000 MWe. As such, the market for the power produced by SPS would be restricted to major utilities that can receive, convert, and distribute electricity in 5000 to 10,000 MWe blocks. The requirement for the power system to absorb potentially large interruptions of power from the satellite system and the large land requirements for the receiving antenna suggest that power from a single system might be distributed through several large power systems or through a national grid.

Program Status

DOE and NASA are jointly engaged in a 4-year, 16 million dollar concept evaluation program to estimate the economic, social, and environmental feasibility of satellite power systems. Small-scale ground tests have established that microwave transmission of energy is technically feasible. Development of these systems requires significant parallel development and expansion of aerospace industry capabilities to launch, assemble, control, and manage extremely large orbital and ground-based systems.

Preliminary cost estimates for deployment of a network of 60 to 100 satellites indicate a capital cost of 3500 $/kWe. This baseload electric power from the system could be delivered for a projected 6.5 cents per kWh at the distribution terminal. The most significant economic problem is the extremely high cost of the first full-scale demonstration project, estimated at $50 to $75 billion.

Industry Status

Commitment to a solar power satellite system would require significant expansion of existing aerospace industry capacity, as well as the development of in-space manufacturing and assembly capabilities. Several aerospace companies are now engaged in related feasibility studies.

Environmental Aspects

Environmentally, aspects of solar power satellite systems raise questions related to microwave radiation exposure, large land use requirements for receiving antennas, possible climatological effects, gamma and other high energy radiation exposure for space assembly crews, possible interference with communications, and recovery and processing of large quantities of copper, aluminum, and silicon.

APPENDIX B. ECONOMICS AND MARKET PENETRATION

INTRODUCTION

Many studies have estimated the market penetration of solar technologies by assessing a variety of factors which influence the market share or relative success of products in the marketplace. Such factors as relative capital and operating cost of alternatives; availability of reasonable financing, tax treatment; resale value; compatibility with existing equipment (including utilities); and structure, serviceability, codes and regulations, convenience, safety, and aesthetics are among those which affect the market penetration of solar products.

Due to the number of assumptions which must be made in such studies and analysts' disagreement about the magnitude and importance of such factors as mentioned above, it is not surprising to find that these studies do not produce exactly the same results. Some studies do not include all technologies and others do not address all markets (retrofit, for example), thus great care should be taken if one wishes to compare the results of one report with those of another. Therefore, it is most useful to examine the range of market penetration estimates they provide. A full explanation of why these studies differ has never been attempted and is beyond the scope of this document. Instead, the next section provides a summary of the results of these reports. (See Reference Listing, page 49).

SUMMARY OF STUDIES

Before discussing the results of these studies, it is useful to provide a reference point for their predictions of future energy use by examining present day energy use patterns.

Current Energy Use – Present uses of renewable and nonrenewable primary energy resources are given in Table 4. The renewable resource data in this table and in the tables which follow have been presented in quantities and units equivalent to the nonrenewable primary energy resources which they displace.

This energy accounting procedure permits direct comparison of solar energy inputs with other primary energy inputs.

Table 4 points out that we now make use of solar energy in the forms of hydroelectric power and as biomass which is used in the paper, pulp and lumber industries.

Summary of Solar Market Penetration Studies – Market penetration studies for solar energy may be grouped into two catagories: a) the integrated, multitechnology study in which the roles of solar and nonsolar technologies are examined together in the context of a scenario for the entire United States economy; and b) the technology-specific study which examines a single technology (e. g., photovoltaics) in one or many of its potential market applications. In either case the output is not always a forecast or a prediction of "exactly" what will happen in the future, but is more often a tool used to test the sensitivity of the results to changes in the assumptions about the factors affecting market penetration. Thus, it is important not only to examine the results of the market penetration studies, but to understand the means by which a successful technology or product fits into its niche in the overall economy.

Table 4. 1976 U.S. Primary Energy Consumption

Resource	Consumption Quads[1]
Petroleum	34.9
Natural gas	20.2
Coal	13.8
Nuclear	2.0
Hydroelectric	3.1
Geothermal	0.0 (small)
Biomass	1.3
Other solar (wind, solar heating)	0.0 (small)
Total	75.3

[1]conversion factors:

one quad	physical units
oil	500,000 barrels per day for 1 year
gas	0.97 trillion standard cubic feet
coal	45 million tons
primary energy for electricity	85 billion kilowatt hours net electricity (including conversion and transmission losses)

A summary of the conclusions from eleven studies is provided in Table 5. The contributions of solar energy are represented by displaced primary energy. The studies show a 1985 total energy consumption band of 79 to 120 quads, with a range of 0.5 to 5.0 percent solar contibution, a year 2000 total energy consumption of about 135 quads, with a 4.0 to 24.0 percent solar contribution and a year 2020 total energy consumption of about 180 quads, with a solar contribution of 13.0 to 43.0 percent. It should be noted, however, that most of the studies show a solar contribution of less than 10 percent in the year 2000. The cases that exceeded 10 percent penetration assumed a very heavy national emphasis on solar energy and in some cases, a dramatic change in energy market structure.

