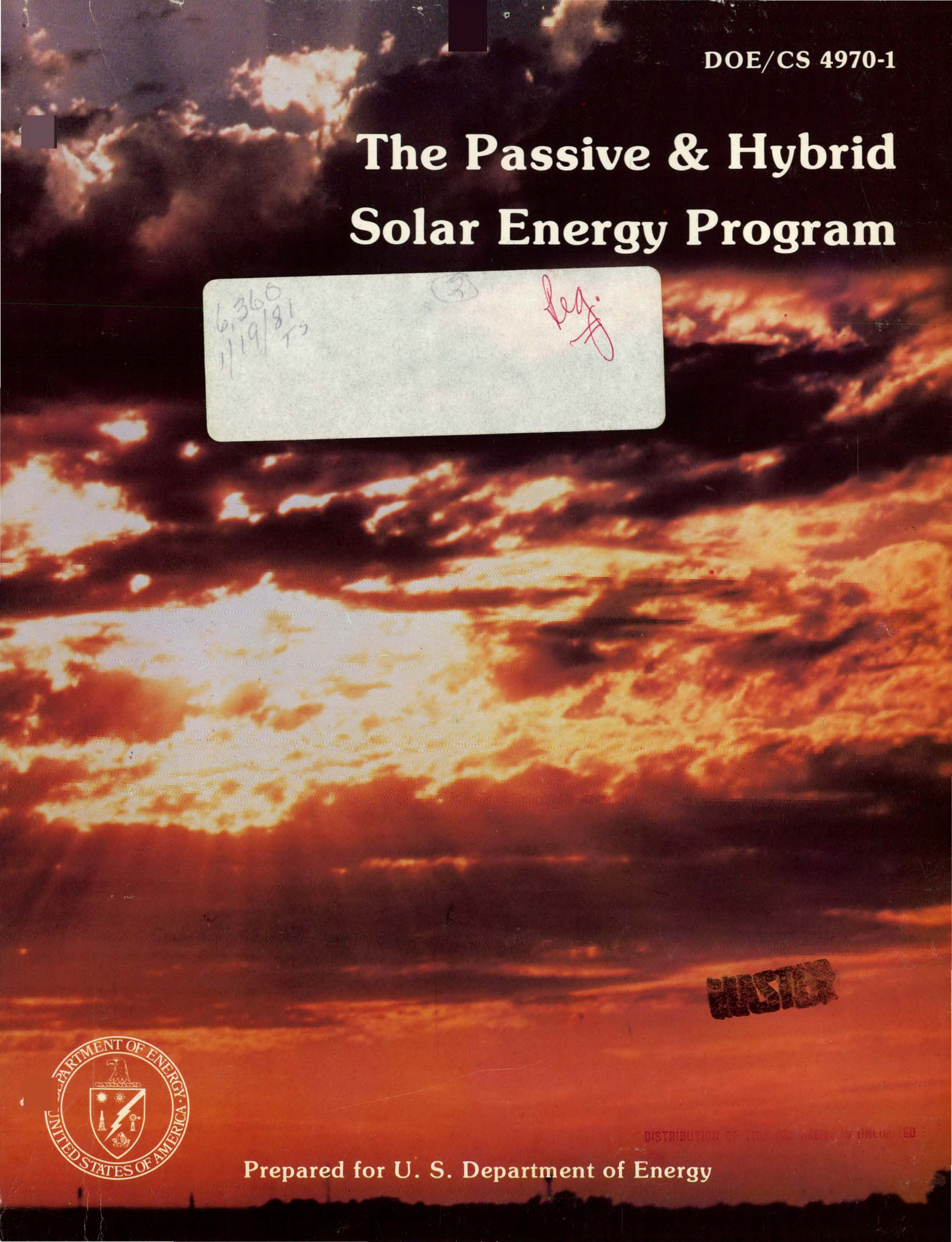

DOE/CS 4970-1

The Passive & Hybrid Solar Energy Program

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Prepared for U. S. Department of Energy

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DOE/CS-4970-1

THE PASSIVE AND HYBRID SOLAR ENERGY PROGRAM

November 1980

PREPARED FOR THE

U. S. DEPARTMENT OF ENERGY

OFFICE OF CONSERVATION AND

SOLAR ENERGY

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PREFACE

On October 26, 1974, the Solar Energy Research, Development, and Demonstration Act (Public Law 93-473) was signed into law, authorizing a vigorous Federal solar program whose goal was to assist industry in providing the nation with the solar option for meeting future energy requirements. In response to the mandates of this act, the Energy Research and Development Administration (ERDA), predecessor to the Department of Energy (DOE), conducted a number of programs to develop and introduce, at the earliest possible date, economically competitive and environmentally acceptable solar energy systems.

The Department of Energy has implemented both long and short term plans to accelerate the development and commercialization of solar technologies. This book is devoted to describing DOE's efforts in the area of passive and hybrid solar technology. It addresses the activities the United States is undertaking to spur a renaissance of solar energy as an alternative to the rapidly increasing costs of fossil fuels.

Chapter I presents the background and scope of the program in general terms. Chapter II is an abstract of the Program Plan describing how individual projects are categorized into mission-oriented tasks according to market sector categories. Chapter III is a primer on solar radiation physics. An acquaintance with basic terms and elementary concepts will foster a broader understanding of the complex management and organizational coordination demanded of project team members. The individual projects funded by DOE are presented in Chapters IV through VIII and are listed, respectively, under the following headings:

- Residential Buildings
- Commercial Buildings
- Solar Products
- Solar Cities and Towns
- Agricultural Buildings.

For easy reference, a summary list of projects by institution (contractors) and indexed by market application area is displayed in Appendix A.

CHAPTER I: INTRODUCTION

1. GENERAL BACKGROUND

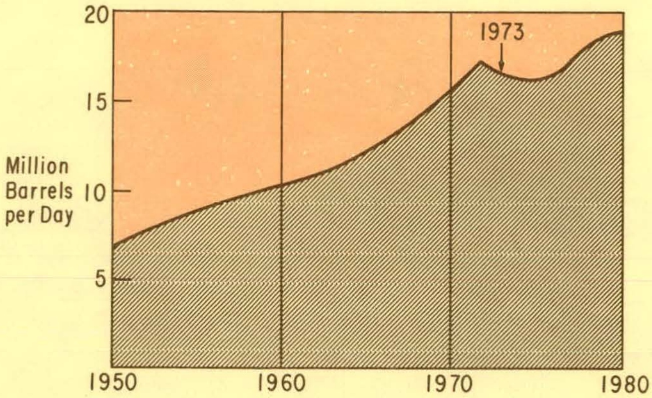
Application of solar energy is not a new idea. Solar energy has been converted for human needs for thousands of years. Egyptians started ritual fires with the sun's rays in 700 B.C. A Roman invasion fleet was reported destroyed in the harbor of Syracuse in 212 B.C. using solar-reflective mirrors. During the 18th century, Englishman Joseph Priestly and his French contemporary Antoine Lavoisier performed many experiments with sunlight. Lavoisier designed and operated a furnace that attained temperatures of 3200°F.

Thomas Jefferson made extensive use of passive solar techniques at his home (Monticello) near Charlottesville, Virginia, by using several design features that reduced summer temperatures. The walls of Monticello were thick and absorbed much of the sun's heat on hot days. Floor plans were designed to take advantage of any summer breezes. Skylights located above the stairways increased air circulation, cooled the interior of the mansion, and provided natural lighting.

Until the middle of the 19th century, the United States relied on wood, water, and wind for its energy needs. These resources were readily available, were renewable, and satisfied the minimum requirements of a relatively primitive state of technology. During the next century, the United States became the world's most advanced

Thomas Jefferson House, Monticello. Photo courtesy of Thomas Jefferson Memorial Foundation.

industrial nation. The standard of living rose considerably owing to the inexpensive use of readily available coal, oil, and gas. Although they were recognized as depletable fuels, there was no pressing national concern over their continued accessibility in the foreseeable future.



U. S. oil consumption

During the 1970's, the nation was made aware of the vulnerability of depletable resources and energy dependence on other countries by the following events:

- Oil embargo (1973–1974)
- Natural gas shortages (1976–1977)
- Nationwide coal strike (1977–1978)
- Loss of Iranian oil (1979).

Today, many economists believe that the growing fuel shortage and spiraling fuel costs are the primary contributors to the nation's current economic recession.

A promising partial solution to this energy problem is the use of solar energy. It is both renewable and in unlimited supply, as well as being free from foreign economic control. Solar conversion systems generate only small amounts of air and water pollution and negligible thermal pollution. In addition, the relative cost of solar energy should decrease as the industry matures, while other sources will experience increasing costs as resources are depleted. The challenge ahead is how to capitalize on this inexhaustible form of energy as quickly as possible.

2. DEVELOPMENT OF A NATIONAL PASSIVE SOLAR PROGRAM

In his Solar Energy Message submitted to Congress on 20 June 1979, the President called for a national commitment to the use of solar energy. The President stated: "I have set a national goal of achieving 20 percent of the Nation's energy from the sun and other renewable resources by the year 2000. To do this, we must commit ourselves to several major new initiatives which will hasten the introduction of solar technologies."

The Department of Energy, under the guidelines of the Solar Energy Research, Development, and Demonstration Act (PL 93-473), established the Passive and Hybrid Solar Energy Program to help promote and support solar technology in building applications. Other public laws also provide guidelines for solar energy planning and programs:

- PL 93-409 – Solar Heating and Cooling Demonstration Act of 1974
- PL 93-438 – Energy Reorganization Act of 1974
- PL 93-577 – Federal Nonnuclear Energy Research and Development Act of 1974
- PL 94-385 – Energy Conservation and Production Act of 1976; and
- PL 95-75 – Department of Energy Organization Act of 1977.

These laws are the basic authority for the Department of Energy (DOE) to engage in a wide range of activities with the objective of effective energy utilization through research, development, demonstration and commercialization projects.

The federal government was involved in solar research several years before the establishment of the Energy Research and Development Administration (ERDA) in January 1975. Then, solar efforts of the federal government were funded primarily through the National Science Foundation (NSF). Additional funding was channeled into solar activities by the Department of Housing and Urban Development (HUD) and the National Aeronautics and Space Administration (NASA). Passive solar recently received the special attention of the President's Domestic Policy Review on Solar Energy. The Domestic Policy Review concluded that passive solar systems can play a vital role in reducing our energy requirements.

The Passive and Hybrid Solar Energy Program of the Department of Energy is but one of a variety of major programs which have promising potential for meeting the President's national energy goal.

Passive solar energy refers to thermal energy flows by natural means, such as conduction, convection, radiation, and evaporation. This is in contrast to the term active solar, in which thermal energy flows through forced means, such as fans and pumps. A hybrid system combines aspects of both active and passive solar systems. A more complete description of passive solar is presented in Chapter III.

The goal of the Passive and Hybrid Solar Energy Program is the displacement of a substantial quantity of nonrenewable energy through the rapid development and widespread use of passive solar heating, hot water cooling, and daylighting systems. Achievement of the program goal would be characterized by an awareness and application of passive systems by designers and builders; an availability of materials, components, and assemblies appropriate for passive solar design; a conducive application environment including necessary codes and standards, informed lenders, insurers, and regulators; understanding of and demand for passive solar heating and cooling by the general public; a significant ongoing research and development capability within the private sector; and, most importantly, a large number of passive solar applications in the residential, commercial, and agricultural markets.

The Passive and Hybrid Solar Energy Program is designed to achieve this goal by supporting research, development, demonstration and commercialization aimed at developing cost-effective passive solar energy materials, components, assemblies, and systems; and by undertaking focused commercialization activities aimed at assuring the utilization of passive solar systems. The application of passive techniques is closely integrated with conservation technologies. Together, passive solar and conservation approaches can significantly reduce our energy requirements in buildings. With this in mind, the following program goals and objectives have been formulated:

- Displacement of 0.1 quad of energy by 1986, 1.5 quads by 2000
- Two million total residential installations by 1986
- Three hundred million square feet of passive commercial building construction in 5 years
- One billion dollars in annual sales of passive solar products by 1986
- Thirty percent cost reduction of installed passive systems by 1986.

As mentioned previously, passive solar technology is not complex. Although a great deal of work needs to be completed before realizing the full potential, many types of passive solar technology systems and products are available now. More significant cost and efficiency benefits will be apparent as newer products are developed and produced on a mass scale. The function of the federal government's participation is to engage in activities which will accelerate the development of the passive solar industry and the utilization of solar products by the general public to a point where passive solar technolgy is considered a common part of everyday life.

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CHAPTER II: PROGRAM PLAN

1. DOE SOLAR ORGANIZATION

The Passive and Hybrid Solar Energy Program is an essential segment of DOE's efforts to promote and support research, development, demonstration, and commercialization of solar energy as a national resource. The other solar technologies supported by DOE include the following:

- Active Solar Heating and Cooling
- Solar Thermal
- Photovoltaics
- Wind Energy Conversion
- Biomass
- Ocean Thermal Energy Conversion.

Each of these technologies have developed annual, multiyear, and long-range plans that have included timetables for achieving the total energy goal of 18.5 quads annually by 2000. Figure II-1 illustrates the management organization used to coordinate the multitude of passive solar activities and projects administrated by DOE.

2. PROGRAM ACTIVITIES

Multiyear plans for the accelerated development and commercialization of passive solar technology have been formulated by DOE, the National Laboratories, the Regional Solar Energy Centers, the building industry, and various public interest groups. These plans have been structured to provide the highest possible energy-saving impact in the following key market sectors:

- Residential Buildings
- Commercial Buildings
- Solar Energy Products
- Cities and Towns
- Agriculture.

Each of these plans has established goals and objectives for each market sector, and identifies the milestones to be achieved in attaining these goals and objectives. Further refinement in the planning process is contained in individual program

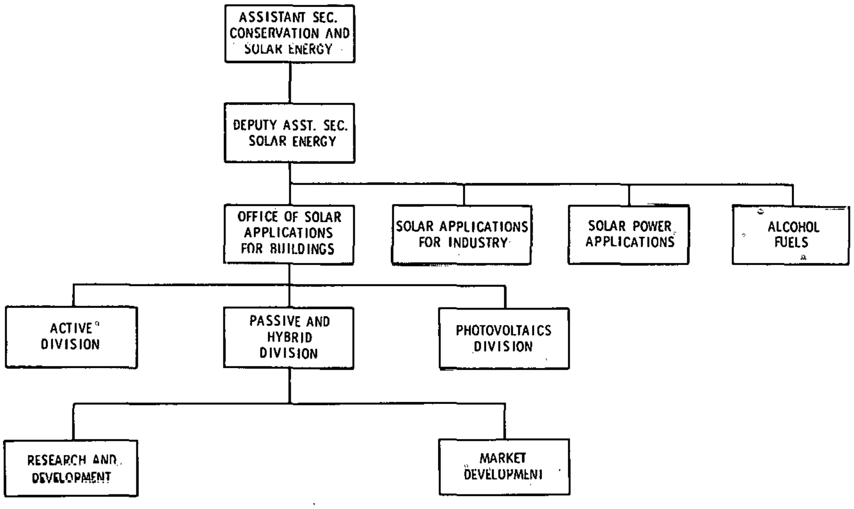


Fig. II.1. DOE Organization

area plans, created for specific program elements such as performance evaluation, design tool development, and communication.

