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ABSTRACT

The purpose of this study was to establish the technical and economic feasibility of using solar energy for the heating and cooling of buildings and to provide baseline information for the widespread application of solar energy. The initial step in this program was a study of the technical, economic, societal, legal, and environmental factors involved with solar energy and the identification of barrier problems in its use and of potential solutions to these problems. The study also includes definitions and plans for proof-of-concept experiments. (Author/MLF)

NSF-RA-N-74-021A

SOLAR HEATING AND COOLING OF BUILDINGS

PHASE 0

FEASIBILITY AND PLANNING STUDY

FINAL REPORT

VOLUME 1

EXECUTIVE SUMMARY

EA 006 623

DOCUMENT NO. 74SD4219
MAY 1974

GENERAL ELECTRIC

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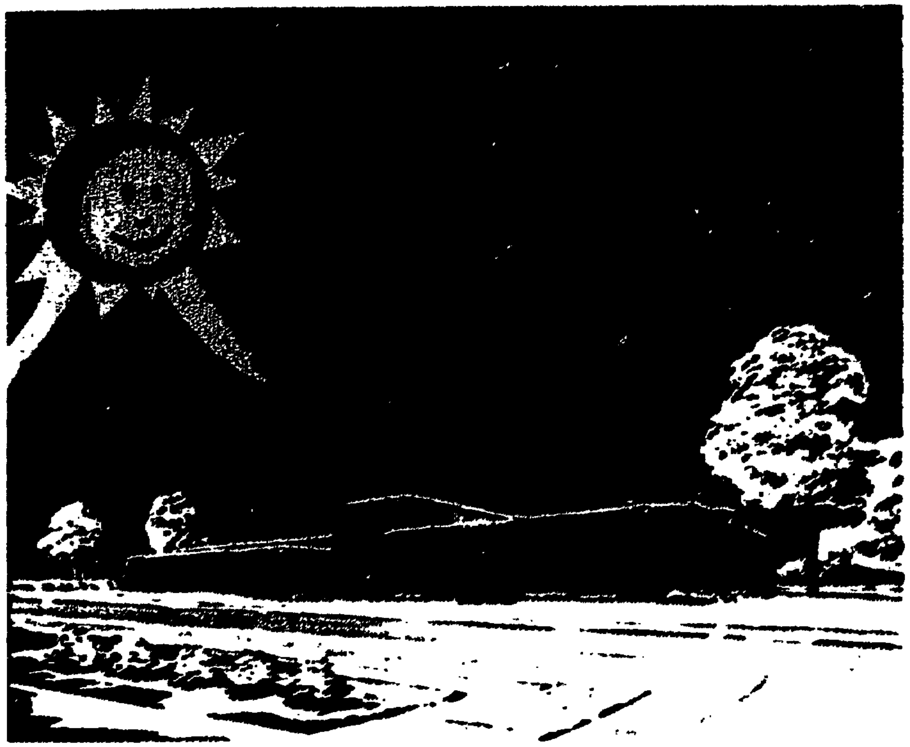

FOREWORD

Wide-spread use of pollution-free, inexhaustible solar energy to heat and cool buildings and provide hot water could significantly reduce the dependence of the United States on imported fuels. The potential contribution to national security, economic strength and environmental protection led the National Science Foundation (NSF) RANN - Research Applied to National Needs to undertake a program to assess the feasibility and practical merits. The initial step (Phase 0) in this program is a study of the technical, economic, societal, legal and environmental factor; and identification of barrier problems and potential solutions. The study also includes definition and plans for proof-of-concept-experiments.

This study was performed by the General Electric Company for the National Science Foundation. Some of its major results are:

- Heating and cooling with solar energy can replace large quantities of fuel. The attendant reduction in pollution will attain an ever-increasing significance as total energy consumption increases.
- The industrial base and public acceptance required for achieving these beneficial results must be developed over a period of time with a planned program involving both the public and private sectors.
- To use solar energy for widespread heating and cooling in the future requires that we begin to develop the tools, the techniques, and the industries today.
- Early Proof-of-Concept Experiments are an excellent starting place for a number of reasons. They will provide:
  - Early design and operational experience.
  - Actual performance and cost data for a variety of climate zones and building types.
  - Comparative performance data on solar energy system concepts and equipment.
  - Identification of the problem areas and solutions for the next generation of equipment.
  - Education tools for the building industry.
- After the Proof-of-Concept Experiments, the next Phase should be wide utilization on governmental buildings - both new buildings and retrofit. This will achieve:
  - An initial market to establish industrial incentive to supply the products and services.
  - Distinct, measurable savings of conventional fuel supplies.
  - Innovations and improvements based on these applications.
- We have time on our side now - solar energy utilization won't happen overnight - we can make an orderly start and move progressively to higher levels of applications.

The General Electric Company, in cooperation with NSF, has recently designed, installed and is currently operating a major experimental installation at the Grover Cleveland Junior High School in Boston. We strongly encourage the implementation of the remaining phases of the NSF proof of concept plan. The Company stands ready to provide system design and integration support as well as the required specialized solar energy equipment as needed for the program.

STUDY BASIS AND APPROACH

Table 1. Study Objectives and Key Elements

STUDY OBJECTIVES

- OVERALL PROJECT

  STIMULATE AND ACCELERATE WIDESPREAD USE OF SOLAR ENERGY

- PHASE 0 STUDY

  ESTABLISH THE THEORETICAL FEASIBILITY AND PROVIDE BASIS OF PLANNING FOR LATER PHASES OF SOLAR ENERGY APPLICATION

KEY STUDY ELEMENTS

- ESTABLISH FUNCTIONAL, PERFORMANCE, AND OPERATIONAL REQUIREMENTS
- DEFINE SYSTEMS TO MEET REQUIREMENTS BY BUILDING TYPE AND CLIMATE REGIONS
- ASSESS THE POTENTIAL FOR SOLAR HEATING AND COOLING THROUGH THE YEAR 2000
- ASSESS SOCIAL AND ENVIRONMENTAL IMPACTS OF SOLAR HEATING AND COOLING
- QUANTIFY COST EFFECTIVENESS AND ENERGY SAVINGS POTENTIAL
- RECOMMEND AND PROVIDE PRELIMINARY PLANS FOR PROOF-OF-CONCEPT EXPERIMENTS (POCE) AND SUPPORTING NEAR-TERM RESEARCH
- DEVELOP STRATEGIES AND PLANS TO STIMULATE WIDESPREAD UTILIZATION OF SOLAR HEATING AND COOLING SYSTEMS

