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Options for Demonstrating the Use of Solar Energy in California Buildings

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State of California
Energy Resources Conservation
and Development Commission

Jet Propulsion Laboratory
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The unique characteristics of solar energy demonstration programs and the involvement of key decision makers are discussed in detail. The demonstration programs are related to specific purposes. The priority structure used to select the generic projects making up each program is discussed in relationship to the purposes of the program. In addition, some implications of the nature of the demonstration program for management are outlined. Related information concerning the ERDA/HUD Solar Energy Demonstration Program in California, statistical data, and a general description of solar energy systems are appended to this report.

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PREFACE

This document presents the results of one phase of research at the Jet Propulsion Laboratory sponsored by the California Energy Resources Conservation and Development Commission under agreement with the National Aeronautics and Space Administration through contract NAS7-100. The findings, conclusions or recommendations expressed in this report do not necessarily reflect the views of the California Energy Resources Conservation and Development Commission.

ABSTRACT

Three programmatic options for demonstrating the most economically attractive applications of solar energy to buildings located in California are formulated. These options are presented to the State of California Energy Resources Conservation and Development Commission to provide 1) a framework for soliciting and selecting projects, 2) a basis for influencing the implementation of federal demonstration programs in California, and 3) factors for budget estimating and assumptions for planning purposes. These options are presented in tabular form corresponding to three budgetary limits; a $500,000 Program, a $1,000,000 Program, and a $3,000,000 Program.

The unique characteristics of solar energy demonstration programs and the involvement of key decision makers are discussed in detail. The demonstration programs are related to specific purposes. The priority structure used to select the generic projects making up each program is discussed in relationship to the purposes of the program. In addition, some implications of the nature of the demonstration program for management are outlined. Related information concerning the ERDA/HUD Solar Energy Demonstration Program in California, statistical data, and a general description of solar energy systems are appended to this report.

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SECTION I

INTRODUCTION

A. BACKGROUND

Many uses for solar energy meet the prerequisites for justifying a major demonstration program. The technology of using solar energy for heating, water heating, and cooling has been understood for several decades. Many companies have the basic capability to manufacture solar collectors, controllers, and associated hardware. The design professions have the educational background to rapidly learn how to specify solar energy hardware. Increasing costs for conventional energy and decreasing availability of inexpensive natural gas have made some uses for solar energy economically attractive in California. If this trend continues, the demand for products to utilize solar energy in buildings will continue to grow. Over 100 buildings in California have already been equipped with solar collection equipment using private funds.

Dissemination of high-quality information about the early applications of solar energy in California is essential to the rapid diffusion of the most economical applications of solar energy. The State of California has an important role to play in the creation, the evaluation, and the dissemination of this information. The solar energy demonstration program initiated by the California Energy Resource Conservation and Development Commission (ERCDC) in fiscal year 1975-76 is just one source of this information.

All the major utility companies in California are engaged in solar energy demonstration projects. Furthermore, California demonstrations are being conducted by the Energy Research and Development Administration (ERDA) and the Department of Housing and Urban Development (HUD). They each plan five cycles of competitive procurements; the second cycle began in the early summer of 1976. The ERDA/HUD program is likely to result in 80 to 120 projects in California over the next 5 years. (Reference 3 and also see Appendix A).

The State ERCDC can help to stimulate the California market for solar energy technology in several specific ways.

(1) By funding projects that demonstrate solar energy applications in those markets where solar energy is now or has the potential to become economically viable within the next 5 years.

(2) By evaluating and comparing the performance and cost of all projects whether or not primarily financed by the ERCDC.

(3) By disseminating information about all projects in the State to key decision makers in the private and public sectors involved in the implementation of solar energy.

(4) By conducting separate activities to formulate alternatives to overcome barriers to rapid diffusion of the technology, and to implement or recommend implementation of the best alternatives.

B. OBJECTIVE OF REPORT

This report describes three options for conducting a program to demonstrate the most economically attractive applications of solar energy in buildings located in California. These options are to provide 1) A framework for the ERCDC staff to solicit and select projects for demonstrating solar energy in California; 2) A basis for ERCDC to influence the implementation of federal demonstration programs in California to maximize the overall effectiveness of the activity; and 3) Budget estimating factors and assumptions for use in planning the California program.

C. GUIDELINES

The guidelines for presenting these options are:

(1) Solar demonstration program options for the State of California will be described at 3 budget levels, $500,000, $1,000,000, and $3,000,000.

(2) The cost of instrumenting and evaluating projects will be included in the programmatic budget guideline.

(3) The information concerning markets for solar energy systems and the design, cost and performance of systems will be based on completed JPL studies. These include:

- (a) Applications of solar energy in buildings (Project BASE).
- (b) Market and technology aspects of solar assisted gas energy water heating for apartments (Project SAGE).
- (c) Barriers to innovation in the building industry. (Reference II)

(4) Elements <u>essential</u> to a successful program but <u>excluded</u> from the guideline budget levels include:

- (a) The cost of evaluating and comparing the cost and performance of demonstration projects funded by the Federal government and private sources.
- (b) The cost of disseminating information generated by the projects.