The activities involved in the research, development, and commercialization of solar energy can be classified into the following six work categories:

- Basic and Applied Research
- Exploratory Development
- Technology Development
- Engineering Development
- Demonstration
- Commercialization.

These basically sequential work categories were established by the Project Planning and Budgeting System (PPBS) to provide overall program management within DOE. They provide a common framework through which program team members communicate and maintain current plans within the passive program and among the other solar programs at DOE. Figure II-2 presents the organizational matrix of work categories within the market application areas.

3. PROGRAM TEAM MEMBERS

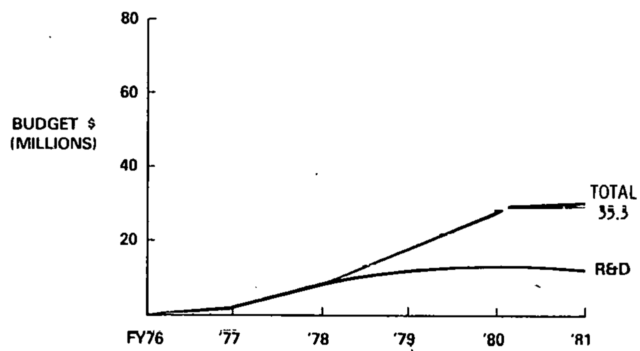
The individuals involved in the Passive and Hybrid Solar Energy Program come from both the public and governmental sectors. The numerous participants from the public sector include public and private companies, universities, and research institutions. Governmental participants include DOE headquarters, DOE Regional Operations Offices, National Laboratories, the Solar Energy Research Institute (SERI), Regional Solar Energy Centers (RSEC's), and other U. S. Government agencies.

Work being performed by nongovernmental participants is administrated and/or technically monitored by the government program participant whose in-house expertise is most clearly associated with that particular area of work. The following subsections describe the responsibilities assigned to the governmental participants.

(1) DOE/Headquarters

The overall management of the Passive and Hybrid Solar Energy Program, in addition to other solar-related programs, rests with the Department's Assistant Secretary in the Office of Conservation and Solar Energy Applications. This office is responsible for funding industry and government efforts, program planning in conjunction with the other program members, interagency agreements, and overall guidance to keep the program moving toward its designated objectives. The Passive and Hybrid Solar Energy Division is responsible for

PASSIVE SOLAR PROGRAM BUDGET



SOLAR PRODUCTS
SOLAR CITIES AND TOWNS
AGRICULTURAL BUILDINGS
COMMERCIAL BUILDINGS
RESIDENTIAL BUILDINGS

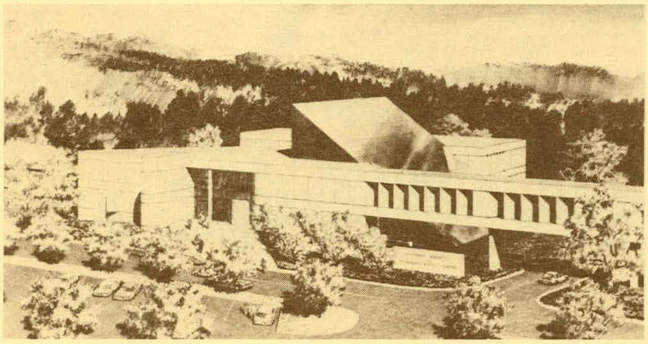
BASIC AND APPLIED RESEARCH	EXPLORATORY DEVELOPMENT	TECHNOLOGY DEVELOPMENT	ENGINEERING DEVELOPMENT	DEMONSTRATION	COMMERCIALIZATION
BASIC PHYSICAL STUDIES MATERIALS RESEARCH	CONCEPT GENERATION SYSTEM SPECIFICATION SYSTEM SIMULATION	PERFORMANCE DATA ACQUISITION SYSTEMS ANALYSIS	DESIGN DEVELOPMENT PROTOTYPE TEST FIELD TEST DECISION TOOL DEVELOPMENT	PILOT PROJECTS	MARKETING, TRAINING EDUCATION AND INFORMATION INSTITUTIONAL REGULATORY EVALUATION

Fig. II.2. Organizational Matrix of Work Categories Within Market Application Areas planning and management of the program. The Division is composed of two branches: Research and Development and Market Development.

(2) DOE Regional Operations Offices

DOE's Regional Operations Offices, located in Chicago and San Francisco, are the sources of financial and administrative support for the work being performed by both government facilities and private companies. The operations offices were established to decentralize the management function of DOE to local geographic areas to permit greater control of the individual elements of the Passive and Hybrid Solar Energy Program.

The Chicago Office provides management of and funding and procurement services to SERI, the



LASL Building

RSEC's, certain National Laboratories, and several programs and projects involving private industry. San Francisco manages the Lawrence Berkeley Laboratory and offers support for passive cooling work to the public sector.

(3) National Laboratories

The national laboratories most heavily involved in the Passive and Hybrid Solar Energy Program are the Lawrence Berkeley Laboratory (LBL) and the Los Alamos Scientific Laboratory (LASL).

LBL's Energy and Environment Division carries out a broad program of applied research and development in energy supply and conservation technologies to determine ways of increasing the efficiency and reliability of energy production systems, while reducing their environmental impact. The division's existing capabilities in the fields of energy and environmental policy analysis and energy conservation provide a strong base of support for this program.

Solar energy is a renewable resource that holds promise for providing new energy sources that are environmentally acceptable. Scientists in this group investigate advanced approaches to solar energy conversion; they also develop analysis techniques and obtain information necessary for the future use of solar energy.

Members of this Division have helped DOE and the Solar Energy Research Institute develop the National Passive Solar Program plan. They also provide technical assistance to DOE on solar heating and cooling, including monitoring work at other institutions.

Los Alamos Scientific Laboratory was the first national laboratory to research and develop solar energy applications for the heating and cooling of buildings. The program began in 1973 when a small development project for structurally integrated solar collectors was funded by the National Science Foundation.

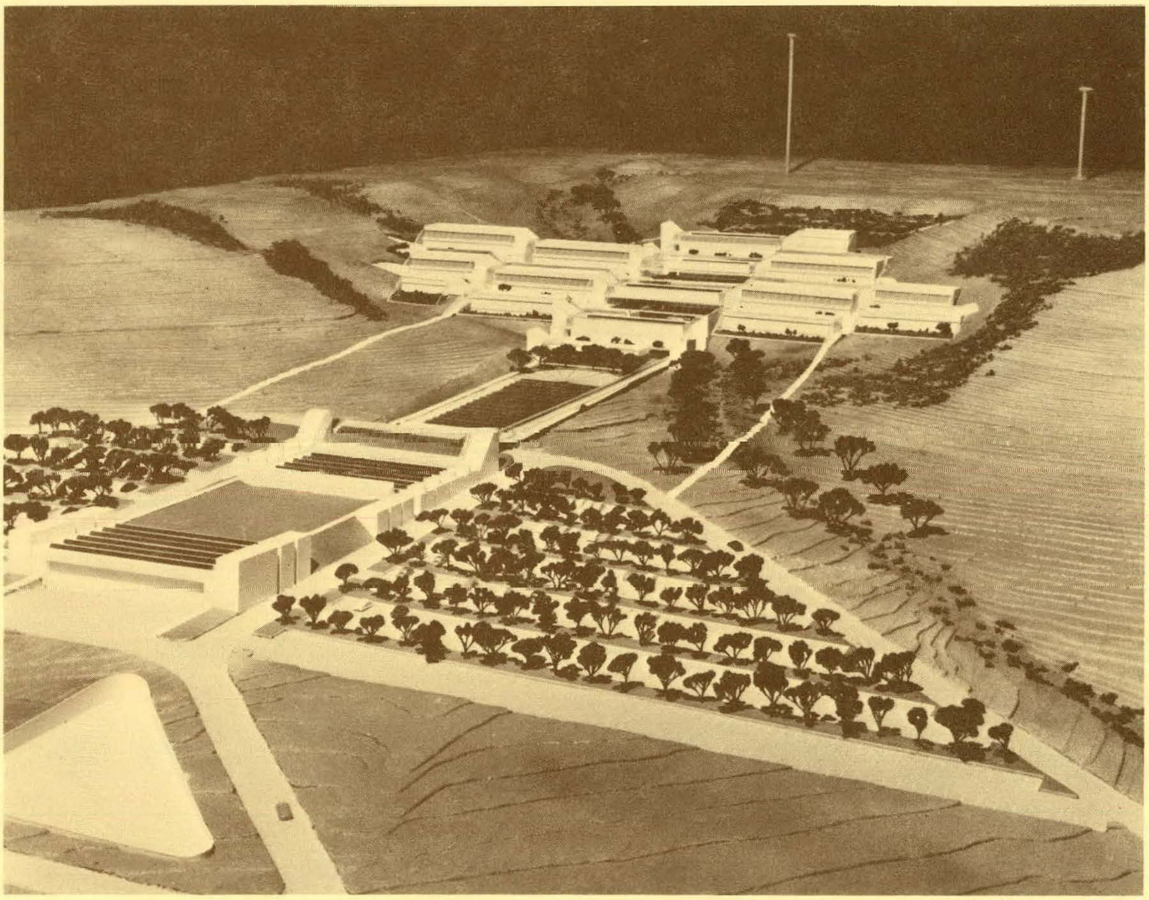
Between 1973 and 1976, the research led to a more comprehensive program which currently includes six program areas funded by the Department of Energy which best exemplify the research efforts: (1) Technical Support to DOE, (2) Solar Collector and Materials Research, (3) Passive Solar Systems Studies, (4) Mobile/Modular Homes, (5) The National Security and Resources Study Center, and (6) The Nambe Community Center.

Other laboratories participating in the program include:

- Ames Laboratory
- Argonne National Laboratory
- Brookhaven National Laboratory
- Idaho National Laboratory
- National Bureau of Standards
- Oak Ridge National Laboratory.

(4) The Solar Energy Research Institute

The formation of SERI was authorized by Congress in 1974 to provide the nation with a center to serve the needs of the public and industry in the development of solar energy. SERI is managed and operated by the Midwest Research Institute, a not-for-profit research organization. Operations at SERI began in July 1977 in interim



Proposed SERI Facility

administrative and laboratory facilities in Golden, Colorado. Plans call for operations to continue in these facilities concurrent with the design and construction of the permanent facilities. SERI presently supports the development of solar energy technologies to the point where they are capable of making meaningful, reliable contributions to the nation's energy supply when required.

SERI's primary missions are to:

- perform research, development, and demonstration activities to ensure the timely development of solar technologies that are economical, reliable, environmentally acceptable, socially attractive, and effectively matched with the nation's end-use requirements

- develop and disseminate materials by establishing a Solar Energy Information Data Bank (SEIDB) to educate consumers about solar applications

- communicate with business and professional communities to explain state-of-the-art solar technologies, discuss solar-related public policies and programs, and provide other assistance needed to promote a mature solar industry

- assist federal agencies to formulate and implement national and international programs to encourage efficient energy use and to foster the solar transition.

(5) Regional Solar Energy Centers

In March 1978, DOE authorized the establishment of four Regional Solar Energy Centers (RSEC's). Their primary responsibilities include the commercialization of solar technologies and promotion of conservation activities related to solar applications that are consistent with national energy goals. These functions are complementary to the work of SERI and the National Laboratories whose responsibilities include research and development up to the point of commercialization.

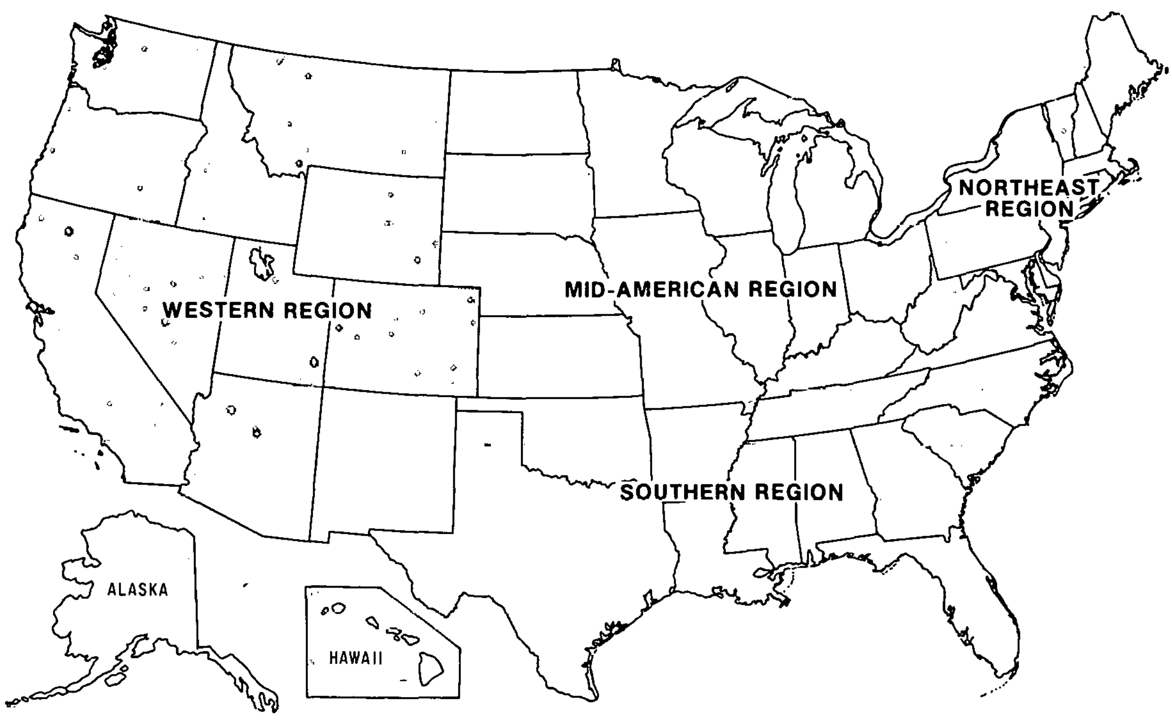
The managerial role of the RSEC's includes the following responsibilities:

- *Regional coordination* – The RSEC's enlist involvement of regional organizations such as state and local governments, educational institutions, consumer groups, industry associations, and labor unions. Their function is to communicate information on DOE policy, national programs, and solar technical and commercialization efforts.
- *Market development* – Each RSEC has established an outreach program (i.e., education, training, and technical assistance) for enterprises engaged in the designing, building, installing, financing, buying, selling, and maintaining of solar systems.
- *Education liaison* – Contact has been made by the RSEC's at all educational levels, from the elementary and secondary schools through the colleges and universities. Academic institutions have been encouraged to include solar energy courses in their curricula.
- *Training* – Basic skills are needed to support solar system manufacturing, installation, and maintenance before the solar energy industry can mature. The RSEC's are coordinating and assisting labor organizations, vocational institutions, and others interested in solar skills development.
- *Information services* – A comprehensive information program has been instituted by each RSEC. Data are collected, analyzed, and disseminated for regional use in planning and promoting solar commercialization.
- *Institutional activities* – Critical to the widespread use of passive solar applications is the establishment (or modification) of codes, standards, and safety criteria. Each RSEC is engaged in activites to obtain these necessary jurisdictions.