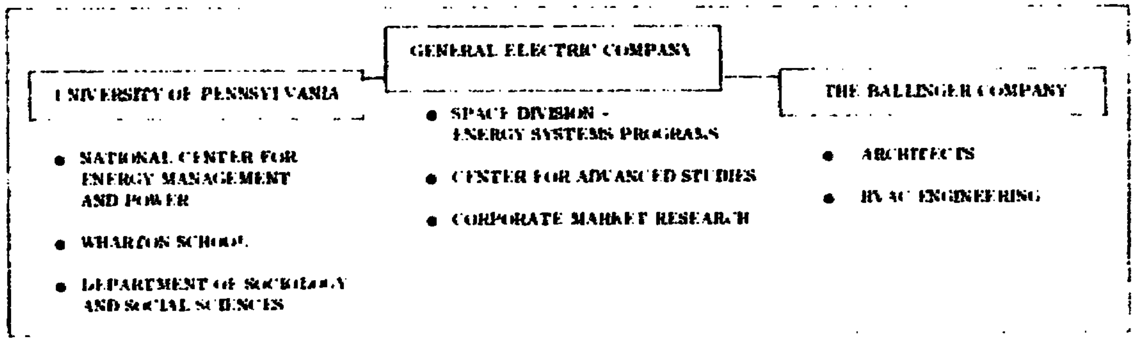

Figure 1. Industry/University Study Team

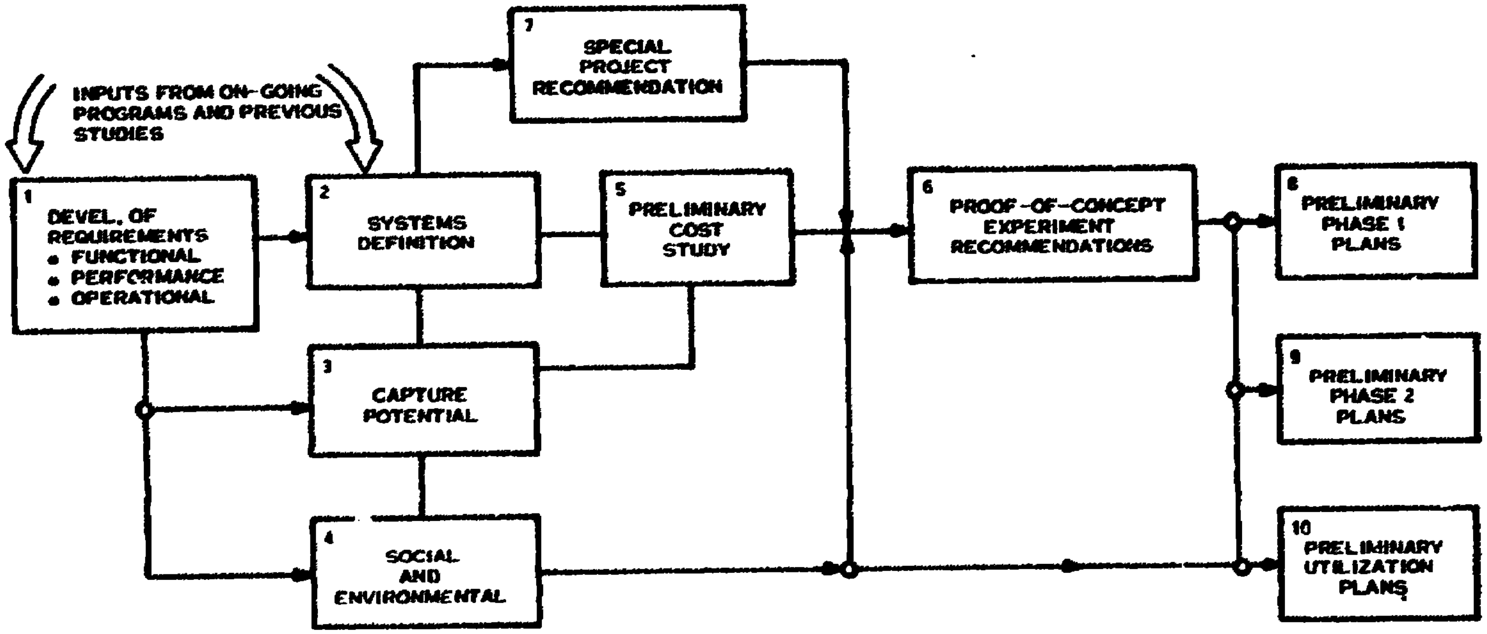

Figure 2. Phase 0 Work Flow Diagram

BACKGROUND

Studies on Solar Heating and Cooling of Buildings (SHACOB) were initiated in September 1973 under the direction of the Research Applied to National Needs (RANN) branch of the National Science Foundation (NSF) to provide baseline information for the widespread application of solar energy. The potential application is dependent upon many factors - costs, systems performance, climatic variation, societal, legal and environmental aspects are representative of these.

The solution of such varied, interrelated problems requires a systematic, multi-disciplinary approach. Such an approach was structured by NSF. It involves participation by government, universities, and industry. The objective of the initial phases of this program are to set the stage for widespread utilization b[illegible]tablishment of the basic feasibility (Phase O) and the [illegible]gn (Phase 1) and implementation (Phase 2) of Proof-of-Concept Experiments (POCE).

One major objective of Phase O is the establishment of an overall experimental program plan to provide visible evidence of the practicality of heating and cooling buildings with solar energy within the socio-economic environment of the United States.

KEY STUDY ELEMENTS

In order to fulfill the study objectives, the elements shown in Table 1 were addressed. The reference time frame for this study is from the present through the end of the century. Emphasis has been placed in deriving a realistic technology base. Potential component and system improvements will improve the cost-effectiveness of future systems and provide increased acceleration to widescale usage. However, it was not the intent of this study to couple the utilization of solar energy with technology "breakthroughs" that may or may not occur. The conclusions reached here should be both conservative and achievable.

Each of the elements in Table 1 were quantified, where possible, and studied in sufficient detail to draw generic comparisons and recommendations and/or provide input data for other elements. Existing information has been used and applied or extrapolated to provide the data base for this study.

STUDY TEAM AND METHODOLOGY

The General Electric Space Division conducted the study and was supported by TEMPO (GE Center for Advanced Studies) and the Corporate Market Research organization. Other Company components, such as the Corporate Research and Development Center, Central Air Conditioning Department, and the Plastics Department were consulted on many issues.

Major roles were played by the University of Pennsylvania and the Ballinger Company.

The team organization is shown in Figure 1.

The study was organized into ten interrelated tasks as shown in Figure 2. Tasks 1, 2, 3, and 5 produced the technical evaluation of alternate solar systems based, where applicable, on the economic, demographic, and environmental data produced in Task 4. Definition and planning of proof-of-concept experiments (POCE) were accomplished in Tasks 6, 8, and 9. Possible special projects which were, in effect, early POCE's were studied in Task 7. Implementation and communication plans to accelerate acceptance of solar energy, where it is applicable, were developed under Task 10.

SCENARIO PROJECTIONS

A common starting point for any study is a statement of the assumptions. This project is concerned with a time frame of at least 25 years, from now until AD 2000. Assumptions on the expected or projected state of society over this period will constitute a baseline scenario. This scenario, significant elements of which are shown in Figure 3, postulates no major wars or depressions during the period to AD 2000, although it is hard to find a twenty-five year period in the country's history for which these postulates are true. If these happen, the alternative scenarios they produce are so varied that no reasonable "surprise-free" scenario can include them.

All dollar values used in this study are given in terms of 1970 dollars.

A sound starting place for economic assumptions about the period to AD 2000 is a projection of the future population and the future productivity per worker. While other factors enter, these are the two most important determinants of the quantitative economic growth.

In the baseline scenario, the population of the United States will grow from 205 million in 1970 to 264 million in 2000; an average growth rate of 0.85 percent. This corresponds to the Bureau of the Census projection known as Series E (Bureau of Census, 1972).

The baseline projection GNP in AD 2000 will be $2400 billion compared to $977 billion in 1970. This is considerably lower than many estimates made within the past few years.

Economic indicators derive from the total labor force and estimates of the production per worker and the unemployment rate.

The GNP is divided into categories called "Kinds of Purchases." Personal consumption and government expenditures will grow most rapidly. Net exports may vary widely from year to year.

The "kinds of outputs" which these purchases buy are categorized as industries. Government will grow the fastest at an average rate of 3.7 percent. Both contract construction and services will grow faster than the 3 percent rate for GNP. Manufacturing, agriculture and mining will grow slower than the GNP. These rates symbolize the state of society: well beyond the agriculture stage, and passing rapidly from the industrial stage to a post-industrial era.

Alternate high and low scenarios have been considered to provide the range of uncertainty. The high and low estimates of total population in AD 2000 are 300 million and 251 million. The high estimate of GNP in AD 2000 is $3400

STUDY BASIS AND APPROACH (CONT)