(c) The in-house cost incurred by ERCDC to manage the program.

(d) The cost of conducting separate activities leading to resolution of institutional barriers to rapid commercialization of technology.

SECTION II

THE NATURE OF THE SOLAR ENERGY DEMONSTRATION PROGRAM OPTIONS

A. THE UNIQUE CHARACTERISTICS OF A SOLAR ENERGY DEMONSTRATION PROGRAM

Any program to demonstrate solar energy in buildings has some unique characteristics compared to demonstrations of technology which have been supported with government funds in the past. This is due both to the nature of solar energy technology and to the nature of the building industry.

The technology for solar energy is applied in the end use market. The solar hardware is always associated with a building. The investment in solar energy hardware, although significant, is a small part of the investment in the buildings served by the hardware. In new construction, this packaging makes it difficult to accurately account for the cost of using solar energy. The association with buildings typically relegates decision making concerning the use of solar energy to subordinate levels.

The scale of a single solar energy demonstration is much smaller than of the scale of demonstrations which have been conducted in other fields. Multi-million dollar budgets are common for single projects in the fields of transportation, nuclear energy, and synthetic fuels, while most solar energy demonstrations will have budgets measured in tens of thousands of dollars.

The number of individual decisions involved in implementing solar energy on a wide scale is very large compared to many of the technologies which government has promoted in the past. The building industry is composed of a large number of separate companies. Each company typically specializes in a limited market of product area. Because of this specialization, separate demonstration projects in each market are needed to effectively demonstrate solar energy to the building industry.

B. INVOLVEMENT OF KEY DECISION MAKERS

Involvement of key decision makers has been found to be an essential ingredient to conducting successful demonstration projects (Reference 1). The building industry is influenced by a large number of decision makers. Most of these are listed below:

Decision Makers Influencing the Building Industry

Architects	Building Managers
Building Owners	Building Contractor (The Builder)
	Sub Contractors
Engineers	Developers
Researchers	Code Officials
Building Users/Tenants	Zoning Officials
Manufacturers	Lending Institutions
Federal Government	Insurance Companies
State Government	Trade Unions
Local Government	Utilities
Suppliers	Realtors

In the new building market the design professions and the developer (who is often the builder) translate the needs of the owners or presumed future owners into specifications for buildings. Specifications of a solar energy system for the building would be included in the many details which are in the hands of the developer and the supporting design professionals. The other decision makers listed above constrain the actions of the key decision makers but traditionally are not critical to diffusion of new technology in the building industry. Once a developer and his design professionals are convinced of the value of a product, an era of continuing application is begun.

In the retrofit market, the building owner is the key decision maker. He must initiate any action to modify his building. But unlike the situation in the new market, adoption of solar energy by the key decision maker does not typically initiate a continuing process of application. Each owner must be convinced to adopt solar energy for his building or buildings. Manufacturers, suppliers, speciality contractors and utility companies have traditionally worked together to encourage innovations in the retrofit market. If the demonstration program is to succeed in the retrofit market, it must involve these secondary decision makers in key roles.

C. PURPOSE OF THE DEMONSTRATION PROGRAM

The purpose of the demonstration program is to stimulate the commercial application of economically feasible solar energy systems. Each project should provide a setting for a commercialization experience for a set of key decision makers involved in the building industry. Emphasis should be placed on training designers and contractors for solar energy systems and creating an early market for manufactured products. Evaluation of performance, cost and maintenance information is an essential part of the process of validating the technical and economic feasibility of solar energy. By feeding this information back to the project designers, manufacturers, and the solar energy research and development community, "integration of technological development and utilization" will be pursued (Reference 2). Disseminating this information to key decision makers who are not directly involved in demonstrations will increase the access of the building industry to solar energy technologies. Information on skill and labor requirements of implementing solar energy is important to formulating training and incentive programs. The demonstration program will provide this type of information to State government, schools and labor unions.

The demonstration program may also serve a number of secondary purposes related to the response of other decision makers which influence the building industry. It is possible that issues related to zoning, codes, insurance, sun rights, and labor union jurisdictions will be encountered in the demonstration program. However, experience to date indicates that there are no substantial problems posed in these areas by the application of currently understood technology to a demonstration program (Reference 2). Even so, a demonstration program will focus debate on zoning, code, insurance, sun rights and labor union issues which might arise during implementation on a commercial scale. It will, therefore, provide an opportunity for resolving concerns before they become problems.

Data related to a number of research oriented questions should be generated by the demonstration program. The program could be designed to collect information on such questions as 1) learning curves for installing solar energy systems, 2) the economies of size for solar energy systems, and 3) effectiveness of State incentives. However, conducting sound research on these questions is beyond the primary purposes of this demonstration program.