The four RSEC's are listed below:

- Mid-American Solar Energy Complex
- Western Solar Utilization Network
- Southern Solar Energy Center
- Northeast Solar Energy Center.

All centers are not for profit organizations. A more detailed description of each RSEC follows.



GEOGRAPHIC RESPONSIBILITIES OF THE REGIONAL SOLAR ENERGY CENTERS

Mid-American Solar Energy Complex

The Mid-American Solar Energy Complex (MASEC) is responsible for a 12-state area that includes Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. State solar offices have been established in each state to assist in commercializing solar energy products and systems.

As part of MASEC's overall commercialization strategy, the following goals have been established:

- Forty percent of all new housing designed after 1985 according to MASEC Solar 80 criteria will consume 80 percent less energy than typical current standards. Goals for 1990 and 1995 are 70 and 80 percent, respectively.
- A 100 percent net energy independence in regional farming operations by 2000.
- A 10 percent reduction of fossil fuels used in ground transportation by 2000.
- A 50 percent reduction in fossil fuels used in industrial processes with temperatures below 350°F by 2000.

Supporting these broad goals are numerous programs that should lead to their accomplishment. These programs are responsible for establishing the passive solar infrastructure, supporting construction projects that could provide the energy savings impact, and conducting additional programs to educate the general public.

Western Solar Utilization Network

The Western Solar Utilization Network (Western SUN), located in Portland Oregon, is responsible for 12 states: Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

Western SUN, acting in coordination with other federal, state, and local groups, is the lead agency for DOE in commercialization efforts in renewable energy technologies in the western states. It is Western SUN's aim to work with each state until the state's own efforts in commercialization of renewable energy technologies are sufficient to reduce the necessity for significant federal intervention. These state efforts will be expected to be consistent with national renewable energy policies and goals.

To expedite the use of solar technologies, Western SUN's solar programs will be designed to create widespread awareness of solar energy and to provide decision makers with pertinent technical assistance. This will involve identifying programs that have particular regional importance and that people in this region are capable of carrying out.

Major criteria applied to Western SUN's programs include the following:

- Potential for increased private sector use of both solar energy and conservation-related applications as alternative energy forms.
- Regional applicability and transferability of project results.
- Potential for enhancing local control of the production and pricing of energy.
- Potential for increased energy production savings.
- Ability to reach key target audiences such as builders, planning and code officials, and the financial community.

Southern Solar Energy Center

The Southern Solar Energy Center (SSEC) was organized in April 1979, with headquarters in Atlanta, Georgia. The center is responsible for 19 states: Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, Virgin Islands, Virginia, Washington, D.C., and West Virgnia.

SSEC's commercialization strategy is structured to respond to the unique climatic, institutional, and economic characteristics of the southern region. Part of this strategy is reflected in SSEC's providing technical and nonfinancial support to project teams that design and build passive solar structures. Maximum emphasis is placed on the development of exemplary projects to verify the viability of passive solar technology to the general public in the southern region.

Some short-term target accomplishments of SSEC include the following:

- *New construction* — Generate up to 20 locally adapted passive residential designs for 10 specific southern climates through the use of locally assembled "design teams and builders" for single-family, detached, multifamily, and manufactured housing.

- *Retrofit* — Initiate incentive-based, technically supervised passive retrofit tasks to reach at least 50 existing residential structures.

- *Codes* — Maintain close contact with the region's code-enforcing bodies, encourage the adoption of prosolar regulations, and disseminate current information on building codes and their interpretation for both residential and commercial market sectors.

- *Passive design coordination* — Provide methods and incentives to improve the working relationship between the building community and solar-design professionals.

- *Information* — Offer parallel information activities and technical guidance for home buyers, building professionals, educators, and others associated with the building industry.

Northeast Solar Energy Center

The Northeast Solar Energy Center (NESEC) was formed in 1977 to foster the widespread commercialization of solar energy. The Northern Energy Corporation is under contract to DOE to operate NESEC. The NESEC region consists of nine states: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The District of Columbia has joined NESEC as an observer/participant.

The nine member states participate directly with NESEC in three ways:

- To work directly with NESEC in planning activities and solar project work;
- To serve on the Regional Advisory Council; and
- To serve on the Board of Trustees of the Northern Energy Corporation.

Although the Northeast Region encompasses only five percent of the total land area of the United States, it has approximately 25 percent of the total population. The Region is rich in resources (both natural and institutional), which are capable of advancing solar energy usage.

The principal mission objectives of NESEC are:

- To reduce regional dependence on oil, especially foreign oil, and gas;

- To increase the use of the Region's natural resources for energy needs, including biomass from forests, farms, wind, and ocean energy;

- To engage the institutional resources of the Region (governmental, intellectual, financial, and industrial) in the solution to energy problems;

- To develop incentive for eliminating barriers to solar energy applications;

- To achieve early, widespread use of solar hot-water heating in the Region;

- To assist in development of solar space heating or hybrid solar systems;

- To identify industrial and agricultural activities, especially for process heat, in which energy efficiency can be enhanced with solar energy; and,

- To achieve continued, widespread implementation of emerging solar technologies as they become economically feasible.

The Northeast Center is an innovative institution, seeking new ideas and imaginative approaches for accelerating the commercialization of solar energy. All projects are outreach in nature, designed to provide the public, as well as professional and technical groups, with comprehensive information. In addition, projects which address the acceleration of commercialization, including market research and technical assistance; solar and conservation alternatives for urban, multifamily and low-income housing; and installation and maintenance training are being undertaken by NESEC.

Other U. S. Government Agencies

- National Bureau of Standards (NBS) — NBS is responsible for establishing testing and rating procedures and standards for components, products, and systems. Their work also involves working with legislative groups to effect necessary changes in codes and standards.

- U. S. Department of Agriculture (USDA) – The role of USDA in the passive program involves engineering development on grain drying, shelter heating, and greenhouses. A joint DOE/USDA solicitation for field testing of hybrid system designs is in progress.

- U. S. Department of Housing and Urban Development (HUD) – HUD has conducted passive design competitions supported by DOE, as well as being involved in other program elements. Since 1975, HUD has managed the Residential Solar Demonstration Program. Since 1976, it has operated the National Solar Heating and Cooling Information Center. In addition, HUD is responsible for the Solar Energy and Energy Conservation Bank.

CHAPTER III: PASSIVE SYSTEM DESCRIPTIONS

A passive solar building is designed to maximize use of the environmental resource while minimizing consumption of the conventional fuels used for heating, cooling, daylighting, and energy distribution/management. This is generally accomplished by the architectural elements and features of the building through the purposeful collection (dissipation), storage, and distribution of energies available at the site. The passive solar components are not easily distinguishable from the remainder of the structure since they serve multiple functions. This section defines passive systems and differentiates active, passive, and hybrid systems for heating, cooling, and domestic hot-water applications.

General Definitions

The most widely accepted definition of a passive system is one in which the thermal energy flow is by natural means (involving conduction, convection, radiation, and evaporation).

An active system is one in which all the thermal energy flow is by forced means (involving fans or pumps).

A hybrid system is one incorporating a major passive aspect, where at least one of the significant thermal energy flows is by natural means and at least one is by forced means.

The distinction being made is based on the driving influence causing the energy flow, and not on the degree of regulation. The term "natural energy flow" is not synonymous with "unregulated energy flow." Natural energy flow can, in fact, be highly regulated by mechanically-actuated controls, such as dampers or moving insulation. The important point is that the flow motivation derives from nonmechanical sources.

Most passive heating systems contain the five basic elements listed below. Passive cooling systems use an environmental sink in addition to or in place of these elements to receive dissipated heat energy.

- *Solar Collection Area* – The term "solar collection area" means an expanse of transparent or translucent material that is located on that side of the structure which faces south.
- *Absorber* – The term "absorber" means a hard surface that is exposed to the rays of the sun admitted through a solar collection area, converts solar radiation into heat, and transfers heat to a storage mass.
- *Storage Mass* – The term "storage mass" means a dense, heavy material that receives and holds heat from an absorber and later releases the heat to the interior of the structure, is of sufficient volume, depth, and thermal energy capacity to store and deliver adequate amounts of solar heat for the structure in which it is incorporated, is located so that it is capable of distributing the stored heat directly to the habitable areas of the structure through a heat distribution method, and has an area of directly irradiated material equal to or greater than the solar collection area.
- *Heat Distribution Method* – The term "heat distribution method" means the release of radiant heat from a storage mass within the habitable areas of the structure, or convective heating from a storage mass through airflow paths provided by openings or by ducts (with or without the assistance of a fan or pump generally having a horsepower rating of less than 1 horsepower) in the storage mass, to habitable areas of structure.

- *Heat Regulation Device* – The term "heat regulation device" means shading or venting mechanisms to control the amount of solar heat admitted through solar collection areas; and nighttime insulation or its equivalent to control the amount of heat permitted to escape from the interior of a structure.

Beyond the general definitions of passive solar heating, cooling, and daylighting are a number of significant factors that influence the performance of passive solar systems and begin to characterize generic types of systems.

Space Heating

There are two particularly important factors which must be accounted for in any scheme for characterizing passive heating systems:

- The characteristics of the collection aperture:
  - orientation with respect to south and vertical;
  - location relative to the rest of the building structure.
- The method of delivering energy to the conditioned space:
  - the energy mechanism(s);
  - inherent degree of thermal control.

Collection Aperture Characteristics

In the temperature zones of the earth's northern hemisphere, the winter sun rises south of east and remains generally low in the southern sky until it sets south of west. In contrast, the summer sun rises north of east and soars to high altitude angles before setting north of west. Consequently, south-facing vertical glazing accepts direct-beam winter sun at favorable angles of incidence throughout the day. On the other hand, south-facing vertical glazing is not exposed to direct beam summer sun during a substantial portion of the day, and during those hours that exposure does occur, the angle of incidence is unfavorable to penetration. Furthermore, modest overhangs can completely eliminate all exposure to direct-beam summer sun. In this sense, south-facing vertical glazing may represent the "ultimate passive technique." Within the building's environment, the sun's motion is used to "counteract the seasons" which that motion has generated. The sun's motion is the major control of the building's thermal environment.

Going to the opposite extreme, horizontal glazing receives modest amounts of direct-beam winter sun, generally at unfavorable angles of incidence, and is subjected to severe direct-beam summer sun, generally at angles corresponding to high glazing transmissivity.

By itself, horizontal glazing responds to the sun's motion in a manner which amplifies the seasonal temperature variation. Obviously, some special method must be used to regulate the flow of energy through the aperture (e.g., movable insulation). Such systems will be more complicated than those employing simple south-facing vertical glazing, but the added complexity may be justified in terms of greater system control or cooling benefits.

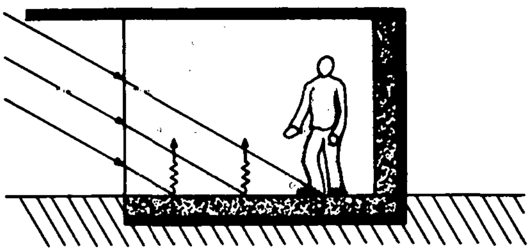
Also of importance is the location of the aperture relative to the rest of the building structure. In the common passive solar heating systems, the three possible locations are the south wall, the roof, and somewhere remote from the building envelope proper. South wall heating systems have the advantages of simplicity and economy. Roof heating systems work well in situations where land constraints limit south wall exposure or restrict proper orientation of the building. They also have the advantage of treating all zones equally. Remotely located apertures are preferred when very fine thermal regulation is stipulated. They also provide additional collection area to supplement energy collected through the building envelope proper.

Energy Delivery Method

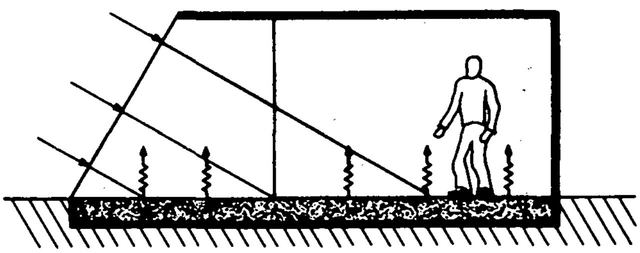
The manner in which energy is delivered to the conditioned space has a profound impact on the degree of thermal uniformity which can be imposed. Selection of the most cost-effective system for any application is strongly influenced by the severity of the thermal requirements.

There are three broad categories of passive solar heating systems based on the energy delivery to the space:

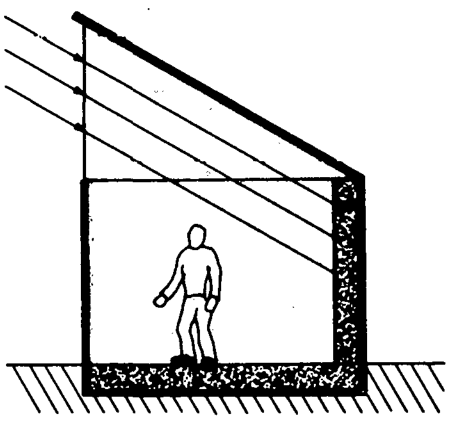
- For direct heating, solar radiation is admitted directly to the space, where it is converted to heat by absorption on the interior surfaces and contents of the space (people, furnishings, plants, etc.). The contents or surfaces of the space must be exposed to solar radiation in order for the system to collect energy. The air temperature in the space "floats" with the absorbing surfaces and/or the storage.



Direct-Gain Wall

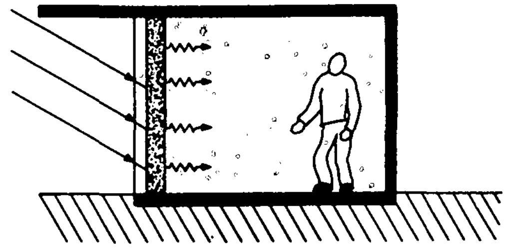


Direct-Gain Wall with Sun Space

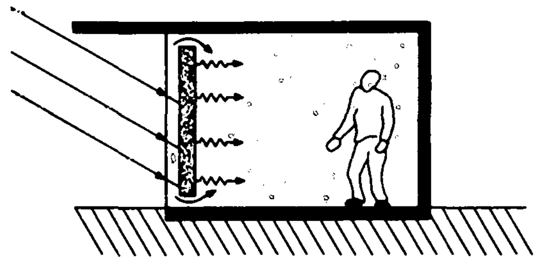


Shaded Direct-Gain Roof (Clerestory)

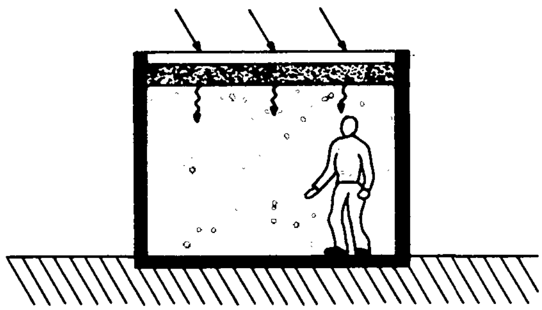
- For indirect heating, solar radiation is converted to heat by absorption on a surface external to the space. Contents of the space are not exposed to direct solar radiation. The air temperature in the space "floats with the absorber and/or the storage.