In the studies, total projected energy consumption tends to be much greater in the earlier studies (NSF/NASA, Project Independence, ERDA-49) than in the more recent ones which consider increased opportunities for energy conservation and reduced energy use as prices increase. The later studies recognize the flexible linkage between energy consumption and economic growth over the long run.

INDIVIDUAL SOLAR TECHNOLOGY MARKETS

Market penetration estimates for nine generic solar energy technologies are reviewed in the following sections. As discussed earlier, market penetration in the integrated studies generally depends on the relative economics of solar technologies and their competitors. A summary of the impacts of the individual solar technologies is shown in Tables 6 through 8 for the years 1985, 2000, and 2020. Technologies have been grouped as follows:

a. Solar Heating and Cooling of Buildings (SHACOB).
b. Agricultural and Industrial Process Heat (AIPH).
c. Solar Thermal Power (SOL. TH).
d. Photovoltaic (PV).
e. Total Energy Systems (TES).
f. Wind Energy Conversion Systems (WECS).
g. Ocean Thermal Energy Conversions (OTEC).
h. Biomass (BIO) – gas, liquids and direct combustion.
i. Satellite Power Systems (SPS).
j. Low-Head Hydro (LHH).

The studies reviewed here have not been consistent as to the inclusion of the full range of solar technologies: for example, total energy systems were considered only in CONAES, IERPS, MOPPS, and CEQ, low-head hydro was only estimated in CEQ and IERPS and satellite power systems are included only by IERPS and NSF/NASA studies. In addition, none of the studies have considered the impacts of passive solar heating and cooling. These passive systems could supplement the active systems market and expand the total solar contribution in this area.

Solar Heating and Cooling of Buildings (SHACOB) – The range of penetration presented in the integrated studies is as follows:

Primary Quads Displaced	Year
0 to 3	1985
0 to 9	2000
3 to 18	2020

The largest contributions are in hot water and space heating with hot water making a significant penetration by 1985. For illustration, consider that 1 quad of primary energy displaced by combined solar hot water and space heating and cooling requires a total collector area of approximately 3 billion square feet, installed in 7 million homes. In 1975, there were roughly 75 million single and multi-family residential units and 25 billion square feet of commercial floor space. By the year 2000, the building inventory is expected to grow to more than 110 million residential units and 44 billion square feet of commercial floor space.

The largest market impacts for solar hot water and space heating are likely to occur in the Southwest and Southeast, due to rising conventional fuel costs, high solar insolation, and relatively rapid housing growth in these areas. Other areas which are expected to have a high solar market share (although total quad impact is smaller because of smaller population). These areas have high insolation and a high heating load such as the Great Plains and the Midwest. Solar market penetration is projected to be less in the Northeast which has a greater frequency of cloudy days and a historically low implementation of electric space heating.

Agricultural and Industrial Process Heat (AIPH) – The range of penetration from the integrated studies is as follows:

Primary Quads Displaced	Year
0 to 0.2	1985
0 to 3	2000
0 to 13	2020

Significant numbers of these studies show zero or low utilization of solar for AIPH in 1985. The high estimate is from the CONAES Solar Resource Group high solar case and probably represents total market potential, rather than market penetration. The InterTechnology report examined AIPH in detail and estimates 0.6 quads penetration in 1985. This report is more optimistic about the cost of solar process heat ($3 to $5/million Btu) than the SRI analysis ($9/ million Btu). The zero penetration for 2000 is from the

Table 5. Summary of Projected Solar Impacts

QUADS DISPLACED
(Primary)

Scenario	1985			2000			2020		
	Total	Solar(1)	Percent	Total	Solar(1)	Percent	Total	Solar(1)	Percent
Mitre SPURR NEP	86	.20	.2	115	6.0	8.0	189	35.4	18.7
Mitre SPURR RTS	85	.09	.1	113	5.0	4.4	188	24.7	13.1
SRI-Reference Case	99	2.0	2.0	145	6.0	4.1	198	11.0	5.6
SRI-Solar Emphasis Case	99	5.0	5.0	148	15.0	10.1	204	44.	22.
SRI-Low Demand Case	79	2.0	2.5	89	7.0	7.9	102	14.	13.7
Solar Working Group -									
with Behavioral Lag	90	.4	.4	115	8.1	7.0	140	19.1	13.6
without Behavioral Lag	90	2.5	2.7	115	8.8	7.7	140	19.5	13.9
MOPPS	94.6	1.2	1.3	117.3	2.8	2.4	-	-	-
IERPS	-	-	-	132.5	5.8	4.3	195.5	29.5	15.0
Lovins (2)	95	5.	5.3	108	40	37.0	76.	70	92.0
NSF/NASA	117	.4	.4	177	11.8	6.6	300	109.	36.0
Project Indep-B.A.U.	120	.8	.7	180	10.8	6.0	-	-	-
- Accelerated Solar	120	1.4	1.2	180	38.8	21.3	-	-	-
CONAES - High Solar	98	3.0	3.0	146	14.0	9.6	-	-	-
- Low Solar	98	0.0	.0	146	0.1	.1	-	-	-
ERDA-49	100	.8	.8	150	10.	6.7	180	45.0	24.1
CEQ-April 1978 (3)	-	-	-	100	24.5	24.5	105	45.0	43.0

