REPORT TO THE SUBCOMMITTEE ON ENERGY COMMITTEE ON SCIENCE AND ASTRONAUTICS HOUSE OF REPRESENTATIVES

Review Of Selected Federal And Private Solar Energy Activities

B-178726

UNITED STATES GENERAL ACCOUNTING OFFICE

JUNE 18, 1974

ASSISTANT COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON DC 20548

B-178726

The Honorable Mike McCormack, Chairman
Subcommittee on Energy
Committee on Science and Astronautics
House of Representatives

Dear Mr. Chairman:

As you requested on October 29, 1973, we reviewed selected Federal and private solar energy activities. In accordance with our understanding of your specific areas of interest, we obtained information on:

--Federal funding of solar energy research, development, and demonstration activities.

--The objectives and goals of Federal solar heating and cooling activities.

--Interagency coordination of Federal solar heating and cooling activities.

--Private-sector solar heating and cooling activities.

--Economic evaluations that have been made of solar heating and cooling, including an examination of the methodology and data used.

Our work included a review of Federal records, literature, and periodicals concerning solar energy, and an analysis of two economic evaluations of solar heating and cooling. We also interviewed individuals and representatives of various Federal agencies, companies, and organizations working on solar heating and cooling.

We briefed your Subcommittee staff on the results of our work on June 7, 1974, at which time arrangements were made for us to brief the Subcommittee members today. The information we presented at these briefings is summarized below and is discussed more fully on the cited pages of the report.

Federal funding for solar energy research, development, and demonstration activities has increased each year since 1970. Solar heating and cooling has received more of this funding than any other solar program area.

A major increase in funding came in fiscal year 1974 when solar heating and cooling received $8.2 million--nearly half the total Federal solar energy budget. The $50 million 1975 solar energy budget request includes $17 million for solar heating and cooling. (See pp. 1 through 3.)

The National Science Foundation was designated in April 1973 by the Office of Management and Budget as the lead agency in Federal support of research on terrestrial applications of solar power. The Federal objectives and 5-year goals concerning solar heating and cooling are discussed on pages 3 and 4.

The Foundation has coordinated the various Federal solar heating and cooling activities through several means, including the formulation of a Federal solar heating and cooling program and an Interagency Panel for Terrestrial Applications of Solar Energy. (See p. 5.)

There is considerable private-sector interest in solar heating and cooling. Activities have ranged from basic research to market analyses of probable buyer and financial and insurance institution acceptance. Efforts have ranged from individuals who fabricated and installed solar heating systems on their own homes to about 70 organizations working together to determine the feasibility of bringing a solar climate control industry into being. (See pp. 6 through 9.)

Our review revealed two comprehensive economic evaluations of solar heating and cooling. One concerns the use of solar energy for heating; the other concerns the use of solar energy for combined heating and cooling.

We adjusted the evaluation results to provide a more current picture of costs and tested the sensitivity of the adjusted results to other assumptions made or factors used when possible or likely variations had the potential of significantly changing the indicated economic feasibility of solar heating and cooling. (See pp. 10 through 23.)

More than anything, the costs presented and the comparisons made in the report lead to the realization that determining the future economic feasibility of solar heating and cooling is a complex task which must be based on a number of assumptions. Differing assumptions regarding certain key factors bear significantly on the question of economic feasibility. Two of the more important factors are conventional fuel prices and solar collector costs.

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Although solar systems may not be economically feasible in many areas of the United States at this time, continued increases in gas, oil, and electricity prices--similar to those occurring in the last year--should improve the relative cost position of solar heating and cooling. However, the key in making solar systems economically competitive with conventional systems appears to lie in the ability of American ingenuity to build, deliver, and install solar collectors at prices substantially lower than present prices.

Aside from questions of economics, efforts to develop solar energy will continue to be important because of the need to conserve non-renewable energy resources and find alternative sources of energy.

As requested by your Office, because of impending congressional action on solar heating and cooling legislation, we did not obtain written comments on this report from any Federal or private organization. We do not plan to distribute this report further unless you agree or publicly announce its contents. We understand that the report may be published as a Committee Print.

Sincerely yours,

Phillip S. Hughes
Assistant Comptroller General

Contents

ABBREVIATIONS

AEC	Atomic Energy Commission
BTU	British thermal unit
DOD	Department of Defense
GSA	General Services Administration
HUD	Department of Housing and Urban Development
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NBS	National Bureau of Standards
NSF	National Science Foundation

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GENERAL ACCOUNTING OFFICE

REPORT ON REVIEW OF SELECTED FEDERAL

AND PRIVATE SOLAR ENERGY ACTIVITIES

At the request of the Chairman, Subcommittee on Energy, House Committee on Science and Astronautics, we reviewed selected Federal and private solar energy activities. Specifically, we obtained information on:

--Federal funding of solar energy research, development, and demonstration activities.

--The objectives and goals of Federal solar heating and cooling activities.

--Interagency coordination of Federal solar heating and cooling activities.

--Private-sector solar heating and cooling activities.

--Economic evaluations that have been made of solar heating and cooling, including an examination of the methodology and data used.

FEDERAL FUNDING OF SOLAR ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACTIVITIES

Before the current widespread recognition of the need to develop alternative sources of energy, solar energy research received only modest Federal support. From 1950 through 1970, for example, annual Federal funding for solar energy research, development, and demonstration activities averaged about $100,000. Since then, however, Federal funding has increased each fiscal year, as shown in the table on page 2.

Since 1970, solar heating and cooling has received more Federal funding than any other solar program area. A major increase in funding came in fiscal year 1974 when solar heating and cooling received $8.2 million--nearly half the total Federal solar energy budget. Although the $50 million 1975 solar energy budget request represents a somewhat more balanced solar energy program, solar heating and cooling funding was more than doubled to a total of $17 million.

Officials of the National Science Foundation (NSF)--designated in April 1973 by the Office of Management and Budget as the lead agency in Federal support of research on terrestrial applications of solar power--advised us that the entire $50 million is to be appropriated to NSF which will be responsible for distributing it to the other agencies.

Federal Funding of Solar Energy

Research, Development, and Demonstration Activities

By Program Area

Program area	1971	1972	1973	1974 estimate	1975 budget request
	(millions)				
Heating and cooling of buildings	$0.54	$0.10	$1.36	$ 8.20	$17.0
Solar thermal energy conversion	0.06	0.55	1.43	2.42	10.0
Photovoltaic conversion	0.03	0.41	0.92	3.71	8.0
Bioconversion	0.60	0.35	0.68	1.05	5.0
Wind energy conversion	-	-	0.20	1.20	7.0
Ocean thermal energy conversion	-	0.08	0.23	0.70	3.0
Workshop and program assistance	-	0.19	0.26	-	-
Total	$1.23	$1.68	$5.08	$17.28	$50.0

The following table shows, by agency, the estimated fiscal year 1974 Federal funding of solar heating and cooling activities.