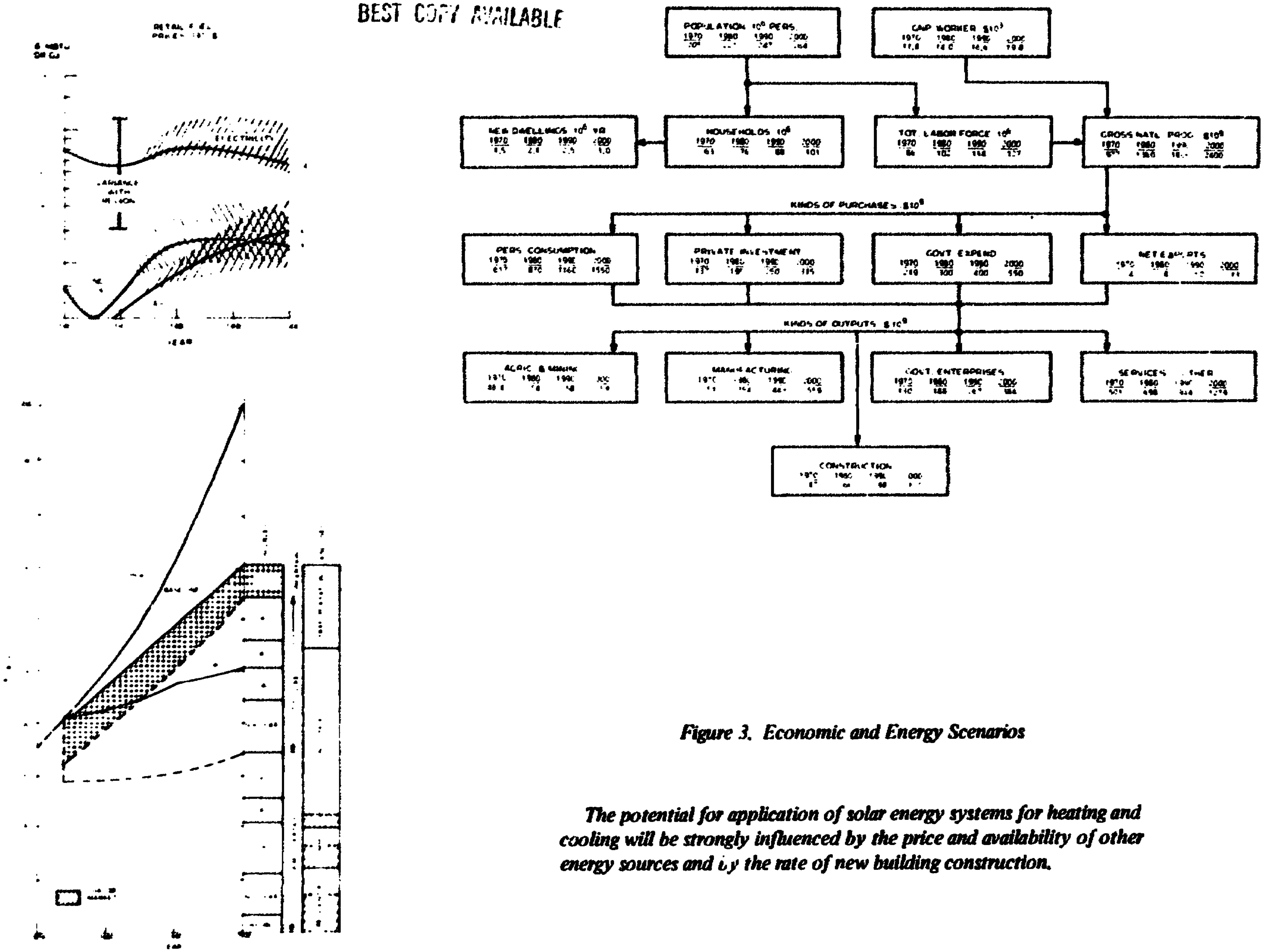

Figure 3. Economic and Energy Scenarios

The potential for application of solar energy systems for heating and cooling will be strongly influenced by the price and availability of other energy sources and by the rate of new building construction.

billion and assumes an average growth in productivity (dollars of GNP per worker) of 2.75 percent, while baseline assumes average growth of 1.5 percent.

One of the major considerations affecting economic viability of solar energy systems is the price of the fuel whose consumption is saved. Figure 3 presents the projected retail fuel prices for various energy sources.

For dollar energy assessments, the retail fuel price at the residence or commercial level is the most significant. The projection for retail prices of fuel into the future is highly speculative since it involves balancing many contradicting factors. The fuel price projections were arrived at by a detailed examination of the interaction of supply and demand, based on historical precedents and projections of technological, economic and political developments.

The units are expressed in terms of fuel energy content and in 1970 dollars. The solid curves are the baseline values used to assess solar systems cost effectiveness.

Fuel shortage in the face of increasing demand, coupled with uncertainty of future supplies, is another driving force to develop alternate energy supplies. As shown in Figure 3, a significant gap exists between readily available supplies and the growing needs of the country.

SYSTEMS DESCRIPTION

The basic elements of a solar heating/cooling system are depicted in Figure 4. Generally, the system may be considered as one which incorporates solar energy equipment with conventional Heating, Ventilating, and Air Conditioning (HVAC) components. A description of the various subsystems follows.

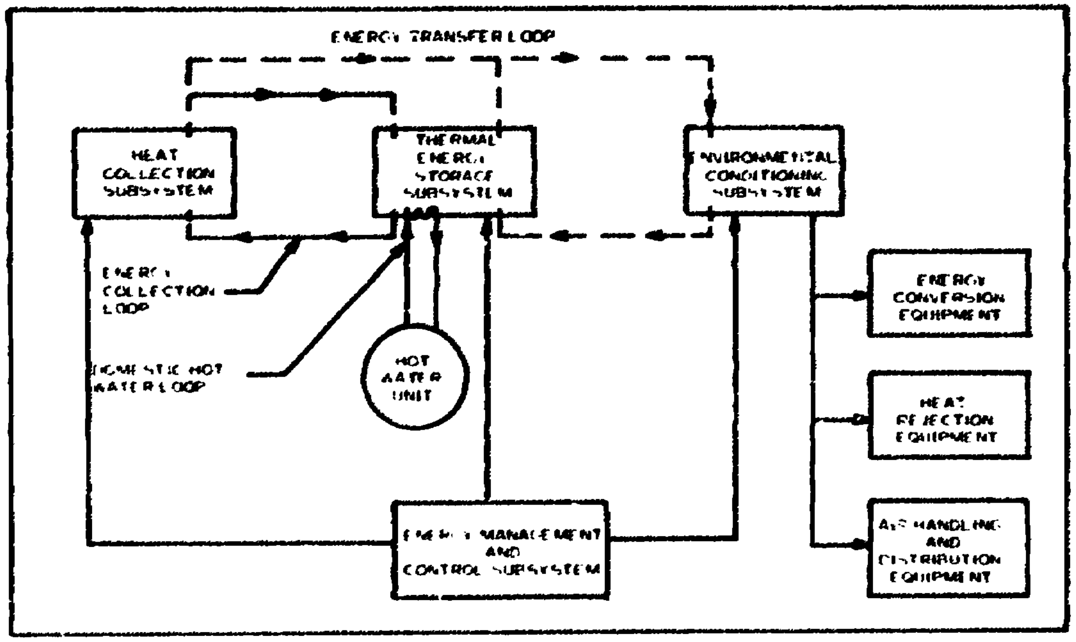

Figure 4. Elements of SHACOB Systems

The heart of the system is the solar collector. These are being designed and tested, but the industrial base to provide economic, reliable equipment does not exist today. Achievement of maximum energy savings on a cost-effective basis also requires specially designed air conditioning with improved characteristics.

HEAT COLLECTOR SUBSYSTEM (HCS) consists of the solar energy heat collection unit such as flat plate solar collectors, water encapsulation devices, or thermal panes. This is the heart of the system, and accounts for approximately half the cost. Development of more efficient, less expensive collectors will be a continuing need for solar energy to reach its full potential.

THERMAL ENERGY STORAGE SUBSYSTEM (TES) provides for the storage of solar energy during periods of surplus of sunshine for use at night or on cloudly days. Storage methods include sensible and latent heat transfer (hot or cold) components, including combinations and/or composites of the two. Here again this specialized solar energy equipment requires improvements - primarily for reducing costs of large installations.

ENVIRONMENTAL CONDITIONING SUBSYSTEM (ECS) - All ancillary components and equipment required to convert and distribute energy to condition the space air within the building. It includes all circulating pumps, valves, condensers, cooling equipment, controls, etc., and supplementary equipment required to condition the space air by gas, oil, or electrical energy.

ENERGY MANAGEMENT AND CONTROL SUBSYSTEM (EMCS) provides the necessary control system logic and components necessary to sense and activate system controls.

TECHNICAL EVALUATIONS

The functional requirements for heating and cooling systems are primarily influenced by climate and type of building.

While local variations in climate occur everwhere, the United States, excluding Alaska and Hawaii, may be divided into twelve climatological regions as shown in Figure 5.