D. PRIORITIES GOVERNING THE SYNTHESIS OF OPTIONAL DEMONSTRATION PROGRAMS

The three demonstration programs described in this report consist of a number of specific projects which have been judged to be worthy of demonstration to the building industry. Each program option has been synthesized with a set of values in mind. These values can be expressed as a set of priorities (in the order listed below) which have been applied in the process of selecting projects to fill each program option to its guideline budget limit:

(1) Top priority is given to conducting demonstrations in each identifiable market sector within the building industry.

(2) Obtaining high quality information on the projects in the most economical way.

(3) Selecting the most economical applications for solar energy.

(4) Demonstrating passive systems with uncertain economics in a variety of climate zones.

(5) Demonstrating a variety of different active systems from different suppliers.

(6) Demonstrating innovative systems where the performance and economics are the subject of uncertainty.

(7) Demonstrating active solar energy in a variety of climate conditions.

The reasons for these priorities requires some elaboration.

Top priority for conducting demonstrations in a variety of markets recognizes the need to conduct industry viable demonstration projects (Reference 6). If the industry does not accept the project as a viable demonstration, the project will not be a stimulus to commercialization. High priority for getting good comparable information on the projects recognizes both the need to have credible results for decision makers not directly participating in demonstration projects, and the value of feeding back the results of early application of solar energy on improving second-generation application and second-generation manufactured products. The economic attractiveness of any particular solar energy application depends on many factors unrelated to the cost of the equipment and the performance. Therefore, presumed economic attractiveness of applications has been used as a secondary discriminator in choosing projects.

Although none of the passive systems have been evaluated in detail by JPL, it is clear that these systems are the best near-term hope for reducing the growth of cooling loads in residential construction (Reference 4). Some elements of so called passive techniques have been incorporated into the proposed Energy Standards For New Residential Buildings (Reference 10). However, information on the performance of the passive system is important to the diffusion of the best design approaches and to developing the skill of the industry to apply concepts and design techniques which are involved. Since cooling loads vary widely in California (see Appendix B), the demonstration of the passive system in a variety of climate conditions is important.

Last priority is given to demonstrating active solar energy systems in a variety of climatic zones. This is because most of the more populated areas of California have an abundance of sunshine (see Appendix B). Therefore, applications of similiar scale and load factor tend to have similar economic viability independent of location. In 65 case studies of active solar energy applications examined in the coastal, inland valley, and desert micro climate zones of Southern California, it was found that size of the load and load factor were more important determinants of economic viability than the detailed differences in the climate when proper sizing criteria were used (Reference 4). It is significant that the Southern California weather stations which were used in the study encompassed the minimum level of insolation for stations operating in California; the Los Angeles Airport for one and the station with maximum heating requirement - Edwards Air Force Base (see Appendix B). It is therefore concluded that the conditions as stated for Southern California are generally applicable to the whole State except in those isolated regions along the northern coast which are subjected to heavy fog, and the low desert area in the southeast corner of the State.

E. SOME IMPLICATIONS FOR PROGRAM STRUCTURE AND MANAGEMENT

The above priorities have certain implications for the program. Some of these affect the budgeting constraints of the program. The most significant implication is that most of the top priority projects can be concentrated in a primary demonstration area. The choice of the primary demonstration area can be based on factors related to:

(1) Building industry visibility and access.

(2) The regional price and availability of auxiliary fuel.

(3) The regional level of activity in building development.

(4) Local support for the program.

Choice of a single contractor for instrumentation and evaluation is recommended. Significant overall budget economies and higher quality evaluation are possible if this approach is followed. This contractor should be selected and the evaluation planning begun before demonstration construction contracts are let.

Demonstration contracts should emphasize a "Demand Pull" incentive philosophy. Prime demonstration contracts should be let to decision makers capable of aggregating markets or promulgating design procedures. Contracts with developers, State agencies, utilities and entrepreneurial groups are preferred. This approach complements the Federal incentives to suppliers which comes from sponsoring development of technology.

In selecting developers, design professional, State agencies, utilities and other entrepreneurs to conduct projects, it is important that contracts and subcontracts are let to the largest possible number of organizations. This can be accomplished by adopting a "one to a customer" limit on demonstration contracts and subcontracts.

Duplication of effort should be avoided. If another agency is already conducting a recommended demonstration project in California, then it may be desirable only to fund the evaluation of the project.

SECTION III

PROGRAM OPTIONS

A. GENERAL CHARACTERISTICS OF THE PROGRAM OPTIONS

Three program options are presented (see Tables 1, 2, and 3).

1. The $500,000 Program

The budget limitations of this option (see Table 1) only allow the application of the first three priorities listed in Section II. The projects include demonstration of active systems in one climatic location. Six market sectors are examined including one single-family sector and the retrofit market.

The division of funds is 51% for the project and instrumentation costs, 20% for instrument and evaluation planning, and 29% for data collection and analysis.