(1) Solar components exclude hydropower. Some studies also exclude the current biomass consumption.
(2) Includes all soft technologies.
(3) Mid range of CEQ estimates for each technology.

Table 6. 1985 Penetrations for Nine Solar Technologies
(Quads-Primary Energy)

Solar Technology[1]	Mitre SPURR NEP	Mitre SPURR RTS	SRI Ref.	SRI Sol. Emph.	SRI Low Dem.	SWG w/B.L.	SWG wo/B.L.	MOPPS	IERPS	NSF/ NASA	CONAES High Sol.	CONAES Low Sol.	Proj. Ind. BAU	Proj. Ind. Acc. Sol.	ERDA 49
Heating and Cooling of Buildings	.15	.080	1.0	3.0	1.0	.20	1.3	.190		.17	.53	0.	.3000	.600	.150
Agricultural and Industrial Process Heat	.02	.013	0.0	0.0	0.0	0.00	0.0	.005		—	.3	0.	0.0000	0.000	.050
Total Energy Systems	—	—	—	—	—	—	—	.001		—	0.0	0.0			
Photovoltaics	0.00	0.000	—	—	—	0	0	0.000		0.00	.000	0.	.0003	.010	.005
Wind	0.00	0.000	—	—	—	0	0.1	.030		0.00	.10	0.	.4000	.500	.054
Solar Thermal Electric	0.00	0.000	—	—	—	0	0	0.000		0.00	.00	0.	.0020	.002	.004
Ocean Thermal Energy Conservation	0.00	0.000	—	—	—	0	0	0.000		0.00	.0	0.	.0300	.030	.005
Satellite Power Systems	—	—	—	—	—	—	—	—		0.00	—	—			
(Solar Electric)	(0.00)	(0.000)	(0.0)	(0.0)	(0.0)	(0.00)	(0.1)	(.03)		(0.00)	(.10)	(0.)	(.4300)	(.540)	(.070)
Biomass	.03	0.000	1.0	2.0	1.0	.20	1.1	1.000		.27	.50	0.	.1000	.300	.500
Total Solar	.20	.090	2.0	5.0	2.0	.40	2.5	1.230		.44	1.46	0.	.8300	1.440	.770

[1] Excludes hydropower

Table 7. 2000 Impacts for Nine Solar Technologies
(Quads-Primary Energy)

Solar Technology[1]	Mitre SPURR NEP	Mitre SPURR RTS	SRI Ref.	SRI Sol. Emph.	SRI Low Dem.	SWG w/B.L.	SWG wo/B.L.	MOPPS	IERPS	NSF/ NASA	CONAES High Sol.	CONAES Low Sol.	Proj. Ind. BAU	Proj. Ind. Acc. Sol.	ERDA 49	CEQ (mid point)
Heating and Cooling of Buildings	1.60	.90	5.0	9.0	6.0	4.0	4.1	.71	.95	2.10	4.25	.00	2.30	3.5	2.00	3.0
Agricultural and Industrial Process Heat	1.60	.90	0.0	0.0	0.0	0.0	0.0	.02	2.27	—	2.67	.00	—	—	1.00	3.5
Total Energy Systems	—	—	—	—	—	—	—	.06	.15	—	.50	.00	—	—	—	—
Photovoltaics	.04	.15	—	—	—	0.	0.	.11	.27	1.50	1.10[2]	.00	1.50	7.0	1.88	5.0
Wind	1.70	2.20	—	—	—	2.0	2.3	.10	.31	.76	1.40	.00	4.00	5.0	1.25	6.0
Solar Thermal Electric	.30	.22	—	—	—	0.	0.	.10	.24	.76	.20[2]	.00	.60	1.3	1.25	1.0
Ocean Thermal Energy Conservation	.01	.01	—	—	—	0.	0.	.03	.04	.76	.40[2]	.00	1.70	7.0	.67	2.0
Satellite Power Systems	—	—	—	—	—	—	—	—	.21	.76	—	—	—	—	—	—
(Solar Electric)	(2.95)	(2.60)	(0.0)	(1.0)	(0.0)	(2.0)	(2.3)	(.33)	(1.22)	(4.54)	(3.10)	(0.00)	(7.80)	(20.3)	(5.05)	(14.0)
Biomass	.40	.10	1.0	5.0	1.0	2.1	2.4	1.66	1.16	5.12	3.50	.10	.70	15.0	3.00	4.0
Total Solar	5.65	4.48	6.0	15.0	7.0	8.1	8.8	2.79	5.75	11.76	14.02	.10	10.80	38.8	11.05	24.5

[1] Excludes hydropower

[2] The impact of photovoltaic, solar thermal electric and OTEC shown in summary of CONAES Solar Resource Group report was allocated in proportion to the larger impact shown in the detailed report.