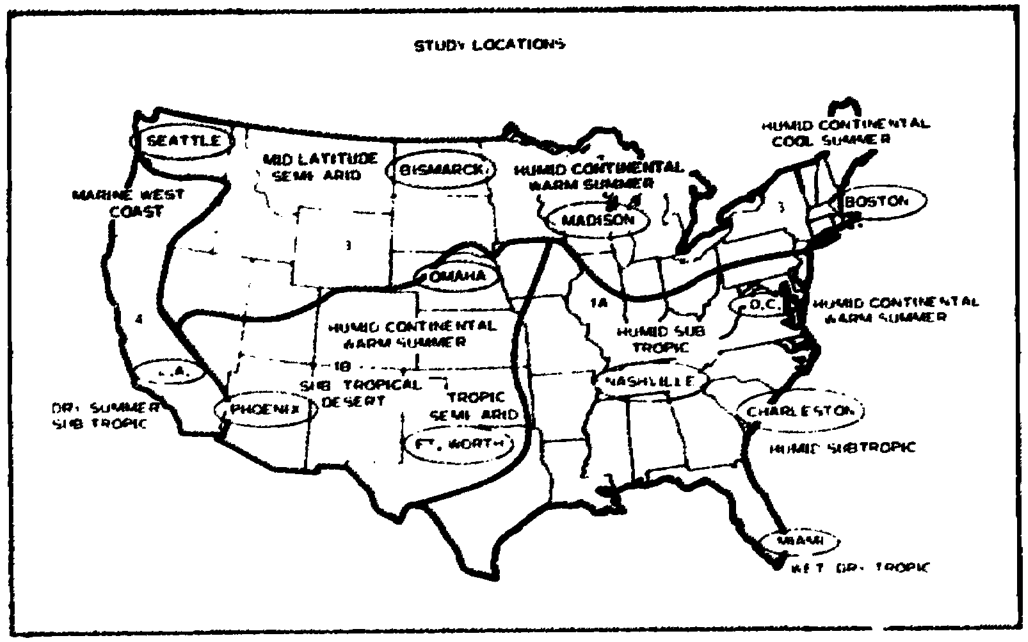

Figure 5. Climatic Regions in the United States

In this study each region is designated by a city where climate is representative of the region. Broad areas of the country are therefore covered by each city designator.

Building types are extremely varied, but they can be categorized for purposes of estimating heating and cooling loads. For this study all buildings which are candidates for solar energy installations are divided into eighteen categories as shown in Table 2.

Table 2. Building Categories

1. RESIDENCE, ONE & 2 FAMILY
2. RESIDENCE, MULTIPLE HIGH RISE
3. RESIDENCE, MULTIPLE LOW RISE
4. HOTEL MOTEL, HIGH RISE
5. HOTEL MOTEL, LOW RISE
6. OFFICE BUILDING, HIGH RISE
7. OFFICE BUILDING, LOW RISE
8. WAREHOUSE
9. INDUSTRIAL, LIGHT PROCESS LOAD
10. INDUSTRIAL, HEAVY PROCESS LOAD
11. SINGLE STORY EDUCATIONAL
12. COLLEGE UNIVERSITY
13. AUDITORIUMS
14. HEALTH CARE, CLINIC
15. HOSPITAL
16. RETAIL, MERCHANDISE MALL
17. RETAIL, INDIVIDUAL STORE
18. MOBILE HOMES

In addition to the climate and building combinations, there are many alternate solar energy system concepts for heating and cooling. The technical discussions in Volume 2 and the Appendices to this report cover a large variety of such systems, many of which appear to be feasible. The main thrust of the technical/cost evaluation was to:

- Identify those solar system designs with the greatest potential for life cycle cost savings.

- Estimate the annual energy savings which would accrue from the application of each selected solar system.

Capital and operating costs were derived through analysis of HVAC design, installation and maintenance practices, standard component prices, historical cost trend data, estimated costs for specialized solar equipment, and fuel projections.

The life cycle cost for such systems studied considered such factors as:

- Component, integration and installation costs.

- Appropriate building types and climate areas.

- Year of installation, useful life, capital and operating costs.
- Interest rates and tax savings on capitalization.

This approach presents all costs on a comparable basis without the additional uncertainty of superimposed inflationary effects. Cost sensitivity analyses were made by varying the baselines for such significant factors as fuel and solar collector costs, interest rates, and capitalization periods.

A typical cost summary sheet is shown in Figure 6. This detailed level of life cycle costing, as compared to applying generalized empirical factors, is considered to meet the study objectives with more definitive data than has been available in previous studies examined.

The solar collectors represent a major element in system cost (typically around 50 percent). Since they are not currently available commercially, their prices were estimated on the basis of projected designs produced in a plant with a capacity of approximately one million 4 ft. x 8 ft. panels per year. It was assumed they would be sold, distributed, and installed like other major HVAC components which have a sale price to the final purchaser between 2.4 and 2.7 times the base manufacturing cost.

On the above basis, user costs are projected to be $\$4.70/ft^2$ for single-window units and $\$5.80/ft^2$ for double windows. These estimates are in 1974 dollars, but the cost-effectiveness computer calculations adjusted them to be consistent for all cases considered. These estimates are considered realistic for the initial period of significant commercial application. It is highly probable that they will be reduced if a continued R&D program for reducing collector costs is adopted.

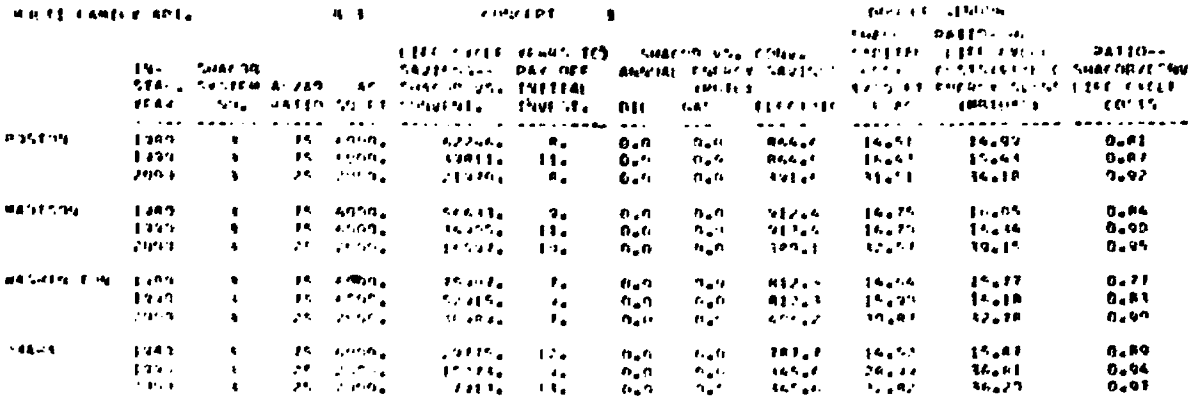

Figure 6. Typical Cost Summary Sheet

Cost Estimates for each system concept were prepared for various building types and climate regions. Values less than 1.0 in the last column indicate that life-cycle costs for the specific solar system concept being analyzed are less than for conventional electrical systems.

Collector performance is based on analyses which have not yet been verified experimentally - particularly for large arrays. The tentative conclusions are that double-window collectors are more cost effective in northern climates and that single-window collectors are more cost effective for southern climates. These conclusions could be changed, however, when adequate data - such as that which will come from the Proof-of-Concept Experiments - is available.

With the complex matrix of solar systems, building types, and climate zones, it would be hazardous to draw oversimplified conclusions regarding preferred systems - especially with the varied state of technical development of such components as solar collectors and air conditioning equipment designed for use with solar systems. Nevertheless, certain conclusions can be reached at this time.

Four systems were found to be especially worthy of further evaluation, development and demonstration:

- Heating with liquid-to-air heat exchangers coupled with absorption air conditioners modified for solar operation. Figure 7 is a schematic diagram of this concept.
- Heating with liquid-to-air heat exchangers coupled with conventional vapor compression air conditioners.
- Heat pumps assisted by solar energy in the heating mode and operated either conventionally or in an off-peak manner ("stored cold") for cooling.
- Heating with liquid-to-air heat exchangers and cooling with vapor compression air conditioners driven by Rankine cycle engines designed for operation with solar energy.

Under certain conditions, each of these systems can be cost effective on a life-cycle basis. It is important to note further that even when cost effectiveness is marginal, substantial energy could be saved. For instance an important design variable considered is the ratio of solar collector area to roof area. It is generally true that energy savings increase as this ratio increases. However, this is not necessarily true of cost effectiveness, since the added collector cost may exceed the value of the fuel saved at projected prices. The relative value of these competing standards could be influenced by Government policy actions. The quantitative data for evaluating these alternatives is presented in detail in the report.