Storage Wall

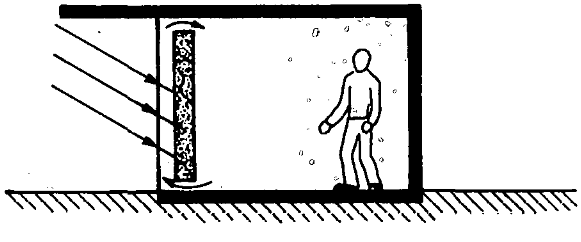


Storage Wall with Vents (Trombe Wall)

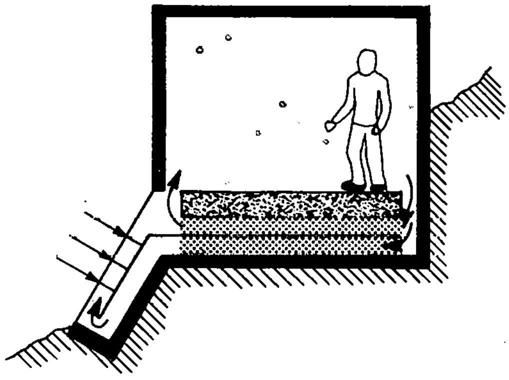


Storage Roof

- For isolated heating, solar radiation is converted to heat by absorption on a surface external to the space. Contents of the space are not exposed to direct solar radiation. The air temperature in the space can be regulated independently of the absorber and storage.



Wall Collection (Convective Space Heater)



Remote Collection with Isolated Storage Floor

The choice of a direct, indirect, or isolated system is strongly influenced by the desired degree of thermal uniformity or control. Where very fine thermal regulation is stipulated, isolated systems will generally be preferred. Isolated heating systems can be completely passive, but in terms of control over the thermal environment, they resemble active systems; that is, the system interaction with the space can be fully regulated and turned "on" and "off." If sizable thermal fluctuation can be tolerated and minimum auxiliary energy use is desired, direct gain or indirect gain systems will generally be preferred.

Combinations of the three systems are of considerable importance. For example, direct gain openings can be placed in a storage wall or an isolated storage wall. The openings can be sized to account for daytime winter heating requirements and for year-round illumination. Another example of combined direct and indirect heating is the use of clear or translucent water storage containers placed in the aperture. Some light is absorbed and stored in the water and some light is transmitted into the space to heat and illuminate.

Space Cooling

Passive cooling involves the discharge of energy by selective coupling of the system to the cooler parts of the environment. If the environmental conditions are correct, this energy flow will occur by natural means. Possible environmental sinks for heat from the system are the sky, atmosphere, ground, and water.

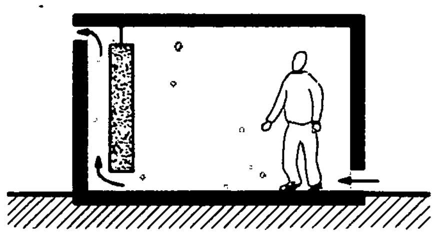
In sky cooling, radiation from the system passes through the atmosphere and dissipates into outer space. Environmentally, it is the "purest" mode of cooling, since none of the energy discharged from the system appears in the local microclimate. Radiative sky cooling works well in environments with clear skies, and has the potential to cool the system below the ambient air temperature. The primary limit to this cooling mechanism is convective and radiative heat gain from the surrounding atmosphere.

Energy from the system can also be discharged directly to the atmosphere during those times when the ambient air conditions are favorable to such an exchange. Heat can be dissipated by raising the sensible heat energy of the surrounding air (e.g., night air cooling) or by raising its latent heat energy (e.g., evaporative cooling). In either case, the energy transfer can be greatly enhanced by increased air movement. The driving force for this movement can come from wind, fans, or special convective drive mechanisms. In dry environments, evaporative cooling has the potential, like radiative sky cooling, to reduce the system temperature below the ambient air temperature. Evaporative cooling has the disadvantage of expending water, a commodity which may be in short supply in the climates where evaporative cooling is most effective.

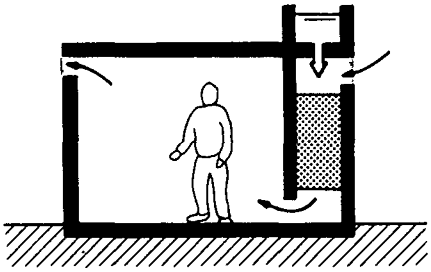
Because of the great thermal mass of the earth, ground and water temperatures during the summer will normally be several degrees below the average ambient air temperature. Unlike evaporative or radiative sky cooling, which require climatic conditions such as dry air or clear skies, ground and water cooling can be used to displace a substantial fraction of the normal cooling load, even in humid, overcast environments. However, dehumidification by mechanical means may still be required.

In analogy to heating systems, there are direct, indirect, and isolated cooling processes:

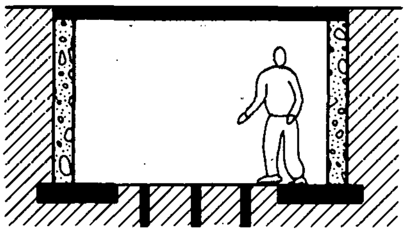
- Direct cooling occurs when the interior surfaces and contents of the space are exposed directly to the environmental energy sink(s).



Solar Driven Ventilation

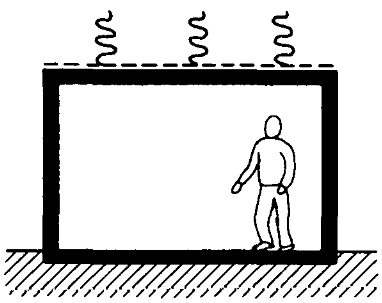


Evaporatively-Cooled Ventilation (Driven by Catabatic Convection)

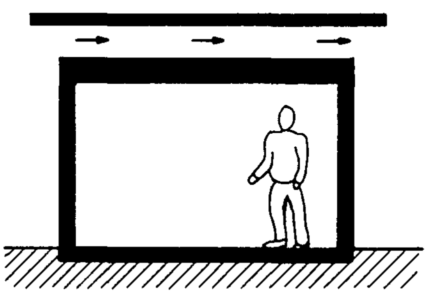


Direct Ground Cooling

- Indirect cooling occurs when the space is cooled by uncontrolled radiation to storage (or some exchange surface) which is in turn cooled by exposure to the environmental energy sink(s).

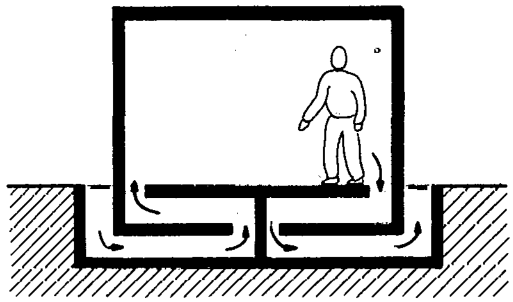


Storage Roof (Night-Sky Radiation)

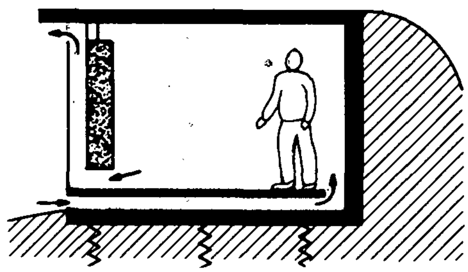


Flat Shaded Storage Roof (Wind-Augmented Evaporation)

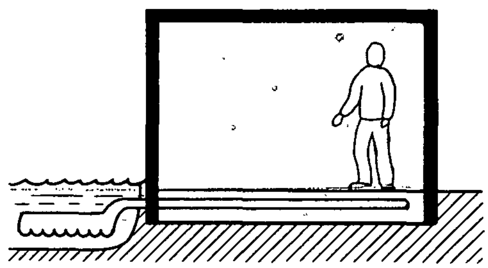
- Isolated cooling occurs when the space is cooled by controlled fluid or radiative transfer to storage (or some exchange surface) which is in turn cooled by exposure to the environmental energy sink(s).



Regenerative Air-Charge Storage



Ground Cooling (Via Heat Exchanger)



Water Cooling (Via Heat Exchanger)

Daylighting

As the building size increases from residential to commercial scale, the energy required for lighting (along with increased cooling load due to the lighting) can comprise a significant, 30 percent or more, fraction of the building's total energy use. The DOE Passive Commercial Building Program has shown that daylighting, combined with passive heating and/or cooling schemes, can cause enough of a reduction in building energy use to make the overall passive system economically attractive. To be effective, daylighting techniques such as clerestories or light shelves must operate to provide a good distribution of light without causing glare, and should operate in harmony with the passive heating and/or cooling schemes. A physical scale model of the building is generally needed to fully analyze the results of the daylighting design.

The above discussions of heating, cooling, and daylighting techniques have been oriented to "skin dominated," residential scale buildings, as opposed to "load dominated" commercial structures. The term "skin dominated" refers to buildings where energy flows are governed by the interaction between the skin (or exterior walls) of the building and the outside environment. "Load dominated" buildings have their energy flows dominated by internal heat gains caused by factors such as lights, occupants, and equipment.

Initial work has been performed on applying passive solar concepts to larger scale commercial buildings with substantial internal energy loads. This work has shown that passive solar design of commercial buildings requires major extrapolation of known solar design techniques – not simply a matter of applying residential solutions to larger buildings.

Much work needs to be done to more fully understand how load dominated buildings really work. For example, daylighting strategies can profoundly affect a building's heating and cooling loads. Another example is that the mechanical system in a commercial building is typically much more complex than for residences and itself affects the operation and effectiveness of passive solar strategies. The DOE Passive Solar Commercial Buildings Projects discussed in Chapter V are intended to aid in developing a deeper understanding of these issues through analysis and examination of results from actual buildings.

CHAPTER IV: RESIDENTIAL BUILDINGS

The projects presented in this chapter pertain to efforts underway to accelerate application of passive solar concepts to residential buildings. The types of activities include research of solar physics, application of these principles to solar design and construction, demonstration of solar buildings, and the commercialization of developed knowledge and systems.

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PROJECT TITLE: **DIRECT GAIN OPTICAL STUDY**

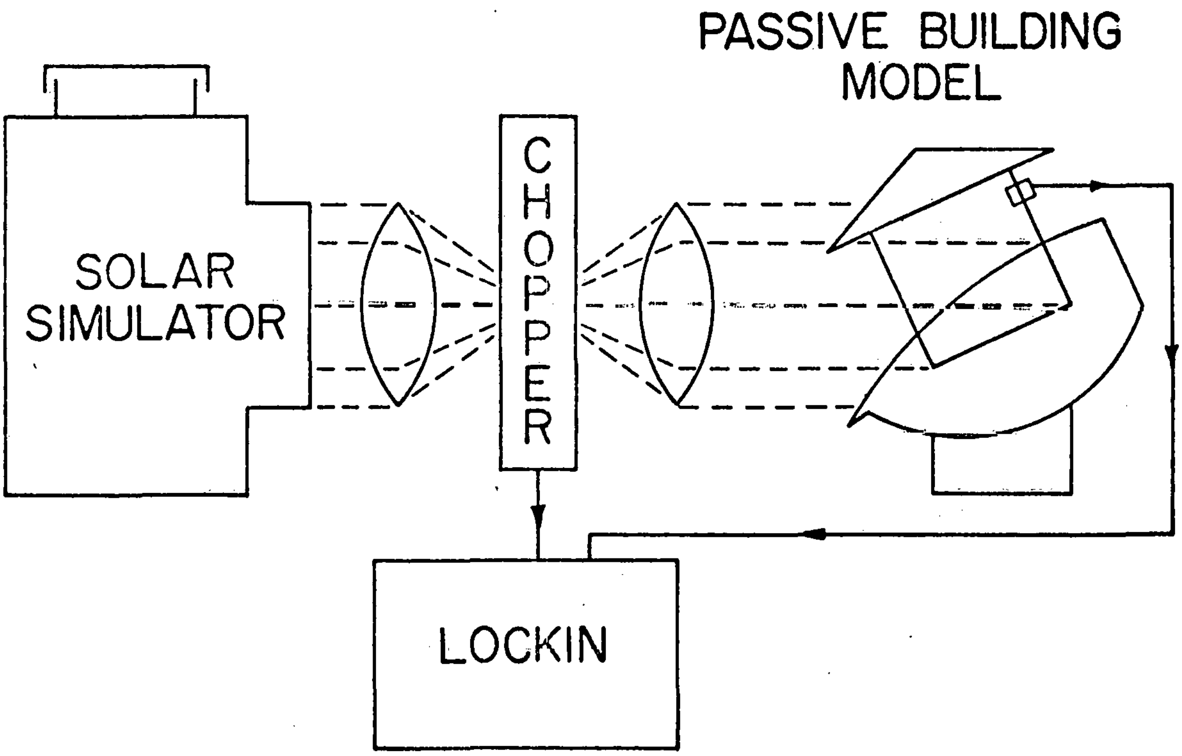
Institution: *Ames Laboratory*
Ames, Iowa

Principal Investigator: *John McClelland*

Task Number: *In-house*

This study is planned to explore the optical aspects of passive solar collection from both a materials and system (direct gain interior) point of view. This involves both development of measurement techniques and acquisition of a data base to characterize solar collection as a function of different important variables. These include design factors such as floor plans and interior colors, enhancement strategies using reflectors, and various insolation conditions. Other areas of interest include selective surfaces for glazing and absorbers and their associated degradation mechanisms, and identification of interior solar thermalization zones to aid in sizing thermal storage. Information obtained in the study will be organized in user-oriented materials.

Significant accomplishments include the development of a measurement approach based on photoacoustic detection for interior optical property characterizations.



EFFECTIVE ABSORPTIVITY MEASUREMENT

PROJECT TITLE:	**USER - ORIENTED EDUCATION**
Institution:	*Ames Laboratory* *Ames, Iowa*
Principal Investigator:	*John McClelland*
Task Number:	*In-house*

Development and field testing of regionally specific user-oriented design tools and handbooks is being undertaken as opportunities arise in cooperation with university and extension service staff members. These activities include contributions to educational materials in the form of lectures, seminars, conferences, university and extension courses, slide and audio shows, and articles for popular and professional periodicals.

Significant Accomplishments

- Development of a university course on passive architecture (3 credits)
- Extensive participation in regional and national passive conferences and workshops
- Provided opportunities for students, faculty, state government personnel and other interested parties to be involved in or exposed to passive projects.

PROJECT TITLE: **WATER FILLED STORAGE WALLS**

Institution: *Ames Laboratory*
Ames, Iowa

Principal Investigator: *J. F. McClelland*

Contract Number: *EW-7405-Eng-82*

Transwall

The "transwall task" involves the development of a semitransparent solar-absorbing thermal-storage wall system to the point of a commercialization decision. The transwall system is a hybrid approach consisting of a modular water-filled wall assembly which combines some of the best aspects of Trombe wall and direct-gain systems with fewer problems. System features include directly irradiated storage with thermalization primarily occurring within the heat storage medium; visual transparency similar to tinted glazing; lower mass and volume loading of buildings relative to concrete thermal storage; and reduced glare, photodegradation and overheating in comparison with some direct-gain interiors.

The FY 1980 work plan includes:

- transwall concept development
- solar heating simulation analysis
- test prototype design and fabrication
- prototype testing in a small passive room (LASL design), including several operating modes
- evaluation of results.