Table 8. 2020 Impacts for Nine Solar Technologies
(Quads-Primary Energy)

Solar Technology[1/]	Mitre SPURR NEP	Mitre SPURR RTS	SRI Ref.	SRI Sol. Emph.	SRI Low Dem.	SWG w/B.L.	SWG wo/B.L.	MOPPS	IERPS	NSF/ NASA	CONAES High Sol.	CONAES Low Sol.	Proj. Ind. BAU	Proj. Ind. Acc. Sol.	ERDA 49	CEQ (mid point)
Heating and Cooling of Buildings	5.00	3.00	10.0	18.0	10.0	6.70	6.70		2.65	10.50					15.0	7.5
Agricultural and Industrial Process Heat	13.00	10.00	0.0	4.0	0.0	.10	.10		9.02	—					5.0	10.0
Total Energy Systems	—	—	—	—	—	—	—		3.58	—					—	—
Photovoltaics	.21	.57	—	—	—	3.40	3.60		2.03	26.50					4.8	20.0
Wind	6.62	6.62	—	—	—	3.80	3.90		.94	16.00					3.6	10.0
Solar Thermal Electric	3.10	1.40	—	—	—	0.00	0.00		1.95	8.00					4.2	7.5
Ocean Thermal Energy Conservation	2.42	1.28	—	—	—	0.00	0.00		.48	16.00					2.4	7.5
Satellite Power Systems	—	—	—	—	—	—	—		1.40	6.00					—	—
(Solar Electric)	(12.35)	(9.87)	(0.0)	(11.0)	(0.0)	(7.20)	(7.50)		(10.38)	(82.50)					(5.0)	(45.0)
Biomass	5.00	1.80	1.0	11.0	4.0	5.10	5.20		3.86	16.0					10.0	7.5
Total Solar	35.35	24.67	11.0	44.0	14.0	19.10	19.50		29.49	109.0					45.0	70.0

1/ Excludes hydropower

SRI reference case in which solar is assumed to be uneconomic relative to competitors (particularly synthetic high Btu gas) while the 3.0 quad penetration is from the SPURR-NEP scenario in which solar process heat is considered to be economically competitive with conventional alternatives. In 2020 these same scenarios (SRI, MITRE), again bound the range of estimates. The InterTechnology report estimates 6.3 quads fuel displacement in 2000. Solar process heat also achieves significant penetrations in the IERPS, ERDA-49, and CEQ estimates.

Agricultural uses of solar thermal energy includes crop drying and the heating of buildings; these applications are now served by conventional fuels. Industrial heating provides a much larger market (approximately 95 percent of the total) and involves applications requiring hot air, hot water, low-temperature steam (up to 350°C), high-temperature steam (over 350°C), and direct heat. The SPURR market analysis shows that 20 percent of the process heat demand is for direct heating of air, 30 percent is for water heating (between 40°C and 100°C) and 50 percent for steam. With economically competitive systems, the AIPH sector is a very large potential market for solar technologies. The SPURR analysis estimates total process heat demand of 8.4, 14.1, and 28 quads of steam in 1985, 2000, 2020, respectively.

It is quite difficult to make economic models reflect some important decision criteria that affect solar energy penetration in AIPH (and other markets as well). For example, concerns about the availability of conventional fuels and the probability of delivery disruptions and consequent loss of business or employment are potentially important and are not easily or uniformly modeled.

Solar Electric Technologies – Electric power plants are usually classified as base, intermediate, or peaking load units. Baseload units operate continuously and are typically the most efficient and largest units (500 to 1000 MWe output) installed in any power system. Intermediate load units are somewhat smaller (100 to 500 MWe) and are operated to follow the daily load cycle. That is, they are loaded early in the morning as power demand increases and throttled down in the evening when demand has decreased. Peak load units such as gas turbines or pumped storage facilities operate for only a small portion of the day during the period of highest demand.

Baseload units generally have high capital costs and low fuel costs; the reverse is true for peak load units. The capital and fuel cost for intermediate load units fall somewhere between those of base and peak load units.

Capital cost estimates for solar thermal electric and photovoltaic systems are expressed in dollars per kilowatt of peak output ($/kW-pk). This measure reflects the fact that solar intensity varies through the day as the sun travels across the sky, throughout the year as the earth tilts, with latitude, and with prevailing weather conditions. About 5 peak Watts of installed capacity are required to produce a daily average of 1 Watt.