The evaluation of each building type in each climate area with the various solar systems yielded a ratio of life cycle cost with solar to conventional systems for each combination. When this ratio is 1.15 or less, the solar system is assumed to be cost effective. This practice was adopted to make some allowance for improvements in performance and cost as R&D progresses. It was also assumed that the dominant trend for future conventional systems will be all electrical. This assumption is valid for the long range projections of interest.

Cost effectiveness of solar cooling systems was based on performance characteristics calculated for present air con-

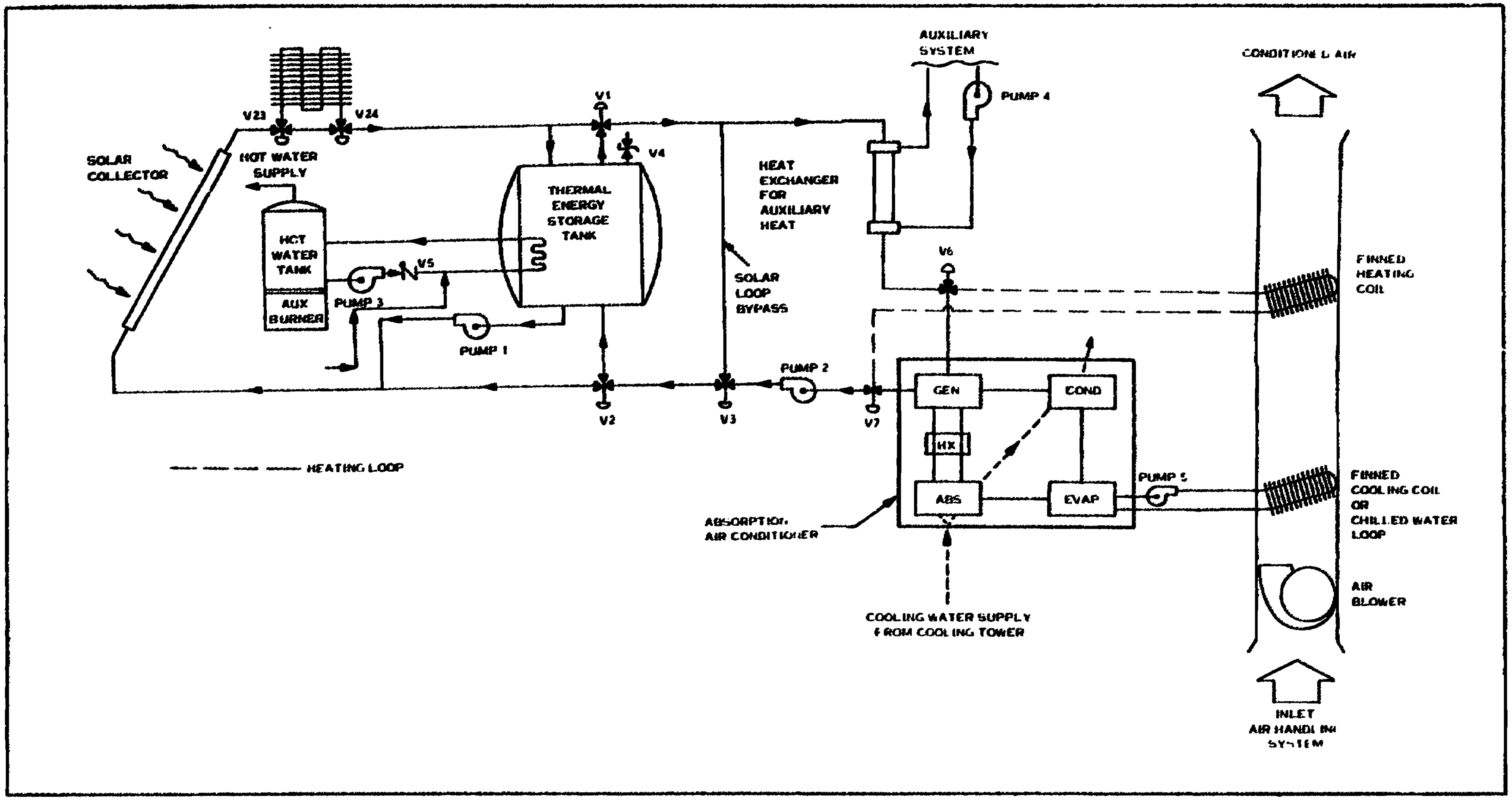

Figure 7. Typical Solar Heating and Cooling System Schematic

One specific type of solar heating and cooling system is shown. It utilizes a direct heat exchanger for heating and an absorption air conditioner for cooling. The coupling of the various subsystems is illustrated. Many other combinations may be employed.

ditioner designs. On that basis cooling plays only a small role in determining the monitary savings of solar energy systems. One major conclusion of the study is that cost effective solar air conditioning depends upon the development of equipment optimized for this purpose, rather than current equipment designed to use conventional energy resources.

The issue of installing solar systems on existing buildings was examined for a number of building types. Aesthetic and structural requirements tend to make these costs both higher and more variable. For those generic types which can be modified satisfactorily in other respects, the costs were found to be so much higher that they would not be cost effective. There are, of course, many individual buildings fortuitously adaptable, but their number is small compared to the major market in new construction.

In the two tables which follow, summary data is given for the number of buildings and total energy savings possible in the year 2000, if SHACOB systems were installed in all suitable buildings. This number of buildings is referred to as the "capture potential" and represents the ultimate market.

Capture Potential AD2000
Numbers of Buildings
in Thousands

	Climate Area									
	Wash., D.C.	Boston	Madison	Bismarck	Los Angeles	Phoenix	Ft. Worth	Omaha	Charleston	Total
Residence, One & Two Family	4,133	8,237	3,075	1,371	3,656	540	1,826	1,308	3,190	27,336
Residence, Multiple Low Rise	444	1,383	302	124	475	39	146	126	239	3,278
Hotel/Motel, Low Rise	10	31	10	5	12	5	7	4	8	92
Office Buildings, Low Rise	118	332	165	64	96	21	46	52	107	1001
Warehouse	69	221	82	28	60	11	29	23	47	570
Industrial, Light Process Load	59	276	75	38	162	10	24	31	36	713
Education, Single Story	9	27	8	4	13	1	5	4	10	81
College/University	2	5	2	1	4	1	3	1	4	23
Auditoriums	54	125	44	16	73	8	24	21	43	408
Retail, Merchandise Mall	2	6	2	1	3	-	2	1	3	20
Retail, Individual Store	222	622	197	81	233	34	95	70	159	1,713
Mobile Homes	554	714	473	265	519	224	234	226	669	3,878
Total	5676	11981	4435	1998	5306	894	2441	1867	4515	39,113

Capture Potential AD 2000
Energy Saved in Milli ons of Giga Joules

Building Types	Climate Areas									Total
	Washington D. C.	Boston	Madison	Bismarck	Los Angeles	Phoenix	Fort Worth	Omaha	Charleston	
Residence										
One and Two Family	244	527	191	144	201	25	110	76	179	1697
Multiple Low Rise	23	80	16	6	12	1	5	6	7	156
Hotel/Motel, Low Rise	28	77	19	17	8	6	5	8	5	173
Office Buildings, Low Rise	42	111	40	15	15	2	7	13	15	260
Warehouse	97	260	71	56	81	7	19	26	40	657
Industrial, Light Process Load	136	452	104	36	157	8	29	36	43	1001
Education, Single Story	15	41	12	5	12	1	3	6	8	103
College/University	2	7	2	1	1	1	1	1	2	18
Auditoriums	16	39	11	8	10	1	4	5	7	101
Retail										
Merchandise Mall	8	29	9	8	2	1	3	4	4	68
Individual Store	121	315	99	40	42	5	28	37	30	717
Mobile Homes	17	23	15	14	15	5	7	6	18	120
Total	749	1961	589	350	556	63	221	221	358	5071

An assessment of the capture potential and market penetration for solar heating and cooling by building type and climate area has been projected through the year 2000. This assessment includes forecasts of energy savings attributable to solar heating/cooling installations.

Capture potential, the number of buildings that could be equipped effectively with solar systems, is less than the total number of occupied buildings. This is attributable to considerations involving climate areas, building types, siting, viability of solar cooling systems, retrofit vs. new installations, and economic viability.