Agency	Amount (millions)
NSF	$6.71
National Aeronautics and Space Administration (NASA)	.28
U.S. Navy	.02
U.S. Air Force	.09
Atomic Energy Commission (AEC)	.60
National Bureau of Standards (NBS)	.10
Department of Housing and Urban Development (HUD)	.40
Total	$8.20

As of March 14, 1974, there were 25 Federal contracts and grants totaling about $4.6 million which related to solar heating and cooling. These are listed in appendix I and cover a wide range of activities from basic research to tests and evaluations of solar collectors, storage devices, and demonstration projects.

OBJECTIVES AND GOALS OF FEDERAL SOLAR HEATING AND COOLING ACTIVITIES

The Federal objectives concerning solar heating and cooling, as promulgated by NSF, are

--to establish the full technology base for the widespread availability and utilization of solar energy systems to help meet the heating and cooling needs of all types of buildings in all the climatic regions of the United States to the degree that such applications can be made economically viable and socially and environmentally acceptable and

--to move the technology to the commercial sector as rapidly as the capabilities and funding in that sector become available.

NSF's 5-year solar heating and cooling goals are (1) to provide increased performance and new options for components, subsystems, and systems and (2) to complete system proof-of-concept experiments to the point that detailed tests and evaluations of systems may be conducted. Information on NSF's proof-of-concept experiments is contained in appendix II, as is information on NSF's other solar heating and cooling activities.

The following table--which indicates the type of involvement Federal agencies have in key solar heating and cooling activities--shows that many agencies are involved in solar demonstration projects and testing and evaluating solar systems, but that only a few are involved in basic research and improvements of technology.

Agency	Demonstration project(s)	Test and evaluation	Improvements of technology	Research
NSF	X	X	X	X
NASA	X	X		X
Department of Defense (DOD)	X			
AEC				X
NBS	X	X		
HUD	X	X		
General Services Administration (GSA)	X			
Postal Service	X			

Appendixes III through VI contain information on each of the above listed agencies' solar heating and cooling activities.

INTERAGENCY COORDINATION OF FEDERAL SOLAR HEATING AND COOLING ACTIVITIES

As the lead agency in Federal support of terrestrial applications of solar energy, NSF has coordinated the various Federal solar heating and cooling activities essentially through:

--The formulation of a Federal solar heating and cooling program, the objectives and 5-year goals of which were discussed on pages 3 and 4.

--An Interagency Panel for Terrestrial Applications of Solar Energy, which meets monthly.

--Frequent communication--formal and informal-- with the Interagency Panel members.

--Sponsorship of and participation in workshops and conferences on solar energy.

The Interagency Panel is made up of representatives of NSF, NASA, DOD, AEC, NBS, HUD, GSA, the Environmental Protection Agency, and the Departments of Agriculture, the Interior, and Transportation.

Our work did not include an evaluation of the effectiveness of the interagency coordination of Federal solar heating and cooling activities.

PRIVATE-SECTOR SOLAR HEATING AND COOLING ACTIVITIES

There is considerable private-sector interest in solar heating and cooling. Activities have ranged from basic research to market analyses of probable buyer and financial and insurance institution acceptance. Efforts have ranged from individuals who fabricated and installed solar heating systems on their own homes to about 70 organizations working together to determine the feasibility of bringing a solar climate control industry into being.

NSF has compiled lists of several hundred individuals, companies and organizations interested in solar heating and cooling. One is a solicitation list of 310 names for NSF proof-of-concept experiment contracts; the other is a list of 214 names NSF prepared for the NATO Committee on the Challenges of Modern Society. These lists were furnished the Subcommittee staff at the briefing on the results of our work on June 7, 1974.

From our efforts there appears to be private-sector consensus on the following important solar heating and cooling issues.

--The development of practical solar heating and cooling systems has no major technical barriers.

--Solar heating technology exists now, and cost reduction through mass production is needed to make it economically competitive with conventional systems.

--Collectors and cooling technology require the most improvement. Improvements can be accomplished through an intensive development program.

--There are major uncertainties with regard to factors such as public acceptance, legal rights to unshaded sun, the establishment of a supporting industry, and methods of marketing and financing high first-cost systems. The development of economically competitive systems would likely provide the incentives needed to overcome these problems.

--Economic incentives such as Federal subsidies, tax credits, and low-interest bank loans may be necessary to encourage widespread use of solar energy.

More than 30 solar-heated structures have been built in the United States; some of these are also cooled with solar energy. Some are houses; some are buildings. Some are for experimental purposes only; others are for conventional uses. They were built with both private and Federal funds in various climatic regions of the country. Appendix VII contains information on each of the structures we identified.

We were unable to determine the amount of private funding of solar heating and cooling activities because individuals who developed and outfitted their homes with solar systems did so on their own time and did not record costs, and companies and organizations with significant activities and financial involvement considered funding as proprietary and confidential information or could not separate the costs of solar activities from costs of their other activities.

Many of the better known individuals, companies, and organizations interested in solar heating and cooling have testified before or provided information on their activities to committees in both Houses of the Congress. A number of organizations have been compiling information on these and other private-sector solar heating and cooling activities. Appendix VIII provides information on documents and publications on such activities in preparation or planning at the time of our review.

The following activities of those we contacted indicate the broad solar heating and cooling interests in the private sector.

Burt, Hill and Associates

This architectural firm headquartered in Butler, Pennsylvania, has a long-standing interest in energy conservation, as well as a more recent interest in solar energy. The firm (1) is testing solar collectors it has made, (2) is working with Westinghouse in a proof-of-concept experiment for NSF, and (3) has designed a solar demonstration house to be constructed in Shanghai, West Virginia, for Ms. A. N. Wilson.

Institute of Energy Conversion of the University of Delaware

The Institute has conducted research and developed a system to provide heating, cooling, and electricity. An experimental house ("Solar One") has been built and instrumented for test purposes. The work of the Institute has received support from the University, NSF, the Office of Naval Research, and several gas, power, and light companies.

Solar Energy Systems, Inc.

This company is an outgrowth of the Institute of Energy Conversion's work and will carry out product and market development of products based on the work of the Institute. Initially, work will be concentrated on photovoltaic cells. Ultimately, Solar Energy Systems plans to combine heat absorption, thermal storage, DC to AC electric conversion, and electric storage into one system.

Energex Corporation

Energex, Las Vegas, Nevada, offers collectors for solar heating and a number of products using solar energy. A total system "package" is available, and there were plans to construct a 24-unit solar heated and cooled housing project near Las Vegas. In addition, Energex planned to operate and test a solar heating and cooling system in a manufacturing building.

Gaydardt Industries

Gaydardt, a research and development firm headquartered in Brandywine, Maryland, has developed and patented a collector. Several have been installed in the suburban Washington, D.C., area. These systems do not provide large amounts of heat storage. Future work is planned on storage and cooling.