Solar Thermal (SOL. TH) – Solar thermal electric systems can be used to provide peaking and intermediate capacity in electric power systems. Such systems are particularly suited to the Southwest where the direct component of sunlight is high and land is readily available for solar collectors. Solar thermal power technologies typically employ a concentrator to produce high pressure vapor for a Rankine cycle turbine-generator. The economic attractiveness of this technology would be enhanced with thermal storage which would permit extended operation.

The output of 300 solar thermal plants of 100 MWe average capacity provides about one quad of primary energy. The range of market penetration is shown as follows:

Primary Quads Displaced	Year
0 to 0.002	1985
0 to 1.3	2000
0 to 8.0	2020

The lowest estimates for 1985 (MITRE, MOPPS, SRI, Solar Working Group, CONAES) and 2000 (Solar Working Group) penetration of solar thermal electric capacity assume a long technology development time and reflect a concern that it may not prove to be economically competitive with other well-developed conventional technologies. However, earlier integrated studies show as much as 1.3 quads in use by the year 2000 (Project Independence-Accelerated Solar Base).

Photovoltaic (PV) – Photovoltaic systems convert the sun's rays directly to electricity. These systems have specialized applications today in providing electric power at remote locations. They can be used in central station arrays throughout an electric power system, and in dispersed applications (rooftop installations, building sides, etc.). Photovoltaic arrays can also be part of a total energy system generating both heat and electricity.

One quad of primary energy displaced by photovoltaic power would require roughly seven million units of 5 kWe average for dispersed residential and commercial applications or 300 central power station units of 100 MWe (average) capacity. The range of penetration of integrated studies is shown as follows:

Primary Quads Displaced	Year
0 to .02	1985
0 to 7.0	2000
0.2 to 26.5	2020

The extreme ranges of estimates here reflect basic differences in opinion about the costs (capital and operating) of both photovoltaics and the technologies with which they must compete in the marketplace. Both SPURR scenarios assume that solar electric technologies (excluding OTEC) operate in a fuel saver mode where the solar technology displaces energy from a conventional fossil fuel or hydro units. Other technology-specific studies have assumed that photovoltaic systems can operate in a firm capacity mode and give solar technologies credit for some capacity displacement. In other words, full backup capacity from conventional systems would not be required.

Total Energy Systems (TES) – Total Energy Systems provide both electricity and heat and can be used both in the buildings sector (residential and commercial) and in industrial processes. Photovoltaics and solar thermal electric systems can be used as a basis for such total energy systems. Integrated studies have not, in general, examined this option, with the exceptions of MOPPS, IERPS, CONAES, and CEQ. One quad of primary energy displaced represents approximately ten million TES units 5 to 10 kWe in size. Estimated penetrations are shown as follows:

Primary Quads Displaced	Year
0 to 0.001	1985
0 to 0.15	2000
0 to 3.4	2020

Such penetrations are dependent on the achievement of RD&D goals and the resolution of institutional barriers. The OTA study examined both photovoltaic and solar thermal TES for four U.S. cities (Albuquerque, Boston, Omaha, and Fort Worth) and found that by 1985 photovoltaic TES would be competitive with an all electric home assuming the home owner pays 6 cents per kilowatt hour for electricity. TES's have high thermal efficiencies because heat that would otherwise be wasted is used for heating or cooling a building. There is difficulty, however, in making economic estimates (and comparing estimates from different sources) for dual product systems like TES (thermal and electric energy) because the system cost cannot be precisely allocated between the heat and electricity functions.

Wind Energy Conversion Systems (WECS) – Wind machines can be used to provide electrical and mechanical energy, although they are most often considered as being integrated with electric power systems. One quad of primary energy displaced would require roughly 15,000 one to two MWe wind machines or a larger number of machines of smaller capacity. The range of penetrations in the integrated studies is shown as follows:

Primary Quads Displaced	Year
0 to .1	1985
.1 to 6	2000
1 to 16	2020

The 1985 penetration of .1 quad reflects dispersed wind applications in the CONAES and MOPPS studies. The year 2000 penetration is bounded below by MOPPS (0.1) and above by the CEQ midrange estimate. Note that the primary energy accounting procedure used in this report implies that 1 quad of electricity supplied by wind machines displaces 3 quads of primary energy.

CEQ estimates a range of 4 to 8 quads primary energy displaced in 2000. The Solar Working Group and SPURR estimates show approximately 2 quads of primary energy displaced by large (1 to 2 MWe) wind machines (at a capital cost of $870/kWe in 1985) integrated with electric power systems as fuel savers. In the fuel saver mode, when wind is available, wind turbines substitute for oil and gas burning units or provide charging for energy storage. When wind is not available, the conventional backup would be used.