Table 1. The $500,000 Program

	Major Market Sector					
	Institutional Private and Public, New and Retrofit	Commercial, New	Multiple-Family, New	Commercial, Retrofit	Multiple-Family, Retrofit	Single-Family, Retrofit
System	Central Water Heater	Central Water Heater	Central Water Heater, Central Auxiliary	Central Water Heater	Central Water Heater, Central Auxiliary	Space/Water Heating, Off-Peak Cooling
Example Building	Hospital, New	High-Rise	Low-Rise Condominium	High-Rise Retrofit	Low-Rise Apartments	Non-Energy Conserving Home
Approximate Size (Collector Structure)	1000 ft^2, 100 Beds	1000 ft^2	1000 ft^2, 40 Units	1000 ft^2	1000 ft^2, 40 Units	275 ft^2
Project Costs	$30,000	$30,000	$30,000	$40,000	$40,000	$8,000
Instrumentation Costs	$15,000	$15,000	$15,000	$15,000	$15,000	$8,000
(First Cost):* (kWh/Year)	0.12	0.12	0.12	0.15	0.15	0.29
Subtotal	$45,000	$45,000	$45,000	$55,000	$55,000	$13,000

Budget Summary:

Project and Instrumentation Costs	$258,000
Instrument and Evaluation Planning	$98,000
Data Collection and Analysis	$144,000
Total	$500,000

*Note: (First Cost):(kWh/Year) is used as an indicator of the relative economic attractiveness of the market.

Table 2. The $1,000,000 Program

	Major Market Sector		
	Institutional Private and Public, New and Retrofit	Commercial, New	Multiple-Family, New
System	$500,000 Program		
Example Building			
Approximate Size (Collector Structure)			
Project Costs			
Instrumentation Costs			
(First Cost)÷(kWh/Year)*			
Subtotal	$45,000	$45,000	$45,000
System			Central Water Heater, Individual Auxiliary
Example Building			Apartment
Approximate Size (Collector Structure)			100 ft^2, 40 units
Project Costs			$40,000
Instrumentation Costs			$15,000
(First Cost)÷(kWh/Year)*			0.16
Subtotal			$55,000

Budget Summary:

Project and Instrumentation Costs	$521,500
Instrument and Evaluation Planning	267,000
Data Collection and Analysis	288,000
Total	$976,500

*Note:

(First Cost)÷(kWh/Year) is used as an indicator of the relative economic attractiveness of the market.

Table 2. The $1,000,000 Program (Continuation 1)

Major Market Sector (cont'd)				
Commercial, Retrofit	Multiple-Family Retrofit	Single-Family Retrofit	Single-Family Custom, New	Single-Family Tract, New
$500,000 Program (cont'd)			Space/Water Heating, Off-Peak Cooling	Space/Water Heating, Off-Peak Cooling
			Energy-Conserving Home	Energy-Conserving Home
			225 ft^2	200 ft^2
			$7,500	$6,000
			$15,000	$15,000
			0.31	0.38
$55,000	$55,000	$13,000	$22,500	$21,000
			Three Passive Homes, Each in a Different Area	
			Variety of Designs	
			--	
			$10,000 Each	
			$15,000 Each	
			--	
			$75,000	

Table 3. The $3,000,000 Program

	Major Market Sector		
	Institutional Private and Public, New and Retrofit	Commercial, New	Multiple-Family, New
System	$500,000 Program		
Example Building			
Approximate Size (Collector Structure)			
Project Costs			
Instrumentation Costs			
(First Cost):(kWh/Year)*			
Subtotal	$45,000	$45,000	$45,000
System	Central Water Heater, New	Skytherm	Central Water Heater, Individual Auxiliary
Example Building	Fire Station	Store Complex	Apartment
Approximate Size (Collector Structure)	1000 ft^2, Low-Rise	Single Story	1000 ft^2, 40 Units
Project Costs	$30,000	$30,000	$40,000
Instrumentation Costs	$15,000	$15,000	$15,000
(First Cost):(kWh/Year)*	0.12	--	0.16
Subtotal	$45,000	$45,000	$55,000
System	Central Water Heater, Retrofit		Solar Augmented Heat Pump
Example Building	Police or Fire Station		Apartment, Condominium
Approximate Size (Collector Structure)	1000 ft^2, Low-Rise		>600 ft^2 >30 Units
Project Costs	$40,000		$25,000
Instrumentation Costs	$15,000		$15,000
(First Cost):(kWh/Year)*	0.15		0.2
Subtotal	$55,000		$40,000

Budget Summary:

Project and Instrumentation Costs	$1,642,000
Instrument and Evaluation Planning	347,500
Data Collection and Analysis	960,000
Total	$2,949,500

*Note:

(First Cost):(kWh/Year) is used as an indicator of the relative economic attractiveness of the market.