Arthur D. Little, Inc.

This firm, headquartered in Cambridge, Massachusetts, has organized a program, involving about 70 organizations, to determine the feasibility of bringing a solar climate control industry into being. The three-phase program is planned to (1) identify potentially successful businesses in solar climate control and the prerequisites for success, (2) evaluate specific solar energy hardware and formulate detailed business plans, and (3) collaborate with companies participating in the project to implement these business plans.

The firm has done design work on a solar heated and cooled office building to be built for the Massachusetts Audubon Society in Lincoln, Massachusetts.

Solarex Corporation

Solarex has ongoing research and development in heating, cooling and collector coatings. Solarex is also testing and evaluating solar collectors at its facilities in Rockville, Maryland. The company has a collector available and will quote prices for specific installations; costs vary with the size and complexity of the installation contemplated.

Solar Systems of Delaware

Solar Systems is a research and development firm which can provide total systems or any of the various components. A foam tubing has been developed for collectors, and work has been done using asphalt for heat storage. Some 30 collector units have been fabricated; one is set up to show how the units will work. The company believes providing an alternate source of energy to agricultural and industrial users is the single area of greatest solar promise, unless the aesthetic and technical problems of retrofitting buildings can be overcome.

Sunworks, Inc.

This Guilford, Connecticut, firm markets a collector and designs systems. The collector is of the flat-plate, single-pane type. A house in Westbrook, Connecticut, was fitted with a solar system in February 1974, and another was planned for April 1974. A solar system will provide space and water heating at the factory where the units are fabricated.

Thomason Solar Homes, Inc.

Dr. Harry Thomason, of District Heights, Maryland, has built and lived in three solar heated and cooled homes over the last 15 years. Dr. Thomason has developed and obtained patents in the areas of collectors, storage, heating, cooling, and other features of the "Thomason Solaris System."

At the time of our review, seminars were being held for builders, developers, and others to proivde a basic knowledge of solar heating and cooling. More detailed courses were scheduled. Licenses are available for construction of homes using the Solaris system, and plans were being made for the construction of solar heated and cooled houses to be sold to the public.

Westinghouse Electric Corporation

In addition to its NSF proof-of-concept contract, Westinghouse has an ongoing project for design and production of models of solar collectors for heating and cooling applications. A corporate Solar Energy Advisory Board serves to assess applications of solar energy with respect to corporate objectives and direction.

ECONOMIC EVALUATIONS OF SOLAR HEATING AND COOLING

Our review revealed two comprehensive economic evaluations of solar heating and cooling. Dr. George Löf of the Colorado State University and Dr. Richard Tybout of the Ohio State University published the evaluations jointly. One, published in 1970, concerns the use of solar energy for heating; the other, published in 1973, concerns the use of solar energy for combined heating and cooling.

Drs. Löf and Tybout are pioneers in economic studies of solar heating and cooling. Their cooperation and assistance made our analysis of their evaluations possible. Because of the impending congressional action on solar heating and cooling legislation, however, they were not given an opportunity to comment on the results of our analysis.

In both evaluations, Drs. Löf and Tybout estimated solar and conventional energy costs in each of eight cities representing eight world climatic regions. Both evaluations were based on then noncurrent cost data unadjusted for inflation and assumed solar collector costs of $2 and $4 per square foot installed.

The 1970 heating evaluation covered two different size houses. The published 1973 combined heating and cooling results covered only the larger house; results for the smaller house are not yet available.

A solar energy system requires a large initial capital outlay. Discount rates of 6 percent for the 1970 evaluation and 8 percent for the 1973 evaluation were used to convert the initial solar systems capital costs into equivalent annual solar systems costs which could be compared to the fuel costs of conventional systems. Conventional systems were found to be necessary in each location to supplement the solar systems during periods when adequate solar radiation was not available. Thus, the evaluations attempted to determine whether the cost of the solar systems could be justified on the basis of fuel savings alone.

In making our analysis, we sought first to present the results of both evaluations in terms of 1972 costs--the latest year for which we could obtain complete conventional energy cost data[1]--using an 8-percent discount rate in both evaluations because that rate more nearly reflects today's home mortgage rate. Use of a lower than actual discount rate results in an overstatement of the economic feasibility of solar heating and cooling because of the high initial capital costs of solar systems.

[1]The gas, oil, and electricity prices which were used are shown in appendix IX.

We then tested the sensitivity of the adjusted results to other assumptions made or factors used when possible or likely variations had the potential of significantly changing the indicated economic feasibility of solar heating and cooling. These relate to

--gas and oil furnace efficiencies,

--conventional fuel prices,

--solar collector costs, and

--structural heat loss and gain.

The results of our adjusting the economic evaluations to reflect 1972 costs and an 8-percent discount rate are shown in the tables on pages 12 and 13, and our adjustments and analysis of the other assumptions or factors are discussed and explained under the captions beginning on page 14.

The tables show costs of supplying one million British thermal units (BTU) of energy with least cost solar systems--solar equipment combined with conventional heating systems to obtain the least cost combination of both--and conventional systems alone. The 15,000 and 25,000 BTU per degree-day (BTU/DD) figures in the tables represent author-assumed energy requirements for a "small" house and a "large" house, respectively.

"Low" solar costs and "high" solar costs are based on collector costs of $2.50 and $5.00, respectively, per installed square foot of collector area. These are based on author-assumed costs of $2 and $4 which we adjusted upward to more nearly reflect author-assumed costs in 1972 dollars. The Wholesale Price Index was used for this adjustment.

The 1970 heating evaluation table on page 12 indicates that solar heating would be more expensive than fuel oil heating in 31 of the 32 situations presented, more expensive than heating with natural gas in all 32 situations, but less expensive than electric heating in 22 of the 32 situations.

The 1973 combined heating and cooling evaluation table on page 13 indicates that solar heating and cooling would be more expensive than electric cooling and gas heating in 13 of the 16 situations presented, more expensive than electric cooling and oil heating in 12 of the 16 situations, but less expensive than all electric heating and cooling in 8 of the 16 situations.

As discussed earlier, the two tables are the result of our adjusting the 1970 and 1973 evaluation results to more nearly reflect 1972 costs and an 8-percent discount rate. The tables do not reflect any adjustment for the other assumptions made or factors used in the evaluations. Beginning on page 14, we discuss the sensitivity of the adjusted results to changes in the other assumptions or factors which had the potential of changing the indicated economic feasibility of solar heating and cooling.