The projections for numbers of buildings of each type to be constructed in each climate region were based on detailed ecomonic and demographic forecasts. For this purpose the United States was divided into 171 Business Economic Areas (BEA), and individual forecasts were made for each. Of the 60 million buildings to be constructed in the United States in the next 5 years, approximately 40 million were found to be viable, cost effective, candidates for solar systems.

The number of buildings suitable for solar energy systems from 1975 to 2000 is indicated in Figure 8-A. If all these buildings were so equipped, the yearly equivalent electric power savings would be approximately 1500 billion kilowatt-hours (Figure 8-B) by the end of the century—equivalent to the total electrical generating capacity of the United States in 1970. Also, as indicated by a comparison of Figures 8-C and 8-D the annual value of the solar savings of fuel would, by that time, exceed the annual additional outlay for the solar systems.

The annual costs in Figure 8-D are the increment attributed to the solar systems. In many building types, substantial savings in roofing material can be made by substitution of solar collectors. Since this factor is taken into account, the cost of the solar equipment itself is higher.

While the capture potential represents an ultimate goal, its achievement by the 2000 is limited by a number of factors. As shown in Figure 8-D the annual cost of installing solar equipment in that time period would be of the order of 400 billion dollars. This estimate is high because it does not account for all the potential cost reductions which could be obtained by future R & D. The total, however, is still much larger than the market which can realistically be served in the time period considered. Factors limiting penetration of the potential market include commitment of risk capital, development and emplacement of manufacturing capacity, training personnel and overcoming public inertia to new products.

A major conclusion of this study is that the growth of the market for solar energy systems during the 1980's can be impacted more by early industrial participation than by the availability of cost-effective applications.

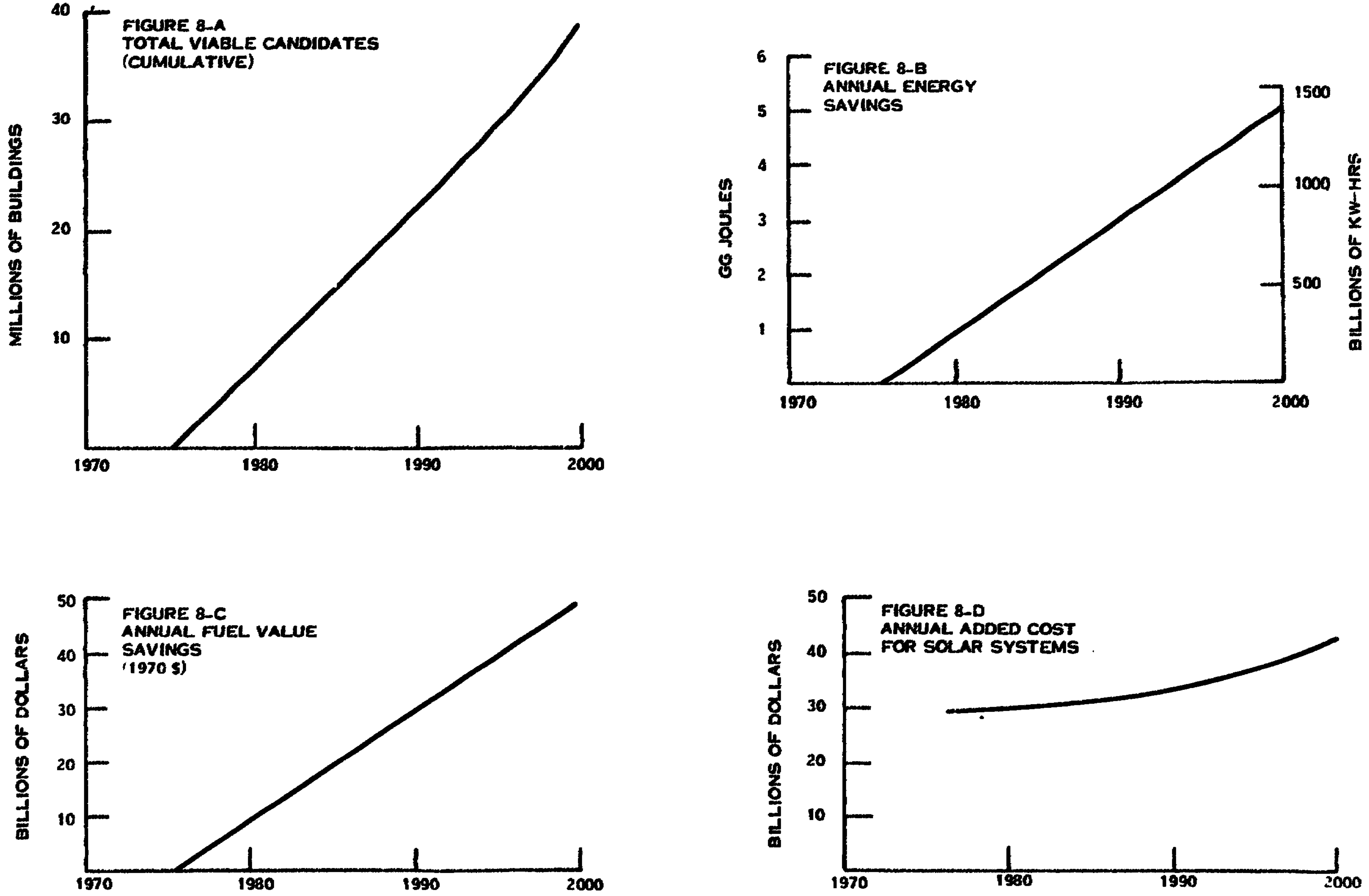

Figure 8. Capture Potential Projection Summary (New Construction Only)

If all new buildings for which solar systems are viable and cost-effective were so equipped, the annual energy savings by the end of the century would equal the 1970 U.S. electrical generating capacity.

Each new technology, as it is introduced into the market, encounters its own impediments. Not all of these can be forecast--such as premature sale of unreliable equipment creating a negative public image. The projected market penetration, summarized in Figure 9, is based on historical data for a variety of similar industries, augmented by estimated effects of government policies designed to stimulate the use of solar energy. Policy alternatives were explored in depth in the study. The major ones considered most likely to be effective include:

- Proof-of-concept experiments to provide improved design tools, operating experience, equipment and visibility to early decision makers.
- An early introduction of installations on government buildings--new and retrofit--which will provide an initial market to speed the development of the industrial base for equipment, distribution and service.
- Economic incentives, such as loan guarantees and interest incentives, to private purchasers to tip their decision balance in favor of the favorable solar system life-cycle costs.
- Establishing the requisite legal safeguards (such as "sun rights") and minimizing zoning restrictions.
- Continued sponsorship of R & D to assure that economic, reliable equipment and systems will be available as required.

The projections summarized in Figure 9 result from the baseline scenario for fuel costs, solar equipment costs and other factors Higher fuel costs, reduced per unit solar equipment costs, and higher efficiency would yield higher market penetration and fuel savings.

The projections indicate adoption of solar heating and cooling at an accelerating rate as we enter the twenty-first century. The in-depth detailed analyses were made only to the year 2000, but less exhaustive analysis for the subsequent period indicates a far greater impact by 2020.

CAPTURE POTENTIAL/MARKET PENETRATION PROJECTIONS (CONT)