Subsequent work will involve similar procedures for a commercial prototype with a cooperating commercial firm.

Passive System Testing

This task supports the transwall task by establishing a passive solar test room facility of the LASL design. Additional evaluations occur on glazing assemblies, surface materials, and direct-gain interiors. Testing involves monitoring insolation, as well as ambient and interior temperatures as a function of time. At the present time, two passive test rooms with thermal sensors and an insolation monitor have been constructed.

PROJECT TITLE: **PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**

Institution: *Acorn Structures, Inc.*
Concord, MA

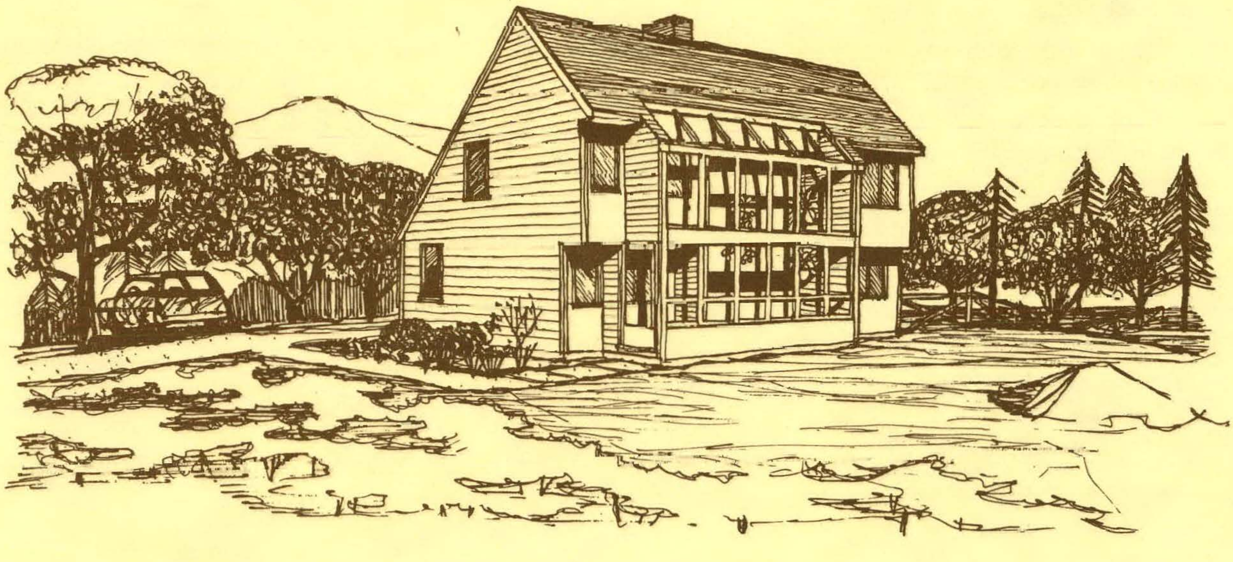
Principal Investigator: *Mark Kelly*

Contract Number: *DE-FC02-80CS30363*

Acorn Structures, Inc., a privately held corporation, located in Concord, Massachusetts, has proposed to design and build a prototype home using passive solar techniques that will appeal to families in the middle income range. This model will rely almost entirely on passive solar energy.

Although the building model intended to be developed under this program has not yet been clearly identified, it will contain the following Acorn standard solar features:

- Double glazing
- R-30 roof insulation
- Slab isolated from the ground and containing the air distribution ductwork off the ground floor
- Extensive south glazing (including a greenhouse)
- Freestanding central chimney containing an air re-circulation duct.



Design Team

The design team will consist of Architects and Engineers on Acorn's staff and Massdesign Architects and Planners, Inc., a Cambridge, Massachusetts, consulting firm with established expertise in solar energy system design. Massdesign will provide conceptual solar house and system designs as well as cost estimates which Acorn's in-house design employees will convert to working drawings and shop drawings.

Design Approach

Solar considerations that will be explored during the design phase include the following:

- Determination of maximum and minimum levels of direct solar gain for selected geographic areas
- Investigation concerning the most appropriate form and location of energy storage elements
- Development of innovative forms of suspended-slab construction for use in 1-1/2- and 2-1/2-story passive houses
- Development of portable and/or easily site-fabricated energy storage systems
- Investigation of passive solar roof and/or wall collector systems when used in conjunction with direct gain south windows
- Development of cost-effective seasonally variable shading devices
- Investigation of the use of increased building-envelope ground contact for natural cooling
- Development of optimally compatible natural ventilation and occasional-use mechanical air conditioning system
- Development of cost-effective thermal shutters.

Some of the design aids to be applied include the following:

- Mazria's rules of thumb for first cut design decisions
- Balcomb/LASL's three-stage thermal/solar behavior estimating techniques available in a prepublication form
- Massdesign's own hand-held calculator program
- TEANET solar/thermal simulation techniques
- ASHRAE's standard heat-loss calculation procedures.

Prototype Fabrication and Testing

Acorn will build the first prototype fabrication on a midwest site with construction scheduled in 1980. The house will be open to the public for viewing for a 3 to 6 month period. It will then be sold and occupied by a family who will provide data monitoring.

PROJECT TITLE: **SOLAR ENERGY USING A HYBRID SOLAR SYSTEM**

Institution: *Architectural Alliance, Inc.*
Minneapolis, Minnesota

Principal Investigator: *Peter Pfister*

Contract Number: *EG-77-G-04-4146*

The original purpose for Architectural Alliance, Inc., in this project was to design and construct a single-family residence which uses passively collected solar energy for a significant portion of its space heating requirements. The building site was located in the Minneapolis metropolitan area, an area that has a high winter heating load, average to above average winter sunshine, and periods of relatively warm summer weather. The original hybrid system design used south facing windows, a skylight, an interior solar collector wall, storage in both the present concrete floor and a rock bin, movable insulation, and an air circulating fan.

Problems of construction complexity, cost, and financing led to the prospective owner's decision not to construct the residence. As an alternative, the contractor, Architectural Alliance, Inc., proposed to and received approval to do a passive solar retrofit of a two-story Minneapolis residence.

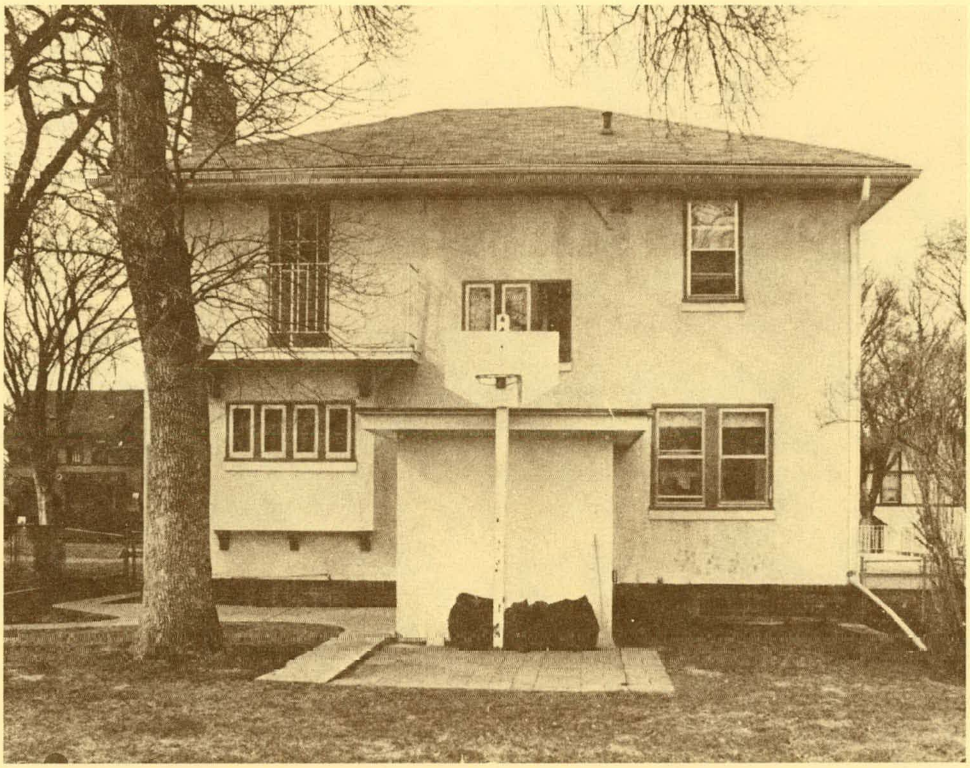
The key facets of the proposed retrofit are: 220 net square feet of south glazing; thermal storage in new and existing concrete flooring, waterwall thermal storage augmented with thermosiphoning air collector, distribution of passive solar heat augmented with fan and duct air system, and movable window insulation to protect new and existing windows.

Design of the retrofit was accomplished from August 1978 through July 1979. Construction started on May 3, 1979, with a completion date set for December 1, 1979.

Publications

Information on this project was presented at the following conferences and seminars:

- DOE Regional Solar Update Conference, Dearborn, Michigan, July 12, 1979
- Underground Space Center (University of Minnesota) "Going Under to Stay on Top" Conferences:
  - Rushford, Minnesota, June 16, 1979
  - Amherst, Massachusetts, June 8, 1979
  - Des Moines, Iowa, September 15, 1979
- The University of Wisconsin Extension Service Passive Solar Seminars, Madison, Wisconsin, October 18, 1979
- Fourth National Passive Solar Conference, Kansas City, Missouri, October 4, 1979



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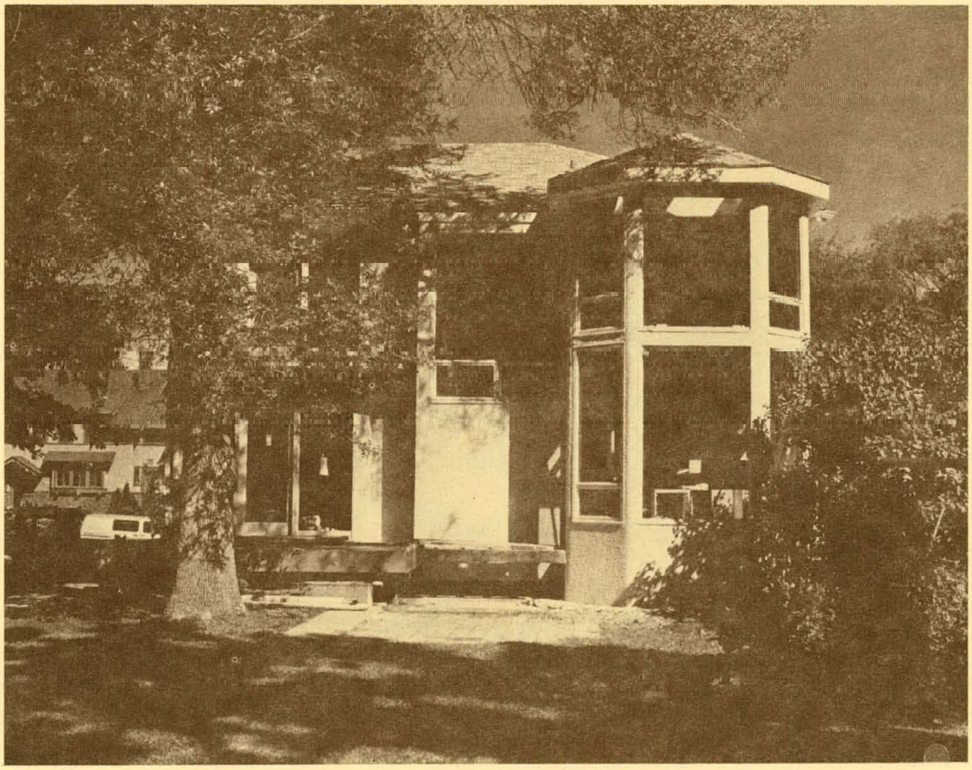


After

PROJECT TITLE: **DESIGN & ENERGY: A STUDENT COMPETITION**

Institution: *Association of Collegiate Schools of Architecture Washington, D.C.*

Principal Investigator: *Roger L. Schluntz and Sharon Machida*

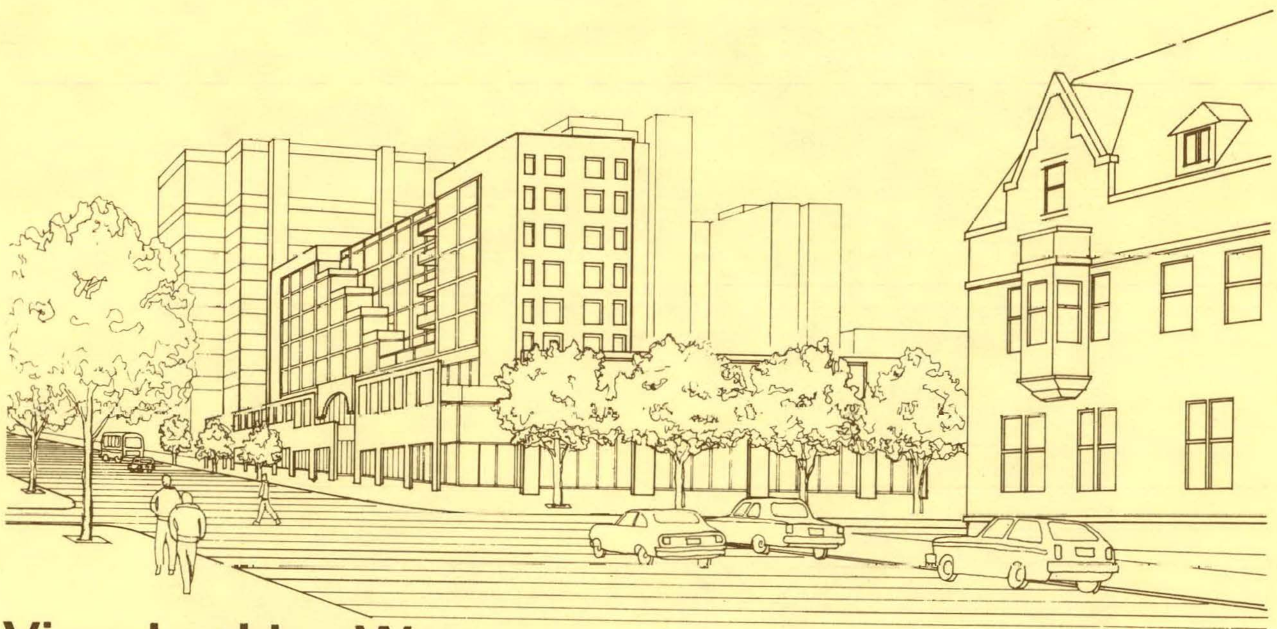
Contract Number: *DE-FG01-80CS22003*

This grant is for the support of the first in a yearly series of three national design competitions for graduate and upper division students in the nation's schools of architecture. The intent of the competition is to involve students and faculty in professional schools in rigorous design exercises within the studio setting, emphasizing the use of energy conserving and passive solar energy opportunities. The participating students and faculty will follow supplied design criteria to ongoing problems in their regular courses.