There are other uses of wind energy which were not examined in these studies. For example, in certain locations, the wind may be of sufficient speed and reliability that WECS can provide firm capacity (i.e., be available a large fraction of the time), and thus full backup capacity is not required. Utility interconnections may also be effective for leveling the variation among windy and calm areas.

Ocean Thermal Energy Conversion (OTEC) – Ocean thermal energy conversion plants can produce electricity and electricity-intensive products such as ammonia by tapping the energy associated with thermal gradients in the ocean. One quad of primary fuel displaced represents approximately thirty-five 400 MWe OTEC plants. The range of penetration estimates is shown as follows:

Primary Quads Displaced	Year
0 to .002	1985
0 to 7	2000
0 to 16	2020

The 1985 estimate reflects the current state of development of this technology. The zero penetration estimates for 2000 and 2020 reflect the Solar Working Group's judgment of the economics of OTEC ($2700/kWe) relative to other alternatives. The high estimates for 2000 and 2020 are those of the NSF/NASA study which assumed a total energy demand in 2000 of 300 quads. SPURR penetrations assume an ultimate capital cost of $1400/kWe (based on mass production) and projects a contribution of 2.4 quads in 2020.

Production of energy intensive products from OTEC was not projected in most of the integrated studies although ammonia production is modeled in SPURR and MOPPS.

Biomass (BIO) – Biomass is a generic term for agricultural and silvicultural organic materials which can be either used directly or converted to other useful energy forms such as liquid and gaseous fuels.

Recent studies project that there are 1 to 3 additional quads of biomass available for the cost of collection in forest residues and animal feedlots.

As a reference point, 1 quad of biomass converted to high Btu gas represents roughly 250 dispersed biomass gasification plants each producing 12 million standard cubic feet of gas per day. A typical coal gasification plant would produce 250 million standard cubic feet per day. The range of penetration estimates is as follows:

Primary Quads Displaced	Year
0 to 2	1985
1 to 15	2000
1 to 16	2020

For 1985, the low estimate is from the SPURR Recent Trends Scenario (RTS) which assumes relatively low conventional fuel prices and a business-as-usual world (note that current SPURR runs do not include biomass consumption in the industrial sector). The high 1985 estimate is from the SRI Solar Emphasis scenario which assumes large Federal subsidies for solar technologies.

Satellite Power Systems (SPS) – Satellite power involves several steps: the generation of electricity with photovoltaic systems in satellites, microwave transmission to earth, rectification at an earth station, and integration with electric grids. This technology is in the concept formulation stage under joint DOE/NASA efforts to assess its technical, economic, and environmental feasibility. One quad of primary energy would be displaced by three 5000 MWe systems in stationary orbit above the United States. Satellite power systems are considered only in the NSF/NASA and IERPS reports where market penetrations are as follows:

Primary Quads Displaced	Year
0	1985
0.21 to 0.76	2000
1.40 to 6.0	2020

Low-Head Hydro – The low-head hydro resource assumes numerous dispersed applications with a total vertical fall of roughly 50 feet or less. The power generating capacities of these sites ranges from 50 kWe to 50 MWe. Because of the differing treatment of hydropower as a solar energy resource, most integrated studies do not report the potential impact of this technology. CEQ estimates a 1 to 3 quad impact in the year 2000 and beyond. The IERPS estimate is 0.3 quad displaced in the year 2000 and 2 quads in the year 2020.

A reference listing of the integrated studies reviewed is provided.

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APPENDIX C

THE WHITE HOUSE
WASHINGTON

May 16, 1978

MEMORANDUM FOR: THE SECRETARY OF ENERGY
THE SECRETARY OF STATE
THE SECRETARY OF THE TREASURY
THE SECRETARY OF DEFENSE
THE SECRETARY OF THE INTERIOR
THE SECRETARY OF AGRICULTURE
THE SECRETARY OF COMMERCE
THE SECRETARY OF LABOR
THE SECRETARY OF HOUSING AND URBAN DEVELOPMENT
THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY
THE ADMINISTRATOR OF GENERAL SERVICES
THE ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
THE DIRECTOR OF THE NATIONAL SCIENCE FOUNDATION
THE CHAIRMAN OF THE COUNCIL OF ECONOMIC ADVISORS
THE CHAIRMAN OF THE COUNCIL ON ENVIRONMENTAL QUALITY
THE DIRECTOR OF THE OFFICE OF MANAGEMENT AND BUDGET
THE DIRECTOR OF THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY
THE SPECIAL ASSISTANT TO THE PRESIDENT FOR CONSUMER AFFAIRS

FROM: STUART EIZENSTAT

SUBJECT: DOMESTIC POLICY REVIEW OF SOLAR ENERGY

The President has directed that a Solar Energy Policy Committee be established under the Chairmanship of the Secretary of Energy and consisting of the Addressees. This Committee shall review the current federal programs related to the research, development, demonstration, and commercialization of solar energy and shall develop for Presidential consideration policy options and recommendations for effective development and maximum economic use of solar energy, both short and long term. This memorandum will serve to inform you of the initiation of an interagency study under the procedures established in the Domestic Policy Review System.