1970 Heating Evaluation Results
Adjusted To More Nearly Reflect
1972 Solar And Conventional Energy
Costs And An 8 Percent Discount Rate
(Costs per million BTUs)

Location	Least cost solar energy 15,000 BTU/DD House Low	High	25,000 BTU/DD House Low	High	Conventional energy Electric	Oil	Gas
Albuquerque	$2.48	$3.36	$2.33	$3.38	$8.20	$1.71	$ .61
Boston (note a)	3.93	4.59	3.64	4.40	5.86	2.18	2.66
Charleston	4.59	6.07	3.71	5.19	3.81	1.99	1.21
Miami	8.53	9.46	5.91	6.77	6.45	2.09	2.26
Omaha	3.86	4.61	3.57	4.34	4.69	1.77	.92
Phoenix	3.71	5.17	2.99	4.50	5.27	2.38	1.11
Santa Maria	1.96	2.68	1.60	2.31	4.69	1.74	1.05
Seattle	4.15	5.91	3.79	5.57	2.34	2.13	1.94

(a)Blue Hill Observatory in the Boston area, which, according to one source, "receives 23.5 percent more solar energy than Boston, enough to make a solar collector there perform about 35 percent better." (We did not attempt to determine whether similar variations existed for the other cities.)

1973 Combined Heating And Cooling Evaluation Results
Adjusted To More Nearly Reflect
1972 Solar And Conventional Energy Costs
(Costs per million BTUs)

Location	Least cost solar energy 25,000 BTU/DD		Conventional energy		
	Low	High	Electric cooling with gas heating	Electric cooling with oil heating	All electric
Albuquerque	$2.16	$2.93	$2.59	$3.29	$5.89
Boston (note a)	3.85	5.48	2.95	2.92	4.85
Charleston	3.07	4.41	1.78	2.06	2.31
Miami	2.67	3.85	3.19	3.20	3.34
Omaha	3.11	4.55	1.64	2.34	3.58
Phoenix	2.25	3.21	2.45	2.71	2.98
Santa Maria	3.07	3.81	1.54	2.33	3.93
Seattle	4.72	6.31	1.95	2.48	2.08

(a)Blue Hill Observatory in the Boston area, which, according to one source, "receives 23.5 percent more solar energy than Boston, enough to make a solar collector there perform about 35 percent better." (We did not attempt to determine whether similar variations existed for the other cities.)

Sensitivity of evaluation results to changes in gas and oil furnace efficiencies

Gas and oil furnace efficiencies were used to estimate conventional energy costs. The 1970 evaluation used 75 percent for gas and oil furnace efficiencies, and the 1973 evaluation used 67 percent for gas furnaces and 56 percert for oil furnaces.

NBS and other authorities have questioned the 75-percent factor. In an October 24, 1972, report to the Chairman, House Committee on Science and Astronautics, describing the application of solar energy to heating and cooling, NBS commented on the 1970 Löf and Tybout evaluation. NBS said that while domestic furnaces, as sold, do operate at 70- to 75-percent efficiency when run at full capacity, two important factors combine to reduce the average efficiency of domestic furnaces in service. First, the performance of a typical furnace is extremely sensitive to the care with which it is maintained. Minor items of unattended maintenance, according to NBS, can reduce furnace efficiencies markedly. Second, furnaces are seldom, if ever, operated continuously at full capacity. NBS said that when operated intermittently, or at less than full capacity, furnaces provide significantly less efficient performance than that found in tests conducted on new, properly adjusted equipment running at full capacity.

NBS suggested that furnace efficiencies somewhere between 35 and 50 percent may provide a more realistic basis on which to calculate conventional heating costs.

Using lower furnace efficiencies than those used in the 1970 and 1973 evaluations results in higher conventional systems costs than those indicated by the evaluations and thus improves the relative cost position of solar systems.

The tables on pages 15 and 16 show the furnace efficiencies at which conventional fuel costs would equal solar energy costs for a number of cases based on the adjusted 1970 and 1973 evaluation results.

The efficiencies on page 15 indicate that solar heating is less costly in 5 of the 32 situations presented if a 50-percent furnace efficiency is used, but less costly in 15 of the 32 situations if a 35-percent efficiency is used.

The efficiencies on page 16 indicate that solar heating and cooling is less costly in 7 of the 32 situations presented if a 50-percent furnace efficiency is used, but less costly in 10 of the 32 situations if a 35-percent efficiency is used.

1970 Heating Evaluation

Furnace Efficiencies At Which Conventional Fuel Costs Would Equal Solar Energy Costs
(Based on 25,000 BTU/DD demand, 8-percent discount rate, and 1972 costs)

	$2.50/ft² collector		$5.00/ft² collector	
	Gas furnace efficiency	Oil furnace efficiency	Gas furnace efficiency	Oil furnace efficiency
Albuquerque	19.6%	55.0%	13.5%	37.9%
Boston (Blue Hill)	54.8%	44.9%	45.3%	37.1%
Charleston	24.4%	40.2%	17.4%	28.7%
Miami	28.6%	26.3%	25.0%	23.1%
Omaha	19.3%	37.1%	15.8%	30.5%
Phoenix	27.8%	59.6%	18.5%	39.6%
Santa Maria	49.2%	81.5%	34.0%	56.4%
Seattle	38.3%	42.1%	26.1%	28.6%

1973 Heating And Cooling Evaluation

Furnace Efficiencies At Which Costs Of Conventional Fuels For Heating Combined With Electricity For Cooling Would Equal Solar Energy Costs (Based on 25,000 BTU/DD demand and 1972 costs)

	$2.50/ft² collector		$5.00/ft² collector	
	Gas furnace efficiency	Oil furnace efficiency	Gas furnace efficiency	Oil furnace efficiency
Albuquerque	(a)	(a)	31%	89%
Boston (Blue Hill)	45%	37%	29%	24%
Charleston	12%	20%	6%	11%
Miami	(a)	(a)	8%	8%
Omaha	18%	35%	10%	20%
Phoenix	(a)	(a)	13%	25%
Santa Maria	22%	38%	17%	29%
Seattle	25%	28%	18%	20%

(a) Combined conventional energy costs exceed solar costs regardless of furnace efficiency, because of high electricity costs.

Sensitivity of evaluation results to changes in conventional fuel prices

Both the 1970 and 1973 economic evaluations were based on then noncurrent conventional fuel prices. Because the evaluations attempted to determine whether the cost of the solar systems could be justified on the basis of fuel savings alone, we adjusted the results of both evaluations in our tables on pages 12 and 13 to more nearly reflect 1972 prices--the latest year for which we could obtain complete conventional fuel cost data.

Recent substantial increases in oil, gas, and electricity prices make even the costs in our adjusted tables highly questionable. As these prices increase, the relative cost position of solar systems should improve.

The tables on pages 18 and 19 show percentage increases in gas, oil, and electricity prices which would equalize conventional and solar heating and cooling costs in a number of situations on the basis of the adjusted 1970 and 1973 evaluation results. The increases required are based on 1972 prices. A reader should note that oil, gas, and electricity prices increased 74 percent, 13 percent, and 18 percent, respectively, from January 1973 to April 1974, according to the various Consumer Price Index components for that period.