Table 3. The $3,000,000 Program (Continuation 1)

Major Market Sector (Cont'd)				
Commercial, Retrofit	Multiple-Family Retrofit	Single-Family Retrofit	Single-Family Custom, New	Single-Family Tract, New
			Space/Water Heating, Off-Peak Cooling	Space/Water Heating, Off-Peak Cooling
			Energy-Conserving Home	Energy-Conserving Home
			225 ft^2	200 ft^2
$500,000 Program (cont'd)			$7,500	$6,000
			$15,000	$15,000
			0.31	0.38
$55,000	$55,000	$13,000	$22,500	$21,000
Central Water Heater, Individual Auxiliary	Solar Augmented Heat Pump	Water Heater Plus Conventional Heat Pump	Three Passive Homes, Each in a Different Area	Space/Water Heating Hydronic
Store Complex	High-Rise Apartment	Non-Energy Conserving Home	Variety of Designs	Energy Conserving Home
1000 ft^2, Low-Rise	600 ft^2, 30 Units	50 ft^2	--	200 ft^2
$35,000	$20,000	$1,000	$10,000 Each	$6,000
$15,000	$15,000	$15,000	$15,000 Each	$15,000
--	0.25	0.4	--	0.38
$50,000	$35,000	$16,000	$75,000	$21,000
			Space Heating, Air	Space Heating, Air
			Energy-Conserving Home	Energy-Conserving Home
			200-400 ft^2	200-400 ft^2
			$15,000	$10,000
			$15,000	$15,000
			0.31	0.38
			$30,000	$25,000

2. The $1,000,000 Program

An expenditure of $1,000,000 as shown in Table 2, enables consideration of the first five priorities. All the active systems of the $500,000 Program are studied plus two more single-family markets, an additional concept in the multi-family market that has good economic advantages, and an investigation of passive systems for single-family homes in three climatic zones for a total of eight markets and twelve projects.

Single-family projects have a much higher ratio of planning, data collection and analysis costs to project and instrumentation costs than the multiple-family, institutional, and commercial markets. This is illustrated in the following rough budget breakdown of this option: 44% for project and instrumentation costs, 27% for instrument and evaluation planning, and 29% for data collection and analysis.

3. The $3,000,000 Program

The $3,000,000 Program, shown in Table 3, allows consideration of all seven priorities. All the projects in the $500,000 and $1,000,000 Programs are examined. In addition, innovative systems are investigated, e.g., the "Skytherm" system and solar augmented heat pumps, for a total of eight markets and forty four projects.

This program has the financial advantage that the planning phase is used for construction projects at two major sites, thereby lowering the relative instrument and evaluation planning costs.

The budget division for this program is 56% for project and instrumentation costs, 12% instrument and evaluation planning, and 32% data collection and analysis.

The effect of climate on the design, cost, and performance of various solar systems is investigated by repeating the whole program in a second climatic zone. There are a total of six passive systems demonstrated in this program.

B. PROGRAM LAYOUT

The building industry has been divided into eight major market sectors based on the different roles of key decision makers and specialization areas of the building industry. Under each market sector, various projects are listed in descending economic order. An example is given for each project shown, indicating the approximate size of the collector array and the structure to be used. The project costs given indicate the increased costs (in 1975 dollars using 1975 technology) of the building due to the inclusion of a solar system and not the total cost of the building.

The cost of instrumentation is based on previous experience in this type of project, and assumes that one contractor is in charge of the instrumentation for all of the projects.

The figure of merit used to economically rank the projects is the first cost (i.e., the solar equipment cost plus installation) divided by the energy saved by the system over the first year of operation, given in kilowatt hours. A low first cost to achieve a given savings is, of course, desirable. The values used were developed in Reference 4, and in cases where specific figures were not available the ranking was estimated by analogy with previously studied systems. (e.g., commercial markets were compared to multi-family markets.)

New innovative systems where the performance and cost have not been analyzed under the same assumption of Reference 4 were not given numerical figures of merit but were placed in the respective matrixes on non-economic criteria.

C. BUDGET ASSUMPTIONS

The budget summaries for each program cover 1) project and instrumentation (i.e., all hardware), 2) instrumentation and evaluation planning, and 3) data collection and analysis. The first item is simply the sum of the costs indicated for each project in the respective program.

Instrumentation and evaluation planning covers many tasks that should be completed before breaking ground at the construction sites. Table 4 indicates the nature of these tasks and the assumptions used to estimate their respective costs.

It is important to note that this budget will not in itself insure a successful program. By agreement, certain components of a total program have not been included in the estimate presented here. (cf: guidelines in Section I-C).

Table 4. Budget Assumptions

Planning Tasks	Cost
1. Technical Planning for Instrumentation and Evaluation:	
a. Performance Information	
- Design Instruments	$5,000/Generic Solar System
- Write Interface Requirements	$5,000/Generic Solar System
- Documentation	$2,000/Generic Solar System and/Market Sector
b. Cost Information	
- Formulating Approach - Preparing Reports Formats - Documentation	$2,000/Generic Solar System and/Market Sector
c. Summary Documentation	$2,000 to $4,000/Program
d. Plan Management and Coordination	25% of Items a, b, and c
2. Evaluation of Software Preparation:	
a. Evaluation Plan	$5,000 to $10,000/Generic Solar Systems
b. Software Development and Debugging	$10,000 to $20,000/Generic Solar System

Data Collection and Analysis Tasks	Cost
1. Data Collection	$5,000/Project/Year
2. Instrument Maintenance	$5,000/Project/Year
3. Initial Calibration	$2,000/Project
4. Data Reduction	$5,000/Project/Year
5. Analysis and Reporting	$7,000/Project

Note: It is assumed that one contract for project instrumentation, planning, evaluation, data collection, and analysis will be let.