Purpose of the Review: The national security and economic problems posed by our increasing dependence on imported oil establish a clear need for the rapid development and use of alternative domestic energy sources. Continued economic growth can occur only if we prepare now to make the transition from oil and natural gas to energy sources we have in abundance. The National Energy plan stated:

> ". . .The use of nonconventional sources of energy must be vigorously expanded. Relatively clean and inexhaustible sources of energy offer a hopeful prospect of supplemental conventional energy sources in this century, and becoming major sources of energy in the next. Some of these nonconventional resources permit decentralized production and thus provide alternatives to large, central systems. Traditional forecasts of energy use assume that nonconventional resources, such as solar and geothermal energy, will play only a minor role in the United States energy future. Unless positive and creative actions are taken by the government and the private sector, these forecasts will become self-fulfilling prophecies."

In the year since the National Energy Plan was put forward, interest in the possibilities solar energy holds for meeting domestic and international needs in this century and in the next has continued to grow. A wide variety of estimates have been made concerning the level and timing of the contribution solar energy can make to meeting national needs. Numerous recommendations for solar strategies have been advanced at the federal, state, and local level.

The President continues to believe that solar, and other renewable energy technologies, must be vigorously pursued so as to provide our country with reliable energy supply alternatives on an accelerated basis. The overall purpose of the Solar Policy Review is to provide the President with:

(1) a sound analysis of the contribution which solar energy can make to U.S. and international energy demand, both in the short and in the longer term;

(2) a thorough review of the current federal solar programs to determine whether they, taken as a whole, represent an optimal program for bringing solar technologies into widespread commercial use on an accelerated timetable;

(3) recommendations for an overall solar strategy to pull together federal, state, and private efforts to accelerate the use of solar technologies.

The specific areas to be included in the Solar Policy Review are:

(1) an examination of each of the major areas of solar energy use (industry, buildings, agriculture, transportation) and each solar technology (heating and cooling, thermal electric, intermediate temperature-systems, photovoltaics, biomass, wind, hydropower, and ocean thermal) to determine technical or scientific needs relating to their commercial use, both short and long term;

(2) a review of current federal research, development and demonstration programs for solar technologies to determine whether they are structured appropriately to address the priorities and needs identified in area (1);

(3) identification of the institutional, economic, and environmental factors relating to the introduction and use of solar technologies and development of federal policy options and strategies for dealing with barriers or problems identified;

(4) an evaluation of the appropriate federal role in the commercialization of solar energy, including the particular contributions which the various federal agencies can make to the commercialization process;

(5) an examination of the potential for and impacts of using solar technologies abroad;

(6) a review of issues relating to the regional diversity of solar resources, and to the matching of solar equipment to end use requirements, and to the integration of solar technology with the existing energy supply system.

The deadlines established for completion of this review are structured to ensure that its recommendations and analyses are available for use during the FY1980 budget and legislative cycles. It should be clear, however, that undertaking this review is not intended to commit the Administration to larger solar budget expenditures. Rather, it is intended to examine the priorities and policies of the existing program and to determine whether they can be improved. The desirability of additional budget resources will be evaluated in a ZBB mode.

Structure of the Review

The Solar Policy Coordinating Committee, chaired by the Department of Energy, will develop specific plans for each of the areas identified above. A number of other agencies are receiving copies of this memorandum and their participation in the study will be invited as the need arises. To ensure that this Solar Policy Review is responsive to the increasing public and Congressional interest in solar technology, a program for participation by members of the public, and the Congress will be developed.

Schedule

By May 20, work plans for each of the areas of review shall be developed under the leadership of the Secretary of Energy. A Response Memorandum shall be prepared and submitted by the Solar Policy Coordinating Committee by August 15, 1978, so that policy options and recommendations may be submitted to the President by September 1.

The President views this Solar Policy Review as a high priority in developing near term as well as longer term strategies for the acceleration of the use of solar energy. The Agencies involved in this Review will be expected to make an intensive effort to complete this review in order that its conclusions and recommendations may be used in formulating the Administration's budget and legislative recommendations next fall.

cc: The Attorney General of the United States
The Administrator of the Small Business Administration
The Administrator of Action
The Chairman of the Federal Trade Commission
The Chairman of the Board of Directors of the Tennessee Valley Authority

GLOSSARY

Baseload Plant (Baseload Electricity) – an electrical generation facility which is designed primarily to satisfy a continuous demand. Generally, capacity factors are 0.6 to 0.9.

Biomass – living material and its waste products. Usually limited to plant material: trees and other living plants, crop residues, wood and bark residues, and animal manures.

British Thermal Unit (Btu) – the amount of heat required to raise one pound of water one degree Fahrenheit.