Assuming (1) installed collector costs of $5 per square foot, (2) gas and oil furnace efficiencies of 55 percent, and (3) 100-percent increases in gas, oil, and electricity prices over 1972 prices, the adjusted 1970 evaluation results on page 18 indicate that solar heating would be less expensive than electric heating and oil heating in seven of the eight cities, but less expensive than gas heating in only two of the cities.

Using the same assumptions, the adjusted 1973 evaluation results on page 19 indicate that solar heating and cooling would be less expensive than electric cooling and gas heating in four of the eight cities, less expensive than electric cooling and oil heating in six cities, and less expensive than electric heating and cooling in all the cities except Seattle.

Sensitivity of evaluation results to changes in solar collector costs

Solar collector costs made up a major portion of solar systems costs in the 1970 and 1973 economic evaluations. These costs were based on author-assumed solar collector costs of $2 and $4 per square foot installed, which we adjusted to $2.50 and $5.00 to more nearly reflect author-assumed costs in 1972 dollars.

1970 Heating Evaluation

Percentage Increases In
Gas, Oil, And Electricity Prices Which Would
Equalize Conventional And Solar Energy Costs
(Based on 25,000 BTU/DD demand, 8-percent
discount rate, and 1972 dollars)

	$2.50/ft^2 collector							$5.00/ft^2 collector						
	Gas heating Furnace efficiency:			Oil heating Furnace efficiency:			Electric heating	Gas heating Furnace efficiency:			Oil heating Furnace efficiency:			Electric heating
	35%	55%	75%	35%	55%	75%		35%	55%	75%	35%	55%	75%	
Albuquerque	78%	180%	282%	(a)	(a)	36%	(a)	158%	307%	454%	(a)	44%	98%	(a)
Boston (Blue Hill)	(a)	(a)	37%	(a)	22%	67%	(a)	(a)	21%	65%	(a)	48%	102%	(a)
Charleston	43%	124%	207%	(a)	37%	86%	(a)	100%	214%	329%	22%	92%	161%	36%
Miami	22%	91%	162%	75%	107%	183%	(a)	40%	119%	200%	51%	138%	224%	4%
Omaha	81%	185%	288%	(a)	48%	102%	(a)	120%	247%	372%	15%	80%	145%	(a)
Phoenix	26%	98%	169%	(a)	(a)	26%	(a)	89%	198%	305%	(a)	38%	89%	(a)
Santa Maria	(a)	11%	52%	(a)	(a)	(a)	(a)	3%	61%	120%	(a)	(a)	33%	(a)
Seattle	(a)	43%	95%	(a)	31%	78%	61%	34%	110%	187%	22%	92%	162%	138%

(a) Conventional energy cost already exceeds solar energy cost

1973 Heating And Cooling Evaluation

Percentage Increases In
Gas, Oil, And Electricity Prices Which Would
Equalize Conventional And Solar Energy Costs
(Based on 25,000 BTU/DD demand and 1972 costs)

	$2.50/ft² collector							$5.00/ft² collector						
	Electric cooling with gas heating			Electric Colling with oil heating			All elec-tric	Electric cooling with gas heating			Electric cooling with oil heating			All elec-tric
	Furnace efficiency: 35%	55%	75%	Furnace efficiency: 35%	55%	75%		Furnace efficiency: 35%	55%	75%	Furnace efficiency: 35%	55%	75%	
Albuquerque	(a)	(a)	(a)	(a)	(a)	(a)	(a)	2%	10%	14%	(a)	(a)	(a)	(a)
Boston (Blue Hill)	(a)	13%	39%	(a)	30%	58%	(a)	16%	62%	98%	34%	85%	125%	12%
Charleston	49%	66%	76%	26%	47%	61%	32%	115%	139%	153%	82%	112%	130%	90%
Miami	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	20%	21%	18%	20%	21%	15%
Omaha	45%	76%	95%	1%	31%	52%	(a)	113%	158%	186%	47%	91%	123%	27%
Phoenix	(a)	(a)	(a)	(a)	(a)	(a)	(a)	23%	28%	32%	8%	18%	23%	8%
Santa Maria	35%	75%	108%	(a)	30%	58%	(a)	68%	117%	159%	15%	61%	96%	(a)
Seattle	34%	103%	167%	23%	87%	145%	127%	79%	171%	256%	64%	149%	228%	202%

(a) Conventional energy cost already exceeds solar energy cost

Current collector costs that we have identified are higher than $5. We noted single-unit collector prices which ranged from $8 to over $17 per square foot for various types of collectors, not including delivery or installation. One company has quoted a price of $6 per square foot for orders of 1,001 to 10,000 collectors, not including delivery and installation.

Collector costs must be considered in terms of collector efficiency. For example, an $8 per square foot collector would not be as cost efficient as a $14 per square foot collector with twice the efficiency. We did not attempt to compare the efficiencies of collectors now on the market to the assumed efficiencies of the collectors considered in the 1970 and 1973 evaluations.

Higher collector costs than those used in our adjustments of the Löf and Tybout results would increase solar systems costs and lessen the relative cost position of solar heating and cooling.

Substantial reductions in solar collector costs appear necessary if solar systems are to become economically competitive with conventional systems. The installed square foot prices of solar collectors which would equalize the costs of solar and conventional heating and cooling are shown on pages 21 and 22 for a number of situations based on the adjusted 1970 and 1973 evaluation results.

Sensitivity of evaluation results to changes in structural heat loss and gain

Structural heat loss and gain is an important factor in determining the amount of energy--solar and conventional--required to heat and cool a house.

The 1970 evaluation covered 25,000 and 15,000 BTU per degree-day houses, whereas the published 1973 results covered only the larger house. These energy requirements may not adequately represent the energy needs of future houses. Federal and private organizations responsible for or otherwise interested in energy conservation have recently been promoting better insulation, storm windows, and other energy-saving techniques which could reduce energy needs below those in the evaluations.

NBS, in its October 24, 1972, report to the Chairman of the House Committee on Science and Astronautics, stated that the then new Minimum Property Standards of the Federal Housing Administration required insulation which would reduce the heating requirements of the 15,000 BTU per degree-day dwelling to about 8,000 BTU per degree-day.

Neither the 1970 evaluation nor the 1973 evaluation included an analysis of the effect such reductions in energy needs would have on the economic feasibility of solar heating and cooling. Adequate treatment of this matter would require substantial additional technical and economic analysis based on new theoretical designs of optimum solar systems in each of the eight cities.

1970 Heating Evaluation

Collector Costs At Which Conventional Energy Costs
Would Equal Solar Energy Costs
(Based on 25,000 BTU/DD demand, 8-percent discount rate, and 1972 costs)

Location	Gas heating	Oil heating	Electric heating
Albuquerque	(a)	$2.51	$16.26
Boston (Blue Hill)	$2.46	1.51	5.74
Charleston	(a)	.89	2.65
Miami	(a)	(a)	3.65
Omaha	(a)	.90	4.03
Phoenix	(a)	2.92	6.63
Santa Maria	1.90	5.14	13.08
Seattle	.91	1.27	.50

(a) Due to the amount of fixed noncollector solar system costs, there is no collector cost which would result in conventional and solar energy costs being equal. (Even "free" collectors would not result in solar energy being less expensive.)