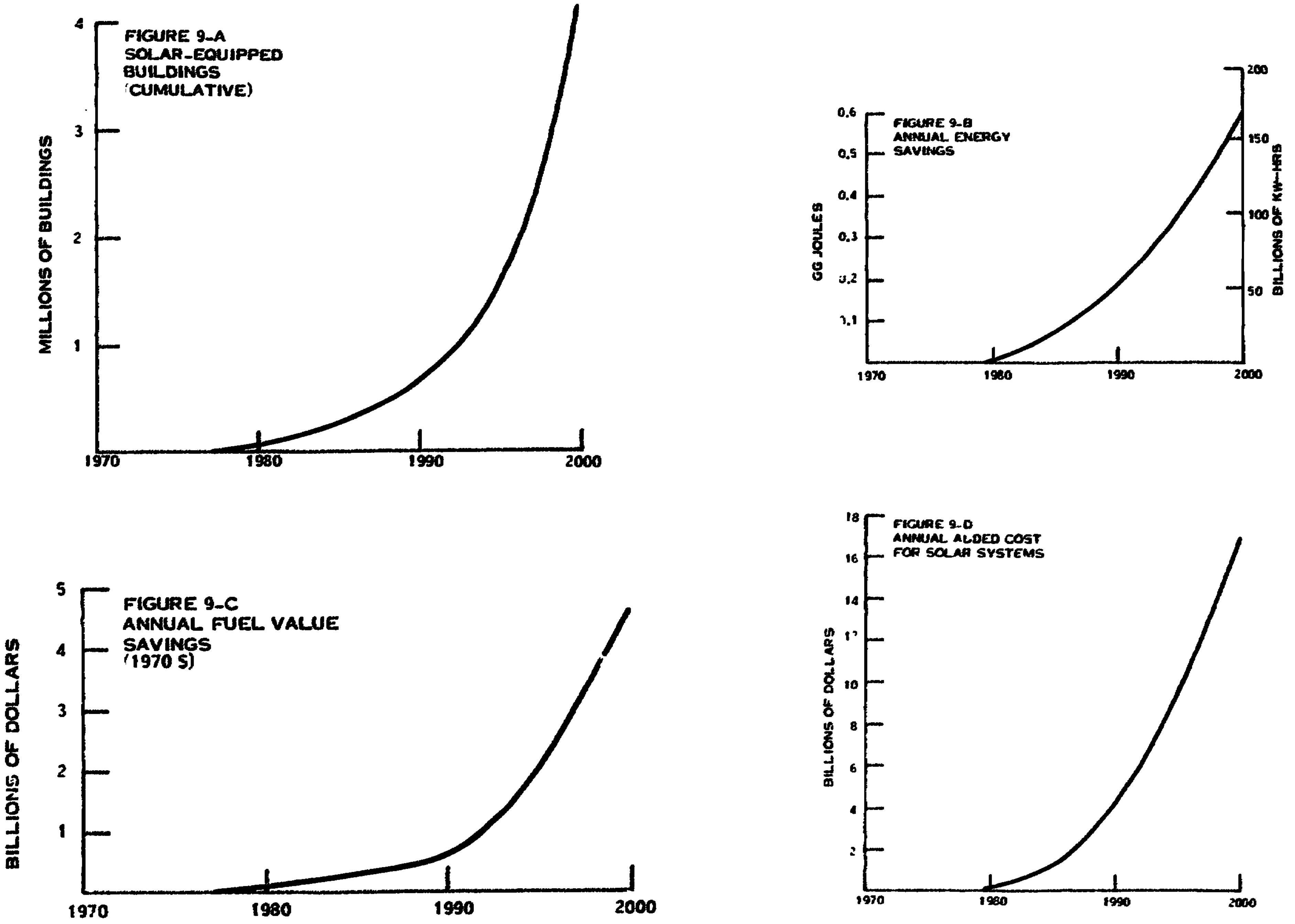

Figure 9. Market Penetration Projection Summary (New Construction Only)

The rate of introduction is expected to accelerate rapidly by the middle 1980's if proper programs and policies are promptly implemented.

The implementation of SHACOB at the rate projected by the market penetration will have an impact on the environment, economy, industry, utilities, government policy, law, and society.

ENVIRONMENT

The primary environmental effects of SHACOB are the reduced conventional fuels required, the consequent reduction in land use and pollution associated with the conventional energy production and the increased consumption of materials used in manufacturing solar energy collectors and components. The energy savings in AD 2000 represent 20 electric generating plants, each with a capacity of 1000 megawatts operating at 90 percent load factor. The pollution impacts are impressive: 390 million kilograms (430 thousand tons) of air emissions, 105 million kilograms (115 thousand tons) of water discharges, and 18 billion kilograms (20 million tons) of solid waste avoided; and 1 million curies in air and water discharge plus 670 million curies of solid waste not generated. Consumption of material resources in the manufacture of solar energy collectors is significant but not excessive.

ECONOMIC

The primary economic impact is the increased capital investment requirement it imposes on the cost of buildings. The development of a 10 billion dollar a year solar collector and component industry by AD 2000 would contribute to economic growth through construction of new factories, increased employment in manufacture and installation and an improved trade balance due to reduced dependence on fuel imports. The impact on conventional energy utilities resulting from decreased sales coupled with the necessity of serving a growing number of customers is difficult to quantify. The market penetration of SHACOB could have an effect on land values. Land with good southern exposure in high insolation regions would be enhanced in value.

UTILITIES

SHACOB systems are most effective in providing energy at the time of day when the electric utilities experience their peak load. The forecast of off loading of only two percent of the energy demand by AD 2000 indicates that on a national scale the impact will be relatively small.

POLICY AND LEGAL

Because of the long period which must elapse before SHACOB can make a significant impact on the U.S. energy picture, the eventual effect of SHACOB as a non-polluting source is its most important characteristic. The forcing function for SHACOB is environmental policy rather than energy policy. Solar energy will look more toward political mechanisms than toward market mechanisms. The technology will not be implemented primarily in response to "consumer sovereignty" but because it may be prescribed for use by government and in buildings that are in part federally financed. Federal laboratories such as the National Bureau of Standards will have an increased role in setting standards for SHACOB systems and Federal regulatory agencies will monitor conformity to their use.

Changes in law may be necessary to treat solar radiation as a common property resource. Legislative action to resolve questions of sun rights and the authority of local governments to engage in three dimensional zoning will be necessary.

SOCIAL

The newly emergent social ethic oriented toward quality of life rather than quantity of goods may become a fundamental tenet of society by AD 2000. Continued movement of the population to the South and Southwest will facilitate introduction of novel architectural forms adapted to use of SHACOB technology. The use of solar energy would tend to change the use of vegetation as an aid to interior comfort conditioning.

Achieving the projected potential for solar energy requires a number of early initiatives. Among the most important are a series of proof-of-concept experiments to assess true viability and acquire the data needed for further major commitments. These experiments should be emplaced in locations representative of the climate region of the United States. They should also cover a representative spectrum of building types and solar energy system concepts.

Final selection of the specifics of individual sites and systems must await the program implementation phase. A detailed analysis was made in the study, however, to establish criteria, determine locations (climate areas and building types), number and type of experiments, work flow schedules, and management structure.

The most important criteria in selection of specific experiments are:

- Representativeness of projected national energy consumption patterns and the degree to which the data can be generalized, considering both current and expected future designs.
- Ability to provide a substantial portion of the heating and/or cooling load (at least 30%).
- Ability to obtain performance, reliability, cost and operating data.
- Visibility of the installation to decision makers in such areas as architecture, building and equipment specification, building financing and public policy.
- Degree to which consuming public awareness of solar energy will be enhanced.

The first two criteria apply to selection of climate areas, building types and experiment category (heating, cooling, or both). The acquisition of the data to assess these factors was discussed in the sections on systems evaluation and capture potential. An analysis of those data led to the recommendation of 82 experiments as shown in Table 5.

Table 5. Proof-of-Concept Experiment Recommendations

82 experiments are recommended to assess viability and lay the basis for expanded commitments. They include heating and cooling in each climate area on those buildings having the largest impact on national energy consumption.

Symbols: H - Heating Only
C - Cooling Only
HC - Both Heating and Cooling

Building Type													
No.	Description	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Residential Single Family	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
2	Residential Multiple High Rise												
3	Residential Multiple Low Rise												
4	Hotel Motel High Rise												
5	Hotel Motel Low Rise							[illegible]					
6	Office Building High Rise												
7	Office Building Low Rise	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	Warehouse												
9	Industrial Light Process Load	[illegible]		[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			
10	Industrial Heavy Process Load												
[illegible]	[illegible]												
[illegible]	[illegible]												
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]				[illegible]	[illegible]		[illegible]
[illegible]	[illegible]												
[illegible]	[illegible]												
[illegible]	Retail Merchandise Mall												
[illegible]	Retail Individual Store												
[illegible]	Mobile Home												

An overlapping two-phase program was studied for implementing this recommendation. Under this plan all installations would be in place within 24 months of program initiation as shown in Figure 10. Site selections experiment designs and other activities preceding construction would be completed in 7 months for early experiments, and in 15 months for the entire array. In general, retrofit and heating-only experiments would be in the early group. New construction and cooling would follow. The construction periods would vary from a few months for some retrofit heating units to approximately a year for some new buildings.

Achieving maximum benefit from this program will require careful and skilled management. The report outlines a management plan based on prime contractor handling blocks of experiments, Figure 11, (28 was used as the basis) and utilizing the services of architect/engineers who, in turn, would employ general contractors.