The first competition focuses on the applications of various passive solar energy systems and thermal massing techniques with an emphasis on brick masonry construction, to a variety of typical and ubiquitous medium-scale buildings. The design problems emphasize successful application of energy conserving and passive solar principles and techniques to buildings at this scale. The student work was undertaken in a 6 to 10 week period between January and May 1980.

Entries were reviewed and judged by a jury of distinguished educators, designers, and energy experts. Awards and winning entries were presented at the 1980 AIA Convention in Cincinnati, Ohio.

The project also included a research component, designed to assess the degree to which the competition encourages and reinforces efforts by students and their instructors to include energy



View Looking West

Award winning design by Robert Nalls who attends the University of Pennsylvania. This project, the International House is located in Philadephia, Pennsylvania.

concerns in their work. This included a series of visits to schools and participation by staff at the annual conventions of the Association of Student Chapters of the AIA (Houston, Texas, in November 1979) and the ACSA (San Antonio, Texas, in March 1980).

The competition included the participation of over 2200 students and 200 faculty: representing 80 of the 93 professional schools of architecture in the U. S. As such, this was the most comprehensive student competition ever conducted.

Partial financial support for the project was provided by ACSA and the Brick Institute of America.

A 74-page publication illustrating many of the winning and other competition entries will be available from ACSA for $6 in late September 1980. Also published is a 28-page "Resource Document" for competition participants (sent free to participants, $3.50 for others) and a 13-page Program Document (out of stock).

Winning entries were exhibited at the AIA National Convention June 1–4, 1980, in Cincinnati, the AIA Headquarters Gallery June 15–July 4, 1980 (Washington, D.C.), at the Department of Energy, and at the Brick Institute of America Headquarters (McLean, Virginia).

PROJECT TITLE:	**SUNCATCHER MONITORING AND PERFORMANCE EVALUATION PROJECT**
Institution:	*Davis Alternative Technology Associates Davis, California*
Principal Investigator:	*Bruce Maeda*
Contract Number:	*DE-AC02-79CS-30169*

Introduction

The purpose of this project is to monitor an innovative passive solar house design and provide detailed, quantitative data on the performance of a breadbox solar water heater, a water mass Trombe wall space heating system and the Suncatcher reflective roof design.

The design of the house is characterized by:

- *Suncatcher Operation* — The Suncatcher design uses a reflective overhang and north sloping roof surface in a configuration that provides enhanced collector area for reflective solar heat gain through clerestory windows. The roof and overhang surfaces form a cavity that achieves a significant increase in winter solar gain, and at the same time prevents overheating in the summer. Inside, manually operated insulated shutters (R-6) decrease winter heat losses, and decrease cooling loads by reflecting diffuse solar gain from their exterior-facing reflective surfaces. A water Trombe collector system is behind the clerestory windows.

- *Direct Gain Components* — Three south facing bedrooms are heated by direct solar gain through the windows. They are shaded by a full-length grape arbor. Heat storage in these rooms is via sunlight water mass in 55 gallon drums and the parquet covered slab floor.

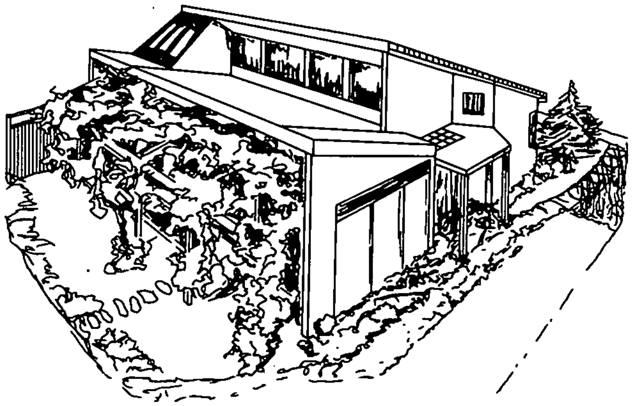
- *Natural Cooling System* — The cooling requirement is decreased by heavy wall insulation, double glazing and well-shaded, draped windows. The remaining cooling load is met with daytime heat storage in water mass and later heat rejection by cross-ventilation through the south windows above the collector/storage tubes, and the north side windows.

- *Breadbox Solar Water Heater* — The breadbox solar water heater has a net collector area of 36 square feet of double glazed, tempered glass. The system heats water through a total of four tanks. The two middle tanks are in parallel with each other, and are in series with an inlet tank and a fourth tank for final solar heating.

- *Other Energy Efficient Features* — Several other energy efficient features include natural lighting with a light shelf above a south bedroom closet, an interior clerestory window providing additional light into the living room on the north side of the house, and a ceiling to north wall hot air circulation fan.

An extensive energy monitoring program has been in continual operation since November 1977. This data is complemented by a series of intensive energy monitoring experiments that give more detailed information such as the shortwave radiation mapping in the vicinity of the collector/storage tubes, infrared exchanges, and heat storage stratification.

Many temperature and energy variables have been recorded by hand throughout the project. This data serves to fill in for data not available during equipment acquisition, installation and downtime.



The hand collected data provides a complementary reference between the two sources and is being gathered in part to determine the feasibility and accuracy of simplified data gathering processes for performance estimation and evaluation.

Performance Results

The breadbox solar water heat provided 100 percent of the hot water for three adults from June through October. The balance of the time the breadbox heater acted as a preheater to the auxiliary domestic hot water heater. During 100 percent operation the water temperature was occasionally cooler than desired (98–105°F or 37–40°C) for morning showers but afternoon and evening water temperatures were quite adequate ranging from 112–130°F (44.4–54°C).

Most recent data and calculations indicate a minimum of 68 percent of the needed heating energy has been provided by solar. Since some crucial thermal improvements have been made since this data was taken viz. draperies, shutters and a commercial cat door, indications are that performance probably exceeds 75 percent of the backup heating required. The winter months covered by this performance evaluation were quite rainy, much more so than average, with lower than average solar gains.

The dwelling achieves 100 percent cooling performance since there is no backup system for cooling. The house has reached 84°F internal temperatures on three separate days during the late afternoon hours. This occurred during the hottest event of the summer, a two-week period with daily maximums over 95°F (35°C), several days over 100°F (37.8°C), and a peak of 108°F (42.2°C).

The Suncatcher cone enhances radiation transmitted through glazing by 40 percent on the average with values ranging from 15 to 60 percent. In summer additional diffuse sunlight is twice that of a shaded south window and slightly less than that of an unshaded south window of similar construction (73 percent) due to the Suncatcher roof overhang design cutting off direct beam radiation. Shutters of course eliminate all or virtually all solar radiation when closed. At peak winter hours near solar noon, the sunlight through the clerestory windows is increased by more than 50 percent. In conclusion, the Suncatcher configuration is very beneficial in heating climates with little or no snowfall.

PROJECT TITLE: **EVALUATION OF HEAT PIPE APPLICATION FOR PASSIVE SYSTEMS**

Institution: *Battelle Memorial Institute*
Columbus, Ohio

Principal Investigator: *John M. Corliss*

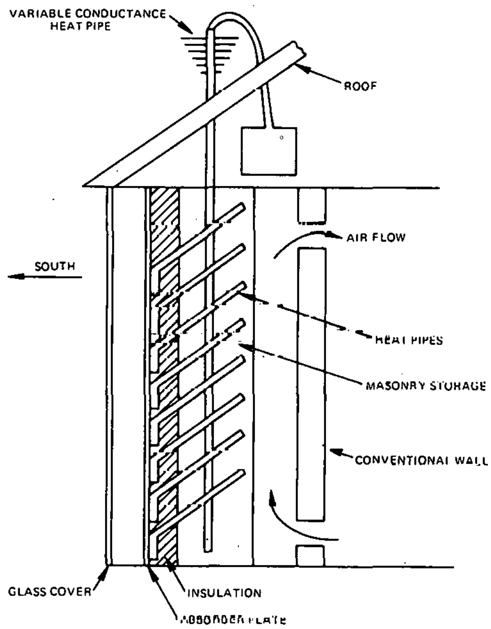
Contract Number: *EG-77-C04-4222*

The objectives of this research program are:

- To determine the potential utility and cost effectiveness of the application of heat pipe principles to heat transfer in passive solar systems
- To develop heat pipe techniques; i.e., phase change, evaporation/condensation heat transfer, convective transport, and capillary pumping to enhance the system component performance as part of a passive heating and/or cooling system

The tasks to be performed in accomplishing these objectives are:

- Identification of New Concepts
  - Literature Survey
  - Heat Pipe Concepts
  - Passive Heating Concepts
  - Passive Cooling Concepts
- Application of Analytical Tools
- Systems Analysis and Evaluation
  - Building Loads/Response
  - Integration of Computer Models
  - Analysis of System Performance
  - Comparison of Results
- Cost Effectiveness Evaluation
- Development/Fabrication of Proposed System
- Assessment of Marketability.



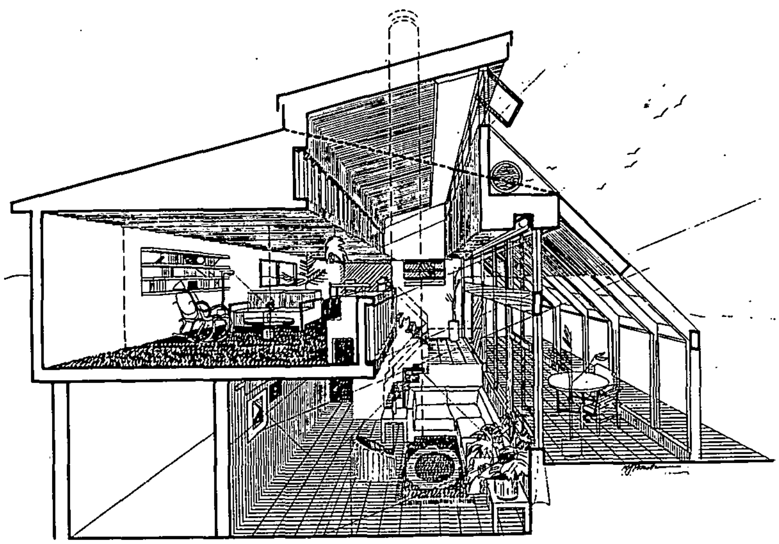
Progress of Work

Original calculations by Battelle indicated that a single-glazed thermal-storage water wall equipped with heat pipes should perform slightly better (and cost less) than a double glazing and movable night insulation interposed between the glass and wall material. Preliminary conclusions indicate that heat pipe solar heating systems are somewhat more costly than waterwall systems w/R9 movable insulation, although performance is comparable.

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Dynamic Homes, Inc.* *Detroit Lakes, Minnesota*
Principal Investigator:	*Tricia Croyle*
Contract Number:	*DE-FC02-80CS30370*

Dynamic Homes, Inc., of Detroit Lakes, Minnesota, is a modular home manufacturer. Approximately 900 houses each year are produced at three plant locations in an eight state region: Minnesota, North Dakota, South Dakota, Wisconsin, Iowa, Nebraska, Montana, and Wyoming.

They intend to integrate a passive solar system into four basic building types ranging in size from 1,008 to 1,968 sq. ft. The prices are from $50,000 to $95,000.



Design Approach

Passive solar energy considerations during design will include:

- Location of windows and use of clerestory windows
- Use of natural heat rise, air flow, and low-velocity fans to distribute air flow in living zones
- Additional mass for direct and indirect solar gain (such as water walls, prefinished, precast interior elements)
- Thermal shuttering techniques for thermal-glazed openings
- Solar greenhouse option with self-contained thermal mass
- Solar domestic hot water heater.

For design tools, Dynamic Homes, Inc., would use rules of thumb during schematic design and larger computer processing equipment and programs to assess detailed design solutions.

PROJECT TITLE: **INCORPORATION OF EVAPOTRANSPIRATION ROUTINES INTO GREENHOUSE ANALYSIS TOOLS**

Institution: *Ecotope Group*
Seattle, Washington

Principal Investigator: *Davis Straub, Ecotope; Michael Connolly, SERI*

Contract Number: *HM-9-8308-1 (under contract to the Solar Energy Research Institute)*

A number of passive solar computational models exist for evaluating greenhouses. However, these models preclude the variance in performance caused by the inclusion of plants in a structure. Evapotranspiration as a heat transfer mechanism is important in greenhouses. One-third to one-half of the incoming radiant energy is converted to latent heat by vaporization. This heat is lost in ventilation air or condenses on the greenhouse cover. The heat is split between inside and outside air in relation to the resistance to heat flow from the inside or outside of the cover. Condensation on the glass refracts the radiation, scattering and diffusing it throughout the greenhouse. Other problems are heat conduction and the capacity of soil, variations in plant cover and metabolism, and the use of innovative heat storage schemes.

The Ecotope Group has explored solutions to these problems as part of a two-year research effort sponsored by the USDA and DOE. One objective of the present study is to complete a set of greenhouse specific algorithms. The project will devise routines for evapotranspiration applicable to attached greenhouses. Results will be translated into user-oriented software and validated against actual structures.

Major challenges of this work center around the problem of the vastly different time constants for the air and the massive elements of the building. The long-time constants of the building allow for inexpensive runs of a year's length to determine a baseline performance of a building. If the time interval on the computer model must be decreased to account for the rapidly varying air and evaporation, then this becomes too expensive to run the design tool for a year (because of the number of computer runs required). However the time interval cannot be too short, or the effects of the initial conditions of the mass cannot be adequately accounted for.

Reports will be submitted to SERI with software and applicable cards (or tape) to drive a designated computer system. Subsequently, a user's manual for this software will be compiled and submitted in the form of camera ready copy for reproduction.

PROJECT TITLE: **ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF THE TROMBE WALL**

Institution: *Energy Engineering Group*
Golden, Colorado

Principal Investigator: *Richard L. Casperson*

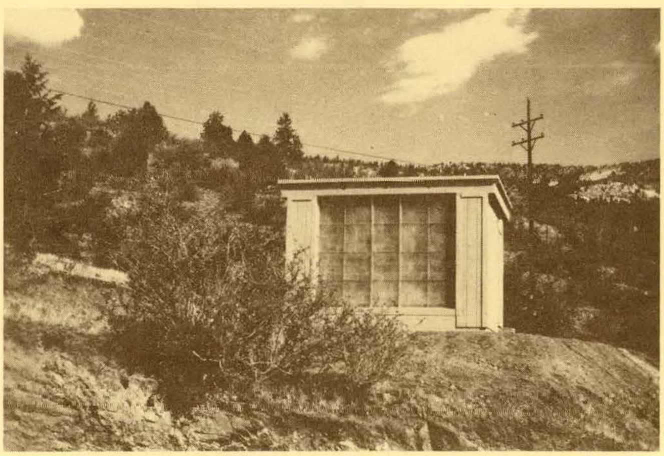
Contract Number: *DE-AC02-79CS30244*

This project is an extension of one successfully concluded under a previous contract with EEG. The Trombe wall facility built under this contract is located in Idaho Springs, Colorado, on Clear Creek County School District Property. The agreement with the school district was that the test building would be turned over to the district upon completion of all research programs.

Under the previous contract, a variable geometry Trombe wall test facility was constructed and an experimental program conducted to investigate the performance characteristics of the Wall. The principal objective met in the research project was the determination of representative values of wall gap thermocirculation parameters for various wall geometries. A second objective accomplished in this research was the characterization of the Trombe wall thermal efficiency for a variety of operating conditions and wall geometries.