1973 Heating And Cooling Evaluation

Collector Costs At Which Conventional Fuels For Heating Combined With Electricity For Cooling Would Equal Solar Energy Costs
(Based on 25,000 BTU/DD demand and 1972 costs)

Location	Electric cooling with gas heating	Electric cooling with oil heating	All electric
Albuquerque	$3.96	$5.93	$13.98
Boston (Blue Hill)	1.71	1.10	3.78
Charleston	(a)	.60	1.01
Miami	3.46	3.45	3.72
Omaha	(a)	1.19	3.20
Phoenix	3.03	3.60	4.25
Santa Maria	(a)	.10	5.15
Seattle	(a)	(a)	(a)

(a) Due to the amount of fixed noncollector solar system costs, there is not collector cost which would result in conventional and solar energy costs being equal. (Even "free" collectors would not result in solar energy being less expensive.)

Although the sensitivity of the evaluation results to changes in structural heat loss and gain is unclear, the 1970 evaluation results on page 12 show that the estimated costs per BTU for the larger solar house were lower than the estimated costs for the smaller house in 15 of the 16 situations presented. This indicates that the relative cost position of solar heating may decrease as the amount of energy supplied decreases, because the high initial capital costs of solar systems cannot be reduced proportionately to reductions in energy supplied.

Conclusion

More than anything, the costs presented and the comparisons made in this report lead to the realization that determining the future economic feasibility of solar heating and cooling is a complex task which must be based on a number of assumptions. Differing assumptions regarding certain key factors bear significantly on the question of economic feasibility. Two of the more important factors are conventional fuel prices and solar collector costs.

Although solar systems may not be economically feasible in many areas of the United States at this time, continued increases in gas, oil, and electricity prices--similar to those occurring in the last year--should improve the relative cost position of solar heating and cooling. However, the key in making solar systems economically competitive with conventional systems appears to lie in the ability of American ingenuity to build, deliver, and install solar collectors at prices substantially lower than present prices.

Aside from questions of economics, efforts to develop solar energy will continue to be important because of the need to conserve non-renewable energy resources and find alternative sources of energy.

SCHEDULE OF FEDERAL CONTRACTS AND GRANTS FOR SOLAR HEATING AND COOLING AS OF MARCH 14, 1974

Federal agency and recipient	Description	Period of performance	Amount
National Science Foundation			
Texas A&M University	Further development of the compressed-film floating-deck solar heater as a solar energy collector	9/1/73-8/31/74	$ 36,900
Colorado State University	Design, construction, and testing of residential solar heating and cooling system	9/19/73-9/18/75	238,000
Arthur D. Little, Inc.	Technology assessment of terrestrial solar energy resources development	9/12/73-9/11/74	246,664
Systems Group of TRW, Inc.	Conduct first phase of NSF's solar heating and cooling of buildings program	10/9/73-6/8/74	485,652
Westinghouse Electric Corp.	Conduct first phase of NSF's solar heating and cooling of buildings program	10/9/73-6/8/74	503,085
General Electric Company	Conduct first phase of NSF's solar heating and cooling of buildings program	10/9/73-6/8/74	547,322
National Bureau of Standards	Development of methods of evaluation and test procedures for solar collectors and storage devices	12/15/73-6/14/74	73,600

Federal agency and recipient	Description	Period of performance	Amount
National Science Foundation			
Hittman Associates, Inc.	Assessment of Rankine cycle engines for potential application to solar powered cooling of buildings	1/9/74-7/8/74	$ 49,149
Massachusetts Institute of Technology (MIT)	Exploring space conditioning with variable membranes to control heat loss and gain	12/13/73-12/12/74	49,800
California Institute of Technology	Workshop on solar cooling of buildings	12/20/73-12/19/74	24,822
Honeywell, Inc.	Operation of transportable solar heating/cooling laboratory to gather data on an integrated solar energy system	1/23/74-8/22/74	225,000
National Academy of Sciences	Studies of private sector research on solar energy for the heating and cooling of buildings	2/1/74-1/31/75	99,720
InterTechnology, Inc.	Solar energy school heating augmentation experiment	1/23/74-6/22/74	168,421
General Electric Co.	Solar energy school heating augmentation experiment	1/24/74-6/23/74	337,087
Honeywell, Inc.	Solar energy school heating augmentation experiment	1/24/74-6/23/74	340,237
Aircraft Armaments, Inc.	Solar energy school heating augmentation experiment	1/24/74-6/23/74	427,408

Federal agency and recipient	Description	Period of performance	Amount
National Science Foundation			
American Cyanamid Co.	Cadmium stannate films for solar energy conversion	7/1/73-12/31/74	$ 151,500
American Society of Heating, Refrigeration & Air Conditioning Engineers	Preparation and publication of an ASHRAE guide chapter on the application of solar energy for heating and cooling of buildings	7/1/73-6/30/74	5,000
University of Florida	Formulation of a data base for the analysis, evaluation, and selection of a low temperature solar powered air-conditioning system	7/1/73-3/31/74	49,400
University of Maryland	Optimization studies of solar absorption air-conditioning systems	8/15/73-2/14/75	129,300
University of Wisconsin	Computer modeling and simulation of solar heating and cooling systems	10/1/73-9/30/74	65,300
University of Houston	Evaluation of surface geometry modifications to improve the directional selectivity of solar energy collectors	11/29/73-11/28/74	53,800
National Aeronautics and Space Administration			
Helio Associates, Inc.	Development and utilization of a solar flux detector to collect data on availability of direct and indirect solar energy at a given location	11/1/73-6/30/74	30,000

Federal agency and recipient	Description	Period of performance	Amount
Department of the Army			
General Electric Company	Feasibility study of heating and cooling systems	11/19/73-6/30/74	$ 174,185
Department of Housing and Urban Development			
California State Polytechnic College Foundation and California State Polytechnic University, San Luis Obispo, California	Testing and evaluating a residential solar energy heating and cooling system	4/2/73-2/2/75	40,201[a]

[a]estimated Government share of cost-sharing contract

NATIONAL SCIENCE FOUNDATION
SOLAR HEATING AND COOLING ACTIVITIES

PROOF-OF-CONCEPT EXPERIMENT

--THREE-PHASE EFFORT

- PHASE 1: TO ESTABLISH FEASIBILITY OF SOLAR HEATING AND COOLING AND PROVIDE A BASIS FOR PLANNING LATER PHASES (STARTED IN OCTOBER 1973)

- PHASE 2: TO PERFORM PRELIMINARY DESIGN AND SYSTEM OPTIMIZATION (TO BEGIN IN FISCAL YEAR 1975)