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APPENDIX A

THE ERDA/HUD SOLAR ENERGY DEMONSTRATION PROGRAM IN CALIFORNIA

Plans for the ERDA/HUD demonstration program have become more firm with the completion of Phase I studies conducted by ERDA contractors. The results of these studies are summarized in Reference 3. The emerging consensus is that 750 to 900 projects will be undertaken in both the residential and commercial markets. In the residential sector, 20% of the projects will be in the multiple-family market. Since the average multiple-family projects will serve 20 dwelling units, the multiple-family market is receiving considerable emphasis in the ERDA program. The probable ERDA program structure is presented in Table A-1.

The split of projects between new and retrofit application is still uncertain. There does not seem to be a consensus developing on this issue. It is likely that early projects will involve more retrofit applications because they are easier to plan. However there is a consensus that new applications will be more economical.

California is recognized as one of the better regions for applications of solar energy in buildings. Phase I contractors have recommended that as high as 26% of the demonstration projects be located in California. It is unlikely that the California share will be this high but it is also unlikely that California will receive less than its population weighted share of 10%. Two estimates for the ERDA/HUD demonstration program are presented in Table A-2, one based on 10% and one based on 15%. At these levels, between 80 and 120 projects will be funded in California.

Table A-1. Probable ERDA/Hud Solar Heating Cooling Demonstration Program (August 1976)

	Demonstration Projects	Dwelling Units
Single-Family Homes	480 - 560	480 - 560
(Including Mobile Homes)		
Apartment Buildings	120 - 140	2400 - 2800
Total	600 - 700	2900 - 3400
Commercial Total	150 - 200	

The ERDA/HUD program has started in California. Fifteen projects have been funded under this program as of August 1976. All of these projects are in the single-family market. The program to date is summarized in Table A-3.

Table A-2. California Share of ERDA/HUD Solar Heating and Cooling Demonstration Program

	10% Projects	Dwelling Units	15% Projects	Dwelling Units
Single-Family Homes	50	50	75	75
Apartment Buildings	12	240	18	360
(Nominally 20 Units/Bldg.)				
Commercial	17	-	25	
Total	80	290	120	435

Table A-3. Total ERDA/HUD Demonstration Contracts in California as of August 1976

	System Type 1	2	3	4	5	Total
Single-Family Homes	10	4	5*	-	-	19
Apartment Buildings	-	-	-	-	-	
Commercial	-	-	-	-	-	

System Type:

1. Hot Water and Heating
2. Hot Water Only
3. Heating and Cooling Only
4. Hot Water, Heating, Cooling
5. Heating Only

* Skytherm

APPENDIX B

SELECTED INSOLATION AND WEATHER STATISTICS

FOR MAJOR POPULATION CENTERS OF CALIFORNIA

Average insolation and other weather statistics are tabulated for stations within the 17 standard metropolitan statistical areas (SMSAs) of California in Table B-1. These stations have been grouped into seven reasonably well unified weather zones. Since they are keyed to SMSAs, they include 92% of the population of California.

It is noteworthy that insolation data is not available for certain areas such as San Francisco. However for the stations available, the total annual average level of insolation does not deviate by more than 10% from a mean of 1581 Btu/ft^2/day on a horizontal surface (cf: the fourth column of Table B-1).

Heating requirements in California are bounded by 1200 and 3300 degree days. This will tend to make the size of solar heating systems smaller in California than in other regions of the Nation.

Many regions of the State require little or no cooling in residential applications, while cooling loads dominate the space conditioning requirements in areas such as Palm Springs.