The present contract involves the following types of work:

- Modify the existing solar test facility in Idaho Springs, Colorado, by the addition of items:
  - An additional velocity probe
  - Additional thermocouples
  - Vent fans to allow the interior air temperature to be controlled
- Obtain velocity and temperature distribution in the air gap and temperature distributions in the masonry wall for 16 distinct vented Trombe wall configurations; gap width and inlet/outlet duct sizes will be varied; data will be used to develop collector efficiency curves which will be needed in the design chart development
- Obtain a computer program from the Solar Energy Research Institute (SERI) and modify as required for this project; and, detailed air gap velocity and temperature data obtained in this project will be used to develop a realistic thermocirculation model which will be incorporated in the computer program.



PROJECT TITLE: **PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**

Institution: *First Manufactured Homes, Inc.*
Lubbock, Texas

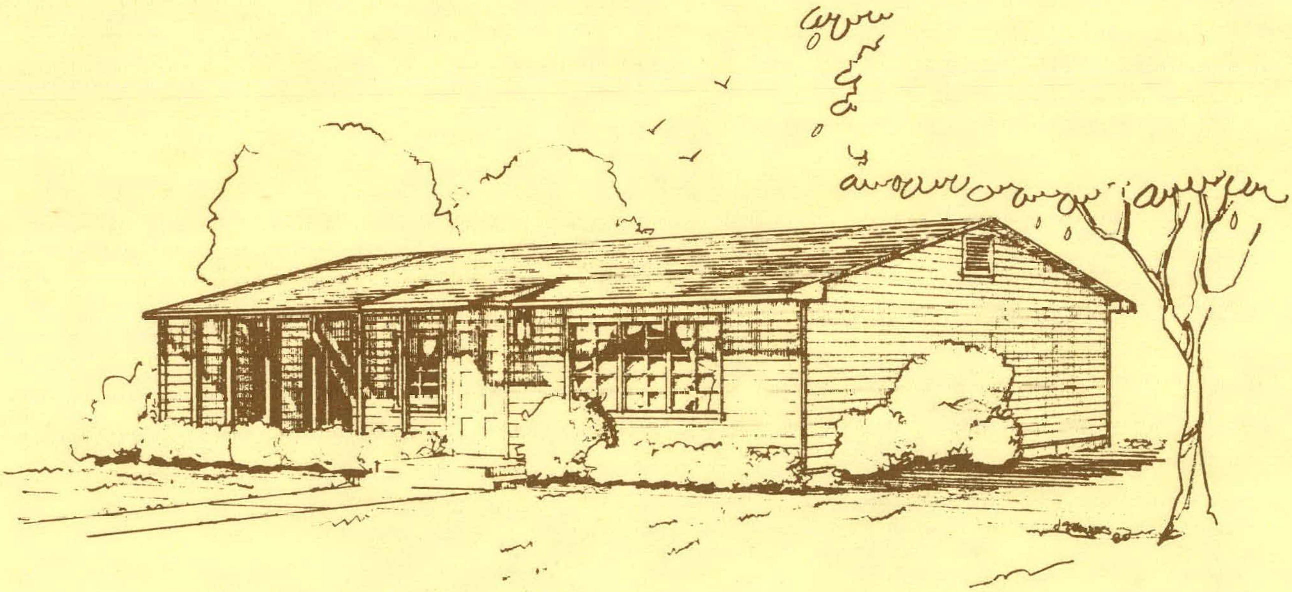
Principal Investigator: *Glen E. Hill*

Contract Number: *DE-FC02-80CS30371*

First Manufactured Homes, Inc., has been producing model homes for shipment to customers up to 200 miles from their factory in Lubbock, Texas. In 1976, First Manufactured Homes developed a package of energy efficient options for their structures and in the past 2 years, all homes sold have included this package.

The basic home model of First Manufactured Homes, Inc., is 1,280 sq. ft., although a larger 1,408 sq. ft. version is available. Standard conservation features include: heat pumps; insulated steel front door, storm windows and sash; and insulated walls, ceiling, and air ducts. Polyurethane foam is used to fill holes and seal around windows. A polyethylene vapor barrier is placed on the inside of the walls, and an infiltration trap is used at the plate line.

Houses are completely fabricated as they leave the Lubbock factory. The 1979 standard models sold for $21,400 (FOB factory, 1,280 sq. ft.) and the energy package for $1,400, a total cost of $22,800. The larger models cost $23,300, with the energy package costing an additional $1,600. Other options available to purchasers were a garage kit, fireplace, and foundation (within 200 miles of the Lubbock factory).

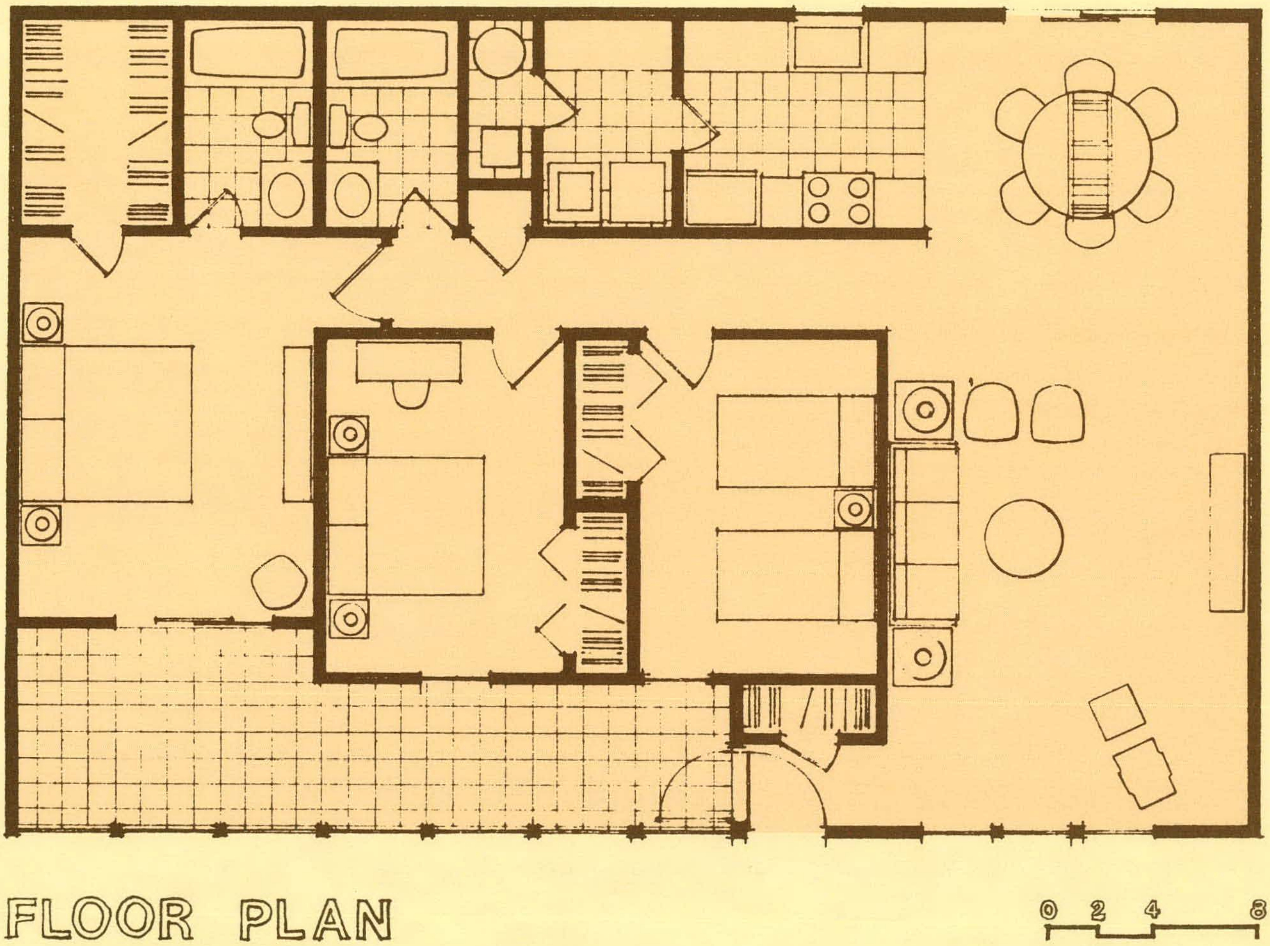


Design Approach

During design, First Manufactured Homes, Inc., will explore alternatives for integrating additional passive solar and energy conserving features into their homes. The design team will begin the process with a complete analysis of user requirements and comfort levels to establish criteria for individual energy-use functions.

Design tools will be used to apply the proper level of mathematical detail to the solar design problems. Hand calculation procedures will be aided by programmable calculators and applied where rough judgments are appropriate.

An Apple II, 32K, minicomputer with floppy disc storage will provide midlevel quantification of solar energy use, and economic elements. This program is used to model typical design days, enabling fine tuning of the window area, heat-loss rate, and internal mass relationship.



FLOOR PLAN

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Guerdon Industries, Inc. Louisville, Kentucky*
Principal Investigator:	*James K. Amrine*
Contract Number:	*DE-FC02-80CS30373*

Guerdon Industries was founded in 1953 and today manufactures over 17,000 housing units in the southern, central, and western United States. Guerdon Industries is a wholly owned subsidiary of GDV, Inc. of Miami, Florida, and is a leading builder of residential homes.

This project will develop a cost-effective, marketable passive heating system configuration for Guerdon's line of double-wide mobile home units. This double-wide prototype mobile unit will be approximately 1,200 to 1,300 sq. ft. in size and will incorporate energy-conservation designs.

Marketing for this mobile housing unit at the retail level will be directed toward private lot installation where site orientation is more flexible, rather than established mobile home parks with fixed orientation and shading conditions.

The objective of this project is to develop a documentation package that is "manufacturing-ready."

Design Approach

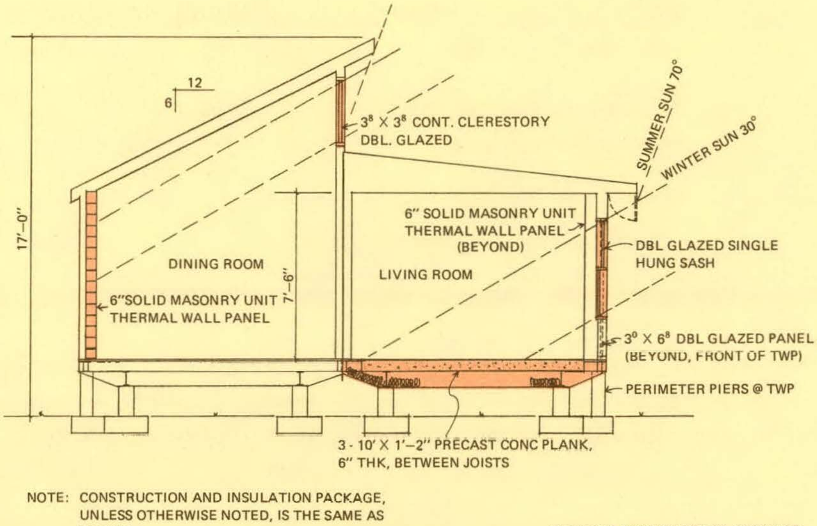
- Preliminary level – identify the largest number of compatible structures, passive concepts, and market requirements

- Intermediate level – will focus on three questions:

  - What will it look like? (appearance and function)
  - How much will it cost? (cost to manufacture, cost to sell)
  - How much will it save? (energy units translated into dollars)

- Final level – prototype system will be selected and complete product documentation developed; emphasis at this level will also include:

  - Methods of delivery, i.e., How will thermal energy storage be transported to site?
  - Servicing techniques, i.e., access to system components
  - Reliability analysis, i.e., What can fail? How often? Is redesign called for?
  - Customer presentation – Identify techniques that will be used to present the cost-benefit features of the passive-designed structure.



DESIGN C MASS THERMAL STORAGE

Guerdon plans to build two prototypes. One is to be located at the main engineering facility in Louisville, Kentucky, and the other at the University of Delaware, which has similar climatic conditions to the target market area of St. Louis.

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Fleetwood Homes, Inc. (Hobmar Homes, Inc.)* *Minneapolis, Minnesota*
Principal Investigator:	*Herbert T. Beatty*
Contract Number:	*DE-FC02-80CS30372*

Fleetwood Homes, Inc., of Worthington, Minnesota, produces homes for builders throughout a seven-state area. Fleetwood is producing more than 300 homes annually. As a goal, they would like to have 20 percent of their annual volume of homes incorporate passive solar features.

Design Approach

Fleetwood Homes, Inc., envision that passive solar homes will have more masonry in their interiors. This offers a more durable quality than typical light frame construction. Yet, it has less flexibility for rewiring and modifications. Masonry floors, too, offer a challenge. When masonry floors are planned for thermal mass, brick pavers, title, slate, and terrazzo can be added to give texture and character to a concrete slab. Fleetwood Homes, Inc., believes carpeting should be avoided over masonry floors intended to store heat, especially in areas where the sunlight strikes the floor directly. Carpeting acts as insulation over the floor mass, making it ineffective as heat storage.

Fleetwood Homes, Inc., contends that if hard floor surfaces are unacceptable to the home market, an equivalent wall mass may be substituted. If this wall mass receives sunlight directly, it will store four times as much heat as a wall or floor that receives heat indirectly.

Components whose functions are primarily structural, spatial, or aesthetic may double as heating components. Through the simplicity of its construction, the passive solar design approach can effectively surpass market hurdles. With few or no moving parts, operating and maintenance costs are minimal. The initial costs for passive solar are not fixed by the cost of the equipment but are determined largely by the design and materials that the builder selects. The passive approach has produced some of the most cost-effective solar homes in the United States.

Design tools include computer programs that permit complete analysis of the passive solar project proposed by Fleetwood Homes, Inc.