- PHASE 3: FOR FINAL DESIGN, CONSTRUCTION, TEST, AND EVALUATION OF OPERATING HEATING AND COOLING SYSTEMS (FISCAL YEARS 1976 THROUGH 1978)

--RESULTS WILL BE GIVEN TO INDUSTRY FOR COMMERCIAL SYSTEM DESIGN AND CONSTRUCTION, OR, IF NECESSARY, TO OTHER FEDERAL AGENCIES FOR FURTHER DEMONSTRATIONS

IMPROVEMENTS OF TECHNOLOGY

--COVER SUCH AREAS AS COLLECTORS, STORAGE, HEAT PUMPS, AND ALTERNATIVE APPROACHES

--AT MARCH 14, 1974, NSF HAD 6 CONTRACTS OUTSTANDING IN THIS AREA, AND PLANNED TO AWARD AT LEAST 10 MORE IN THE NEAR FUTURE

DEMONSTRATION PROJECTS

--MOBILE "LABORATORY" TO GATHER DATA AT VARIOUS LOCATIONS THROUGHOUT THE COUNTRY

--SOLAR HEATED AND COOLED HOUSE IN COLORADO

--FOUR HEATING AUGMENTATION EXPERIMENTS IN SCHOOLS IN MARYLAND, MASSACHUSETTS, MINNESOTA, AND VIRGINIA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
SOLAR HEATING AND COOLING ACTIVITIES

--DEMONSTRATION PROJECTS

- SOLAR HEATED AND COOLED BUILDING TO BE BUILT AT THE LANGLEY RESEARCH CENTER IN HAMPTON, VIRGINIA

- SOLAR HEATED AND COOLED SIMULATED RESIDENCE AT THE MARSHALL SPACE FLIGHT CENTER IN HUNTSVILLE, ALABAMA

--STUDYING POTENTIAL USES OF SOLAR-ENERGY TECHNOLOGIES DEVELOPED IN ITS DEMONSTRATION PROJECTS

--STUDYING POSSIBLE USE OF SOLAR ENERGY IN OTHER NASA BUILDINGS

--DEVELOPMENT OF A SOLAR FLUX DETECTOR WHICH WILL MEASURE SOLAR ENERGY AT VARIOUS LOCATIONS

DEPARTMENT OF DEFENSE
SOLAR HEATING AND COOLING ACTIVITIES

--DEMONSTRATION OF SOLAR HEATING OF TWO HOUSES AT THE HAWTHORNE NAVAL AMMUNITION DEPOT IN NEVADA

--THE DEPARTMENT OF THE ARMY CONTRACTED GENERAL ELECTRIC TO EVALUATE THE ADAPTABILITY OF ITS EXISTING BUILDINGS FOR SOLAR HEATING, AND ITS NEW BUILDINGS FOR SOLAR HEATING AND COOLING

--THE AIR FORCE CAMBRIDGE RESEARCH LABORATORY IS STUDYING SOLAR HEAT STORAGE TECHNIQUES

--THE DEPARTMENT OF THE AIR FORCE PLANS TWO STUDIES TO DETERMINE THE ADAPTABILITY OF CERTAIN AIR FORCE BUILDINGS TO SOLAR SYSTEMS

AEC, NBS, AND HUD SOLAR HEATING AND COOLING ACTIVITIES

AEC

--PLANNED THREE 1974 PROJECTS ON

- A SOLAR TOTAL ENERGY SYSTEM FOR A COMMUNITY
- CONCENTRAT.D SOLAR COLLECTORS
- FLAT-PLATE SOLAR COLLECTORS

NBS

--DEMONSTRATION OF A SOLAR HEATED AND COOLED HOUSE IN GAITHERSBURG, MARYLAND

--MAKES SYSTEMS TESTS AND EVALUATIONS FOR OTHER FEDERAL AGENCIES

HUD

--CONTRACTED CALIFORNIA STATE POLYTECHNIC COLLEGE FOUNDATION AND CALIFORNIA STATE POLYTECHNIC UNIVERSITY TO TEST AND EVALUATE A SOLAR HEATED AND COOLED HOUSE

--PLANS TO INCORPORATE SOLAR ENERGY IN A CENTRAL ENERGY SYSTEM FOR A 500-UNIT HOUSING PROJECT IN NEW JERSEY

GSA AND POSTAL SERVICE SOLAR HEATING AND COOLING ACTIVITIES

GSA

--DEMONSTRATION OF SOLAR HEATING AND COOLING IN AN ENERGY-CONSERVATION BUILDING IN MANCHESTER, NEW HAMPSHIRE

--DEMONSTRATION OF SOLAR HEATING AND COOLING IN AN ENVIRONMENTAL BUILDING IN SAGINAW, MICHIGAN

--WILL DEVELOP PLANS TO USE SOLAR ENERGY IN OTHER BUILDINGS BASED ON ITS DEMONSTRATION RESULTS

POSTAL SERVICE

--DEMONSTRATION OF A SOLAR HEATED AND COOLED POST OFFICE IN RIDLEY PARK, PENNSYLVANIA

--WILL DEVELOP PLANS TO USE SOLAR ENERGY IN OTHER POST OFFICES BASED ON THE RESULTS OF THE RIDLEY PARK PROJECT

SOLAR HEATING AND COOLING

DEMONSTRATION STRUCTURES

During our review, we found numerous references to and four listings of solar heating and cooling demonstration structures. We verified none of the data, but present it on the following pages as gathered from the various sources.

The structures are listed in two parts: (1) structures where operations have started (33) and (2) structures planned or under construction (25). Some of those in the first category may no longer be operating; however, in the absence of clear data, we did not attempt to so designate any of them. Similarly, some designated as planned or under construction may now be in operation.

Part I

Structures Where Operations Have Started

Year operations started (note a)	Name and location	Building type	Applications (note b)
1930	M.I.T. Solar House #1 Cambridge, Mass.	Laboratory	Heating
1947	M.I.T. Solar House #2 Cambridge, Mass.	7-section laboratory	Heating
1949	M.I.T. Solar House #3 Cambridge, Mass.	Simulated dwelling	Heating
1959	M.I.T. Solar House #4 Cambridge, Mass.	2-story house	Heating
1944	Peabody House Dover, Mass.	House, enlarged in 1953	Heating
1945	Löf House Boulder, Colo.	Bungalow	Heating
1950	New Haven, W. Va.	House	Heating

[a] Date approximate, when given
[b] The portion of heating needs supplied by the solar systems varies from 90 percent in some cases to as little as 20 percent in others