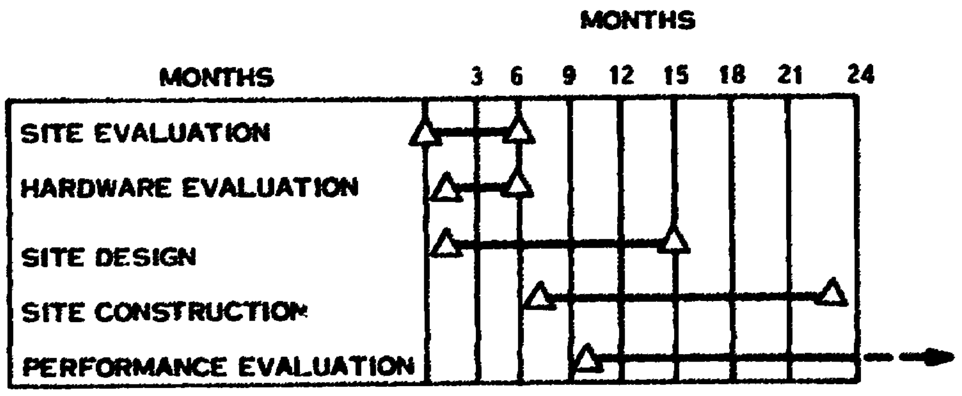

Figure 10. Program Schedule

The POCE installations can be completed in two years. Many of the experiments will yield valuable data much earlier.

In each case, the responsible building official ("landlord") would be involved during selection, installation and operation.

A program systems engineering and integration activity is necessary to assure consistency in data acquisition, analysis and interpretation.

Such a program, properly executed and evaluated, would be a springboard for the broader applications of solar energy.

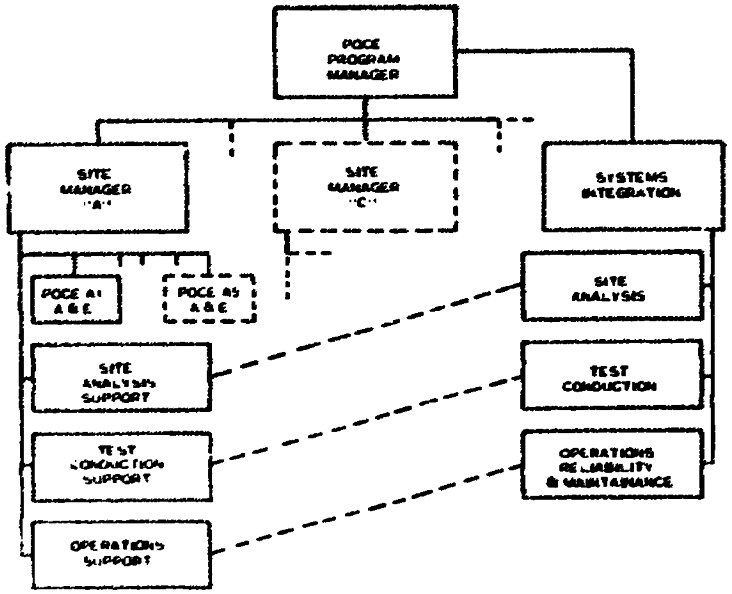

Figure 11. Program Orgcnization Model

Under NSF direction, a prime contractor would manage a block of proof-of-concept experiments, employing the services of architect/engineers and general contractors. This begins building a base of knowledgeable organizations in the solar energy field.

The purpose of these plans is to recommend an orderly route by which SHACOB can progress from its present status of component experiments and limited installations into widespread utilization. The study has indicated that technical feasibility and economic viability are both achievable, but not instantaneously nor easily. Because of a national need to conserve conventional energy sources, it is appropriate that the federal government provide for the seeding of SHACOB via installation in government buildings and sponsorship of related R&D programs.

A schedule of distinct steps to implement the utilization of solar heating and cooling is shown in Figure 12.

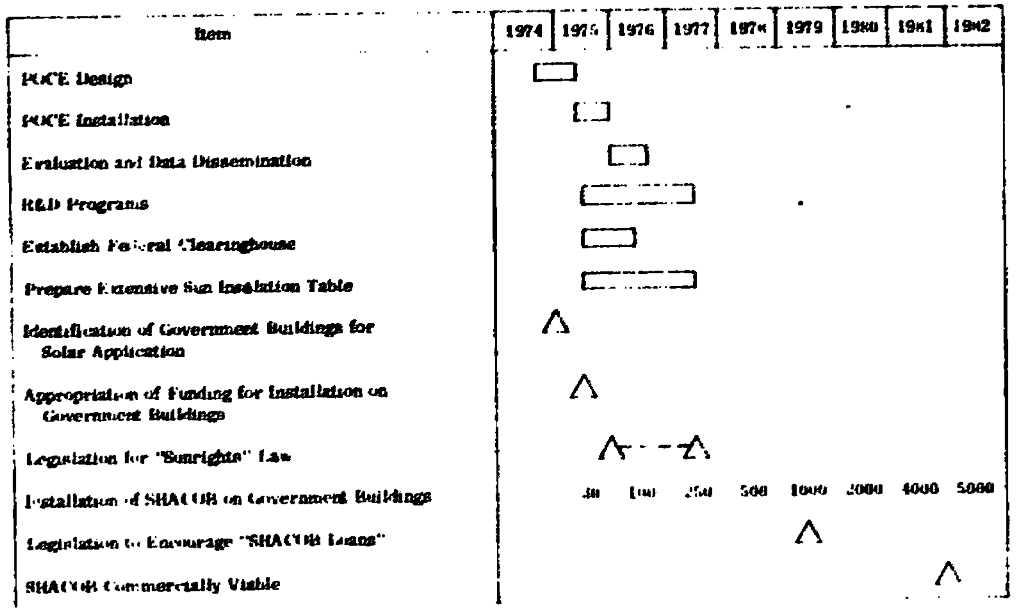

Figure 12. Preliminary Utilization Plan

Commencing with the Proof-of-Concept-Experiment, is the preparation of a time-phase communications plan. This plan is geared to disseminate information, at all stages of the project, to appropriate key actors in the selection of heating and cooling systems and to the general public. A federal clearinghouse for data on all aspects of solar heating and cooling should be established.

An important element is the opening of a real market for SHACOB equipment. This will encourage industry to perform the product engineering and to put into place the tooling, facilities, and people to fabricate, install, and maintain solar equipment. A commitment by the government to install solar equipment on a significant number of buildings over the next ten years could provide the basis for private sector installation in the 1980's. A suggested schedule of application through 1985 is shown in Table 6.

Table 6. Number of Buildings for Solar Installations

Year	No. of Gov. Bldgs.	Application	No. of Commercial Buildings
1975	30	POCE	
1976	100	POCE and Development	
1977	250	Development	
1978	500	↓	
1979	1,000		
1980	2,000		
1981	4,000		
1982	5,000	Market Support	1000
1983	8,000	↓	2000
1984	17,000		3000
1985	25,000		5000

The adoption of this type of program will help to insure the development of the reliable, cost-effective hardware so important to the widespread use of solar energy for heating and cooling.

- By the end of the century the projected capture potential for cost effective solar energy installations is approximately 40 million buildings. If all were solar equipped, the annual energy savings would exceed 1500 Billion Kilowatt-hours.

- Cost effective capture potential is dominated by new construction.

- Market penetration will be limited primarily by the development of the industrial base. With implementation of effective government policies, it will be established by the mid-eighties and grow rapidly thereafter reaching annual energy savings of the order of 150 Billion Kilowatt-hours by 2000. Its growth rate in that time period will yield a far greater impact by 2020.

- The realization of the projected market penetration by 2000 would
    - Reduce annual air emissions by over 430 thousand tons.
    - Avoid about 20 million tons of solid waste annually.
    - Reduce radioactive air and water discharge by over 1 million curies and solid waste by over 670 million curies.

- Introduction of cost effective solar air conditioning equipment would substantially increase the projected capture potential and market penetration in terms of energy savings.

- The most important government policies needed to stimulate solar heating and cooling are in the following areas:
    - Proof-of-concept experiment implementation.
    - Early introduction of solar systems on government buildings (new and retrofit).
    - Economic incentives to encourage a life-cycle approach to HVAC systems.
    - Legal safeguards and minimizing zoning restrictions.
    - Sponsorship of R& D for economic, reliable equipment - especially for cooling.

GENERAL ELECTRIC

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