Table B-1. Insolation and Weather Statistics

Weather Station	Total Cooling Degree Days (65°F Base)	Total Cooling Degree Days (75°F Base)	Total Heating Degree Days (65°F Base)	Total Average Insolation Btu/ft^2/day	January			August			
					Heating Degree Days 65°F Base[b]	Amb. Temp. °F[b]	Insolation Btu/ft^2/day	Cooling Degree Days 65°F Base[b]	Cooling Degree Days 75°F Base[a]	Amb. Temp. °F[b]	Insolation Btu/ft^2/day
A. South Central											
San Diego	722	20	1507	1540[a]	314	55.2	892[a]	201	1.3	71.4	1908[a]
Los Angeles	615	14	1819	1404[a]	331	54.5	844[a]	154	.9	69.5	1940[a]
Santa Barbara	386	2	2110	1534[a]	371	53.2	856[a]	99	0	67.5	1944[a]
Santa Maria	84		3053	1748[a]	450	50.5	973[c]	18	21	62.3	2249[c]
Burbank	1179	94	1701	1582[a]	356	53.7		301		74.6	
B. North Central											
San Francisco	108		3042		518	48.3		22		63.0	1980[c]
Oakland	128		2909	1445[c]	508	48.6	741[c]	28		63.5	
Santa Rosa	315		3065		586	46.1		18		67.0	
Salinas	14		2959		465	50.0		16		62.4	
C. North Inland											
San Jose	444		2416	1519[c]	481	49.5	723[c]	111		68.1	2044[c]
Napa	374		2769		546	47.4		85		67.2	
D. North Central											
Sacramento	1159		2843	1611[d]	617	45.1		286		74.1	
Stockton	1259		2806	1707[c]	632	44.6	472[c]	323		76.7	2253[c]
E. So. Central Valley											
Fresno	1671	484	2630	1615[a]	611	45.3	724[a]	412	134	78.3	2183[a]
Bakersfield	2179	777	2185	1569[a]	543	47.5	706	515	229	81.6	2164[a]
F. High Desert											
San Bernardino	1557	248	2254	1519[a]		52.0	839[a]	409	95	78.2	2014[a]
Edwards		656	3344	1652[a]	722	41.7	869[a]		169	79.9	2141[a]
China Lake		1162	2673	1609[a]	633	44.6	799[a]		335	85.7	2090[a]
G. Low Desert											
El Centro	3794	3082	1216	1695[a]	360	53.6	863[a]	803	655	90.9	2030[a]
Palm Springs	3681		1240		341	54.3		760		89.5	

[a]Reference 5
[b]Reference 7
[c]Reference 8
[d]Reference 9

APPENDIX C

GENERAL SYSTEMS DESCRIPTIONS

Eight generic systems for using solar energy systems are described. All of these systems are ready for demonstration to the building industry.

1. Central Solar Water Heater, Master Metered Auxiliary

<u>System</u>: A heat transfer fluid circulates through solar collectors and delivers thermal energy to a storage tank either directly (if water is used as the heat transfer medium) or through a heat exchanger. This storage is used as a preheater for a conventional water heating system.

<u>Market</u>: Institutional, Commercial, and multi-family, majority of new construction, many possible retrofits.

<u>Time Frame</u>: The project could be completed in one year in new construction and six months in a retrofit situation.

<u>State of Current Technology/Activity</u>: The technology needed for this project is well understood. A number of systems have been installed overseas and in the United States.

<u>Instrumentation</u>: Instrumentation to indicate the amount of energy saved in a hot water system can pose some special problems due to the random nature of hot water demand.

<u>Budget</u>: The collector normalized cost of the system would be in the range of \$15 - \$40 per ft^2. The hot water needs of a 40-unit lowrise building would be satisfied using 1000 ft^2 of collector for a system expenditure of \$15,000 - \$30,000.

<u>Special Circumstances</u>: In new construction, this project is one of the most economical applications of solar energy. The investment is large enough to consider ownership of the equipment by a third party. (i.e., a leasing company or a utility.) The system is applicable where "utilities are included in the rent." Particularly compatible with gas or oil auxiliary.

2. Solar Water Heater, Individually Metered Auxiliary

<u>System</u>: This system differs from a central solar water heater in that water heated by a single collector array is stored in individual small tanks at each individual location. This preheated water is supplied to individually metered auxiliary hot water heaters (see Reference 4).

Market: The majority of new multi-family construction, some commercial new and retrofit.

Time Frame: This project could be completed in one year.

State of Current Technology/Activity: The technology needed for this project is straightforward. However, the particular arrangement proposed has never been demonstrated.

Instrumentation: There are some special problems associated with examining hot water systems.

Budget: The collector normalized cost of the system would be in the range of \$20 - \$40 per ft^2. The hot water needs of a 20-unit low-rise building would require funding in the range of \$10,000 - \$20,000, assuming 500 ft^2 of collector.

Special Circumstances: The system is compatible with the trend away from "utilities included" renting of apartments compatible with electric auxiliary water heating which are popular in high-rise apartments.

3. Hydronic Space/Water Heating

System: A working fluid circulates through solar collectors and delivers thermal energy to a storage tank, usually the order of 600 - 1000 gals. Space heating is accomplished by circulating the storage water in a heat exchanger located in the forced air ducting. The water for the auxiliary hot water system is preheated using a heat exchanger located in the space heating storage tank. Auxiliary heat may be supplied via fossil fuels or electricity. The solar system will be designed to account for 60%-80% of the heating load.

Market: Single-family new construction, multi-family and commercial new construction.

State of Current Technology/Activity: The technology for these systems is well known. Many homes across the country have been heated via this method for several years. Some home builders are already incorporating solar space/water heating systems in their current designs.

Time Frame: Projects could be completed in one year to eighteen months.

Instrumentation: The instrumentation of the space heating aspect of the system poses no special problems. The monitoring of the hot water energy savings poses some special design considerations.