Year operations started (note a)	Name and location	Building type	Applications (note b
1953	Solar Heated House State College, N. Mex.	1-1/2 story house	Heating
1954	Donovan and Bliss House	House	Heating
1955	U.S. Forest Service Desert Grassland Station Amado, Ariz.	Bungalow	Heating and evaporation colling
1956	Alburquerque, N. Mex.	Single-story office building	Heating and evaporation cooling
1958	Löf House Denver, Colo.	Single-story partial basement	Heating
1958	Association for Applied Solar Energy House Phoenix, Ariz.	Single-story	Heating and cooling
1959	University of Arizona Tucson	Single-story simulated home	Heating and cooling
1959	Solar Heated Laboratory Princeton, N.Y.	Single-story laboratory	Heating
1959	Thomason House #1 District Heights, Md.	Residence	Heating and cooling
1960	Thomason House #2 District Heights, Md.	Residence	Heating and cooling
1962	Thomason House #3 District Heights, Md.	Residence	Heating and cooling
1962	Demonstration House Allentown, Pa.	3 story	Heating; no collectors
1964	Edison Electric Institute Philadelphia, Pa.	10 test houses	Heating; no collectors, uses heat pump
1973	Solar One Newark, Del.	1-1/2 story	Heating and cooling

[a]Date approximate, when given
[b]The portion of heating needs supplied by the solar systems varies from 90 percent in some cases to as little as 20 percent in others

Year operations started (note a)	Name and location	Building type	Applications (note b)
1974	Hawthorne Naval Ammunition Depot, Hawthorne, Nev.	2 houses	Heating
1974	Fauquier County High School Warrenton, Va.	School	Heating
1974	Grover Cleveland Jr. High School Dorchester, Mass.	School	Heating
1974	Northview Jr. High School Osseo, Minn.	School	Heating
1974	Timonium Elementary School Timonium, Md.	School	Heating
1974	Coos Bay, Oreg.	House	Heating
	Suburban Washington D.C. area-Gaydardt Industries	4 protype collector installations	Collector only no storage
	Westbrook, Conn.	House	Heating
	Hay House Atascadero, Calif.	House (evaluation under HUD contract)	Heating and cooling
	Zomeworks, several towns in New Mexico	Houses	Heating
	ILS Laboratories Albuquerque, N. Mex.	Experimental house	Heating
	University of Florida Gainesville	Experimental house	Heating; absorption air conditioning planned

[a]Date approximate, when given
[b]The portion of heating needs supplied by the solar systems varies from 90 percent in some cases to as little as 20 percent in others

Part II

Projects Planned Or Under Construction

Location	Building type	Applications
Madeira School McLean, Va.	Science building	Heating and cooling
NASA-Langley Research Center Hampton, Va.	Office building	Heating and cooling
NASA-Marshall Space Flight Center, Huntsville, Ala.	Simulated residence	Heating and cooling
University of Alabama Huntsville	Vacation cottage	Not determined
University of Alabama Huntsville	Center for Environmental Studies	Not determined
Baer Home Idaho Springs, Colo.	Residence	Heating
Fort Collins, Colo.	Residence	Heating and absorption air-conditioning
Massachusetts Audubon Society Lincoln, Mass.	Headquarters building	Heating and cooling
Federal Office Bldg. Saginaw, Mich.	Office	Heating
University of Minnesota Saint Paul	House	Not determined
Federal Office Bldg. Manchester, N.H.	Office	Heating and cooling
Wilson Residence Shanghi, W. Va.	Home	Heating and cooling

Location	Building Type	Applications
Allentown, Pa. (Pennsylvania Power & Light)	Home	Heating
Science Museum Richmond, Va.	Museum	Not determined
Ridley Park, Pa.	Post office	Heating and cooling
Barber residence Massachusetts	Home	Heating
Davis Residence Phelan, Calif.	Home	Heating
Energex Corporation Las Vegas, Nev.	Manufacturing building	Heating
Energex Corporation Las Vegas, Nev.	Housing project	Heating and cooling
RCA Headquarters New York City	Office (addition)	Heating
East Lyme, Conn.	Factory	Heating
New York Botanical Gardens	Office building and laboratory	Heating
National Bureau of Standards Gaithersburg, Md.	Townhouse (retrofit for test and evaluation)	Heating and cooling
HUD Operation Breakthrough Jersey City, N.J.	Central energy systems for community	Heating
Desert Research Institute Boulder, Colo.	Biology laboratory	Heating and cooling

SOLAR HEATING AND COOLING DOCUMENTS AND PUBLICATIONS IN PREPARATION OR PLANNING AT THE TIME OF OUR REVIEW

The National Academy of Sciences, under contract with NSF, was studying private sector research on solar heating and cooling. This contract will run for one year, ending in January 1975. Specific tasks to be performed included

--determining what private efforts are going on, and obtaining suggestions for additional research from the organizations identified,

--preparing profiles of the most significant efforts identified, and

--updating the 10-year-old results of a workshop dealing with a total energy analysis approach to building efficiency, with a view to overcome the difficulties involved in retrofiting solar systems.

Dr. Robert M. Dillon, of the National Academy of Sciences, Washington, D.C. (telephone 202-389-6348), provided the above information.

Environmental Action of Colorado was preparing a directory for the May 1-3, Solar Heating and Cooling and Energy Conservation Conference to be held in Denver, Colorado. The directory was to consist of five parts.

--A listing of manufacturers presently making solar heating and cooling system components.

--A listing of manufacturers who potentially will make and market components.

--A listing of consultants and professionals.

--A listing of current and completed projects.

--An annotated bibliography of literature.

This information was obtained from Ms. Carolyn Pesko, Environmental Action of Colorado, University of Colorado, 1100 14th Street, Denver, Colorado 80202 (telephone 303-534-1602).

The Solar Energy Society of America was

--compiling an industrial index of manufacturers making and contemplating making solar components,

--preparing an index of ongoing research activities,

--planning publication of a journal starting in late 1974, and

--considering publication of a newsletter on solar energy for use in elementary schools.

This information was obtained from Mr. Pat Evans of the Society's Office, P.O. Box 4264, Torrence, California 90510 (telephone 213-326-3283).

Burt, Hill and Associates, was compiling a listing of component manufacturers at the time of our review. This list was to have been included in an interim contract briefing of NSF by Westinghouse sometime before April 15, 197;.

1972 GAS, OIL, AND ELECTRICITY PRICES USED TO UPDATE 1970 AND 1973 [illegible] RESULTS (note a)

(per million BTUs)

Location	Gas	Oil	Electricity
Albuquerque	$ .46	$1.28	$8.20
Boston	2.00	1.64	5.86
Charleston	.91	1.49	3.81
Miami	1.70	1.57	6.45
Omaha	.69	1.33	4.69
Phoenix	.83	1.79	5.27
Santa Maria (note b)	.79	1.31	4.69
Seattle	1.46	1.60	2.34

[a] Prices were obtained from: Gas Househeating Survey, 25th Annual Survey, Department of Statistics, American Gas Association, Arlington, Virginia, 1973.

[b] Complete gas, oil, and electricity prices were not available for Santa Maria, therefore, we used prices from the Los Angeles region.