Capacity Factor – the actual amount of electricity generated by a power plant during one year divided by the amount of electricity that would be generated by the plant during one year if it operated at maximum capacity.

Conversion Efficiency – the actual net output provided by a conversion device divided by the gross input required to produce the output.

Conversion System – a device or process that converts a raw energy form into another, more useful form of energy. Examples: conversion of wood into methanol or sunlight into electricity.

Data Base – a set of numbers, variables and information that is used to provide the operational criteria for processing and decision making.

Demand – the amount of energy required to satisfy the energy needs of a stated sector of the economy. See also End-Use-Demand.

End-Use-Demand – the amount of energy used by final consumers.

Energy Farm – a concept involving the farming of selected plants for the purpose of providing biomass that can be used as a fuel or converted into other fuels or energy products.

Energy Supply – the total amount of primary energy resources used.

Escalation Rate – a number which defines the annual increase in monetary value of a specified quantity.

Ethanol – ethyl alcohol or grain alcohol, C_2H_5OH. It is the alcohol contained in intoxicating beverages. Ethanol can be produced from biomass by the conversion process called fermentation.

Feedstock – a raw material that can be converted to one or more end-products (methanol or synthetic natural gas, for example). Biomass is an energy feedstock.

Fossil Fuel – combustible matter formed from the deposition of organic materials over time.

Fuel Saver – a solar device which is used solely to save fuel at conventional fossil fuel-burning facilities. The conventional systems provide the needed system reliability.

Heliostat – a device that contains a mirror moved by a control mechanism to reflect the light of the sun in a particular direction.

Hybrid System – a combination of a solar technology with a conventional technology to provide the controlled availability needed for everyday use.

Hydrolysis – the chemical process that breaks complex organic molecules into simple molecules. For example, starch and cellulose can be hydrolyzed by acids or enzymes to produce simple sugars such as glucose, which can be fermented to produce ethanol.

Insolation – the rate at which energy reaches the earth's surface from the sun. Usually measured in $Btu/FT^2/Day$.

Life-Cycle Cost – the accumulation of all funds spent for the purchase, installation, operation, and maintenance of a system over its useful life. The accumulation generally includes a discounting of future costs to reflect the relative value of money over time.

MMBTU – Million Btu's (British thermal units).

Market Penetration – how much of a product will be sold on a yearly basis as it gains consumer acceptability over a specified time.

Methane – a simple hydrocarbon, CH_4, that is the prime constituent of natural gas. Methane can be made by certain biomass conversion processes.

Methanol – methyl alcohol, or wood alcohol, CH_3OH. Methanol can be made from petroleum byproducts or from biomass. and can be used as a fuel for motor vehicles.

Ocean Thermal Energy Conversion (OTEC) System – a solar plant located in warm ocean waters which uses the temperature differential between the sun-warmed surface water and cold deeper water to drive a turbine which in turn drives an electric generator to produce electricity.

Passive Solar Design – a structural design that makes use of the structural elements of a building, using no moving parts, to heat or cool spaces in the building.

Peak-Kilowatt (kWp) – maximum power output available from a solar electric device which typically occurs at solar noon.

Photovoltaics – a technology by which electricity is produced directly from sunlight.

Primary Energy – fuels as they are extracted from their original sources, i.e., fuels not derived from other fuels (coal, oil, natural gas, for example).

Process Heat – heat which is used in agricultural and industrial operations.

Projection – an estimation of probable future events.

Quad – one quadrillion (10^{15} or 1,000,000,000,000,000) Btu's (British thermal units).

Renewable Resources – sources of energy that are regenerative or virtually inexhaustible such as solar energy.

Scenario – a set of projections used as an assumption to conduct future planning. See also Simulation.

Silviculture – the technology of raising trees, or forest management.

Silvicultural Farm – an energy farm composed of trees.

Simulation – the use of mathematical representations of real systems to determine what is likely to happen under various possible sets of conditions.

Solar Collector – a structure which collects and converts solar energy into a more useful form.

Solar Energy -- the quantity of energy which reaches the earth's surface from the sun.

Solar Thermal Electric System – a system that converts heat energy from the sun into electricity. See also Appendix B.

Solar Total Energy System – a system in which solar energy is used to produce several types of energy in all temperature ranges needed for the application; for example, a solar system that collects solar radiation to produce electricity, heat, hot water, and absorption air conditioning.

Synthetic Natural Gas (SNG) – a manufactured gas comprised chiefly of methane and roughly equivalent in heating value to natural gas. SNG can be synthesized from biomass or coal.

Technology – the application of knowledge for practical purposes; for example, engineering designs to convert solar energy into more useful forms of energy such as electricity or space heating.

Thermochemical Conversion Process -- any process which transforms an initial set of chemical reagents into a different product set of chemicals involving the application or deletion of heat energy.

Wind Energy Conversion System (WECS) -- a technology for converting the energy in wind streams into useful forms.

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