Budget: Solar space/water heating systems collector normalized costs would be in the range of \$15 - \$30 per ft^2. A new energy-conserving home would require 200 to 250 ft^2 of collector for a total additional cost to the home of approximately \$5,000 - \$8,000.

4. Solar Space Heating with Off-Peak-Power Air Conditioning

System: The system has four major components: a collector array; two storage tanks; a conventional air conditioner, and a fan-coil or forced-air distribution subsystem. One storage tank is used for providing solar energy to the domestic hot water supply. The main storage tank is used either to store solar heat for use in the building at night or to store water chilled at night for use during the day.

Market: Multiple-family low-rise or high-rise, and single-family homes.

Time Frame: The project could be completed in six months in an existing building and within 12 to 18 months in a new building.

State of Current Technology/Activity: There are no projects known to be underway using this particular approach. The only technical development required for this system to work is a mode control subsystem which would automatically decide whether to store solar heat or off-peak cooling.

Budget: \$15 to \$30 per ft^2 for construction. \$20,000 for analysis and design of a mode control system.

Special Circumstances: Current utility rate structures in California do not provide any economic incentive for the off-peak-power air conditioning function in the residential market. The technical demonstration of this system could help electric utility companies and the PUC to formulate appropriate rate structures.

5. Space Heating/Air System

System: The air flow passes through the collector system and then through a dry storage media, usually a rock bed, during daylight hours. The heating of the dwelling is done either directly using the heated air or by convective or driven flow between the heated storage and the interior of the building.

Market: New single-family dwellings.

Time Frame: The time required for dwelling-site design is six months and construction time is on the order of one year.

State of Current Technology/Activity: Several homes throughout the country are now heated using air systems. Normal practice is also to incorporate in the home many passive design concepts. The technology is at the level where each dwelling may require some "tuning" for maximum performance.

Budget: The cost of the system would add about \$10,000 - \$15,000 to the normal price of a custom built home.

Special Problems: The storage area (e.g., a rock bed) requires considerable space. In the Eastern part of the Nation, this volume is usually allocated in the basement area of the home. Some special design consideration may have to be given in relation to the "slab" concrete floor construction which is popular in California.

6. Passive Design

System: There is no manufacturable system per se. Rather, the building envelope and site are designed in such a way as to:

(1) Maximize the solar heat gain when heating is needed and minimize the solar heat gains when cooling might be required.

(2) Stabilize the internal temperature of the building by increasing the thermal capacity of the structure.

Market: Custom housing, commercial and institutional buildings.

Time Frame: Project definition and design - 6 months to 1 year - Construction - 9 months to 1 year.

State of Current Technology/Activity: Undifferentiated lists of ideas and concepts are widely available in the literature. The cost effectiveness of specific measures is difficult to establish, due to the overall interaction of the system components.

Instrumentation: Measurements which isolate the performance of individual design ideas is virtually impossible. Submetering of space heaters, water heaters and total energy consumption along with weather data would allow comparisons to be made with building of conventional design.

Special Problems: Architect - Engineer - Design teams need to work more closely to effectively promulgate the use of concepts in custom building standards. There is a need for these to be established for the speculative sector of the building industry to follow.

Budget: Fees for the extra professional services required are difficult to justify and obtain.

7. "Skytherm" Structure

System: The "skytherm" system is a solar pond technique. The "ponds" are contained in plastic bags on the roof of a single-story structure. In winter, the water bags are exposed to the sun during the day. At night insulated covers are moved over the bags and the home is heated by natural convection.

Market: The Skytherm technique can be applied to a wide variety of architectual design. This can also be used as part of an off-peak power cooling system. Finally, engineering tests are about to be completed and then standard sets of plans will be made available. At that time, a Skytherm could command a good size market in the single-family, multi-family low-rise, and commercial field.

Time Frame: Skytherm structures can be built in the same time frame as conventional buildings.

State of Current Technology/Activity: The skytherm method is now well proven. There are well over ten Skytherm structures in the State, with others being built in various locations in the U.S.A.

Instrumentation: Instrumentation for Skytherm has already been developed.

Budget: Skytherm construction should add 10% or less additional costs to conventional custom structures. Projects could be chosen to fit particular budgets.

8. Solar Augmented Hydrodonic Heat Pump

System: The system substitutes solar energy for either natural gas or electrical energy used to balance a conventional hydronic heat pump system. The system adds a storage tank to the hydronic loop of the conventional system. The tank is used to store solar energy for subsequent use by the building (see Reference 4).

Market: Solar augmentation is primarily applicable to the multiple-family market. The hydronic heat pump system is most often found in high-rise buildings.

Time Frame: In an existing building a demonstration could be completed in six months.

State of Technology/Activity: No technical problems are forseen. The Southern California Edison Company is currently planning to install a similar system on a 10,000 ft^2 office building.

Budget: The system can probably be demonstrated for $20 - $25 per ft^2 of collector.

Special Circumstances: Instrumentation and control may be difficult because of small temperature differences which are inherent to the system.

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