PROJECT TITLE: **IOWA PROJECT PASSIVE**

Institution: *Iowa Energy Policy Council*
Des Moines, Iowa

Principal Investigator: *Philip H. Svanoe*

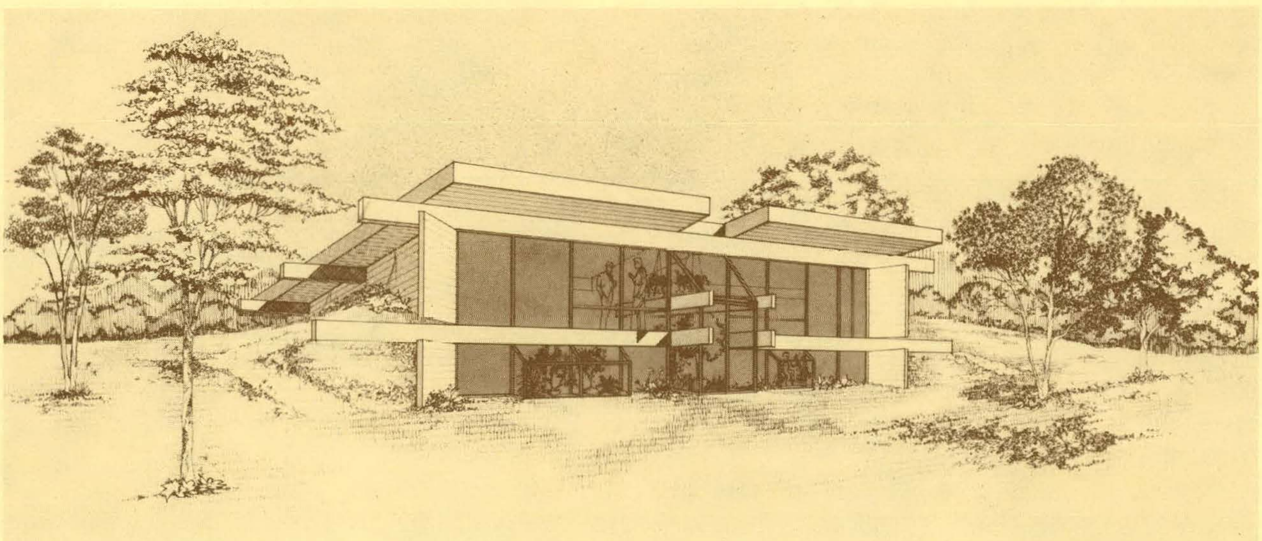
Contract Number: *DE-AC02-79CS-30156*

The Iowa Energy Policy Council has embarked on a model passive solar residential project which can subsequently be introduced into the building trade school curricula for the State of Iowa. The scope of work includes designing an efficient solar building and providing a total design package to the trade schools for construction. This package will include:

- Detailed working drawings
- Construction specifications
- Quantity take-offs
- Cost estimates and cost trade off analysis
- Solar performance calculations.

The present status of the program is that the design and generation of all supportive materials have been completed. Three building trade programs have been selected to build this design. Construction of one of the houses is scheduled for completion in September 1980.

Reports on the construction process, actual construction costs and time, installation prolems and building performance will be published as data become available.



PROJECT TITLE: **THERMOSIPHONING COOL POOL**

Institution: *Living Systems*
Winters, California

Principal Investigators: *Karen Crowther and Bruce Melzer*

Contract Number: *DE-FG02-77CS34153*

Introduction

Roof ponds utilizing night sky radiation and/or evaporation have been used to cool buildings. The majority of these systems use movable insulation to protect the pool during the day, and require direct thermal contact between the building interior and the pool bottom.

The Cool Pool, invented by Jonathan Hammond of Living Systems, combines a shaded roof pond with a thermosiphon system to cool building interiors both day and night. The thermosiphoning Cool Pool requires no movable insulation and allows the roof pond to be physically isolated from the building interior. Although evaporation is the most important method of heat rejection, the Cool Pool does not introduce any additional water vapor into the interior space.

Experiments were conducted on a heavily insulated 144 sq. ft. test building near Winters, California (Fig. 1). The 12 X 12 X 12 wood frame building has R-19 wall, R-30 roof, and R-5 insulation around the perimeter of the concrete slab floor. The 24 sq. ft. of south window is insulated with an R-4 shutter. The roof pond consists of a 60 sq. ft. X 1 ft. deep galvanized steel pan, located on the northern portion of test building roof. The pond is covered by a plywood shade that prevents direct radiation from striking the pool. The bottom of the pond is insulated from the test building interior by R-19 fiberglass batts.

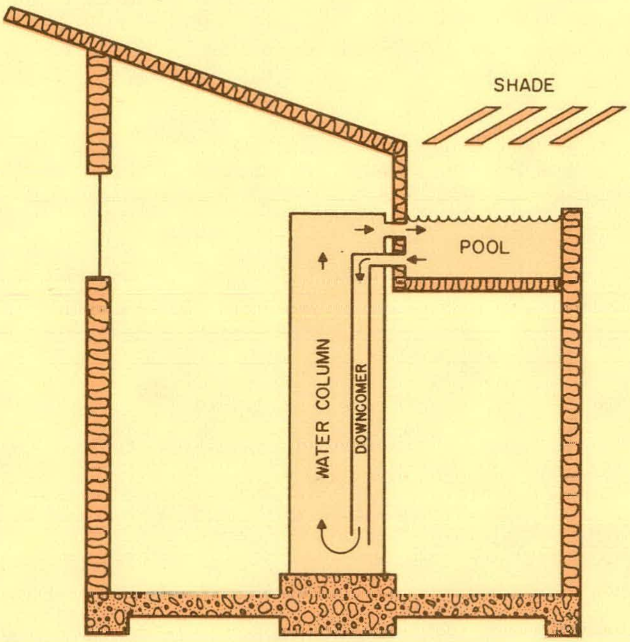
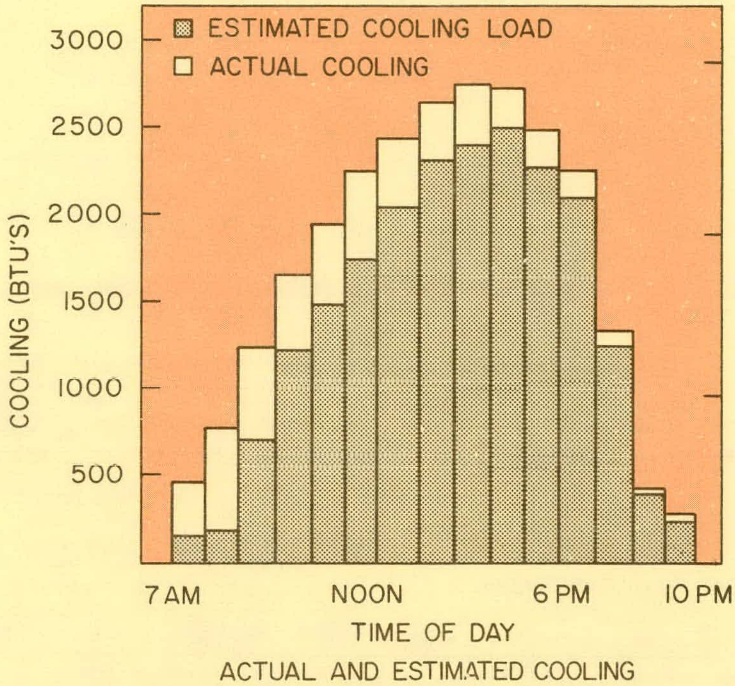


Fig. 1. Cool Pool Test Building

The pool is connected to four 8 ft. high 18 in. diameter steel culvert pipes located in the middle of the test building. A 5-ft. ABS pipe serves as the downcomer, bringing cool, dense water from the bottom of the pool into the bottom of the cylinders. A PVS pipe serves as the riser, bringing warmer, less dense water from the top of the cylinder out to the top of the pool. The pool is cooled by radiation, evaporation, and convection.

The experiments to date have proven that the Cool Pool is a powerful passive cooling system that is capable of providing 100% of the cooling needs of a building in many areas of the country. The system requires no daily operations, and functions without any supplementary power. The thermosiphoning Cool Pool allows the pool bottom to be physically isolated from the interior space. This allows a larger degree of design freedom than previous systems. The cylinders used for



Estimated hourly load and actual cooling provided by the Cool Pool. The load was estimated using Sol-Air temperatures calculated from actual outside temperatures and an indoor design temperature of 78°F. Actual cooling was calculated using measured inside and outside temperatures.

the Cool Pool system during the summer can also be used as thermal mass for a solar heating system during the winter.

The research to date indicates that the Cool Pool system tested here is oversized relative to the cooling load of the test building. The surface area of the pool and number of water columns could be reduced without causing a substantial decrease in performance. Additional research will verify the performance of the Pool system, and enable more accurate system sizing for different cooling loads and different climates.

PROJECT TITLE: **PASSIVE SOLAR RETROFIT**

Institution: *Londe-Parker-Michels*
St. Louis, Missouri

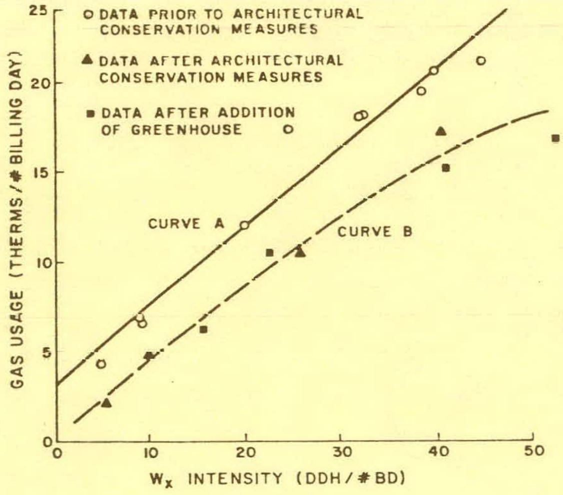
Principal Investigator: *Timothy I. Michels*

Contract Number: *EG-77-G-04-4127*

The subject project is the retrofit of a 40-year old masonry duplex structure with the following passive solar features:

- Transforming 300 sq ft of south wall into a Trombe wall
- Insulating exterior walls
- Installation of heat distribution systems
- Installation of storm sashes
- Providing air lock entries.

Early results of the effectiveness of the improvements are summarized below. Curve A is a regression of winter energy usage vs. weather intensity for the two years prior to the retrofit. Curve B shows recent energy consumption and reflects the impacts of conservation efforts, the second floor glazing and a stagnant greenhouse. Monitoring efforts are continuing through 1980.



PROJECT TITLE: **CONVECTIVE LOOP TEST PROGRAM**

Institution: *Los Alamos Scientific Laboratory*
Los Alamos, New Mexico

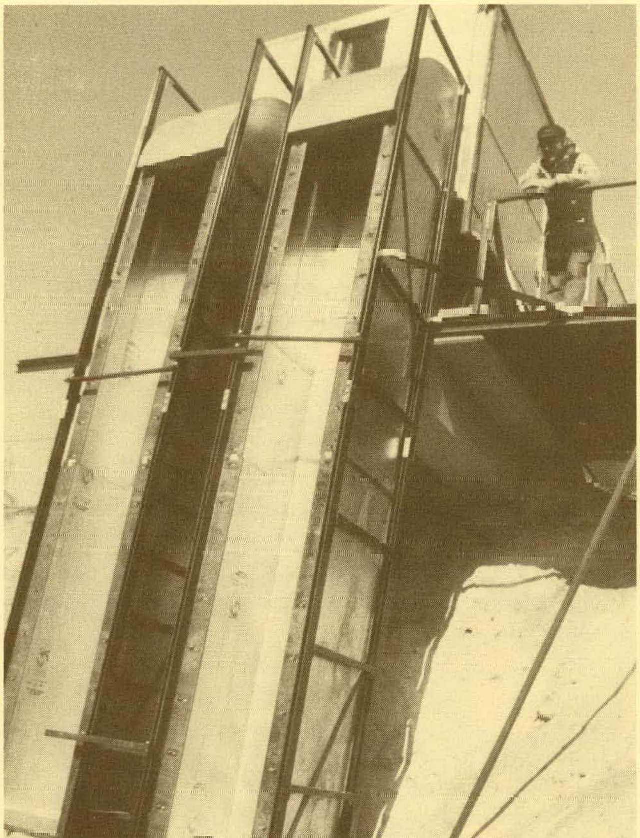
Principal Investigator: *Don Neeper*

Contract Number: *In-house*

LASL is conducting an experimental and analytical investigation of convective loop (thermosiphon) air-heating systems particularly intended for retrofit space heating of multistory buildings. In such systems, the solar collector (which may be similar to an active collector in appearance) is located below the space to be heated, and natural buoyancy lifts warm air from the collector to the living space or storage area.

The purpose of this project is to develop general rules for the design of thermosiphon collectors for space heating applications in any climate. For example, a climate with cold weather and weak insolation may require use of a long collector, in order to obtain sufficient temperature rise and buoyancy to give the air flow rate necessary for heat transfer. Conversely, a short collector may give better performance in a climate with intense sunshine. The sizes of air passages, and perhaps even the configuration of absorber and heat transfer surfaces, may need to be optimized for climate.

The technical approach is to test particular designs and to validate analytic models with an apparatus that permits side-by-side testing of two collectors, each of which may be up to 15 feet long. Heat is extracted from each test loop by heat exchangers that can simulate the influence of either thermal storage or direct delivery of the heated air to a building space. The developed designs will specifically be of the type easily assembled from readily available building materials by tradesmen.



Convective loop test apparatus consisting of two channels, each permitting a collector up to 15 ft. long. A semitrailer at the top houses heat exchangers and instruments.

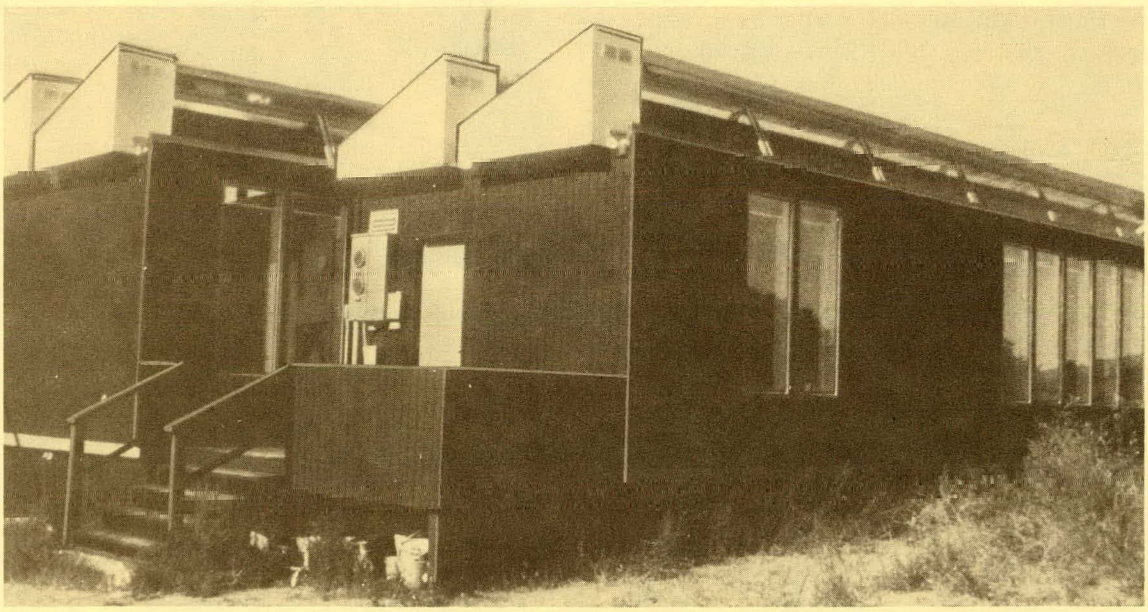
PROJECT TITLE:	**DATA ANALYSIS OF MOBILE/MODULAR HOME II**
Institution:	*Los Alamos Scientific Laboratory* *Los Alamos, New Mexico*
Principal Investigator:	*Don Neeper*
Contract Number:	*In-house*

Mobile/Modular Home II, designed by LASL, is a modular home using a roof pond passive solar heating system. The thermal energy delivery to the house is primarily by radiation. The home collects solar energy through four rows of double-glazed apertures arranged in a sawtooth pattern on the roof. Aluminum reflectors are used to increase the energy collected in the water-filled plastic bags, which also serve as the storage medium. At night, movable insulation within the roof folds downward to cover the bags. The operation is reversed during summer to provide some cooling. Solar heating is also achieved by direct gain through the south-facing windows.

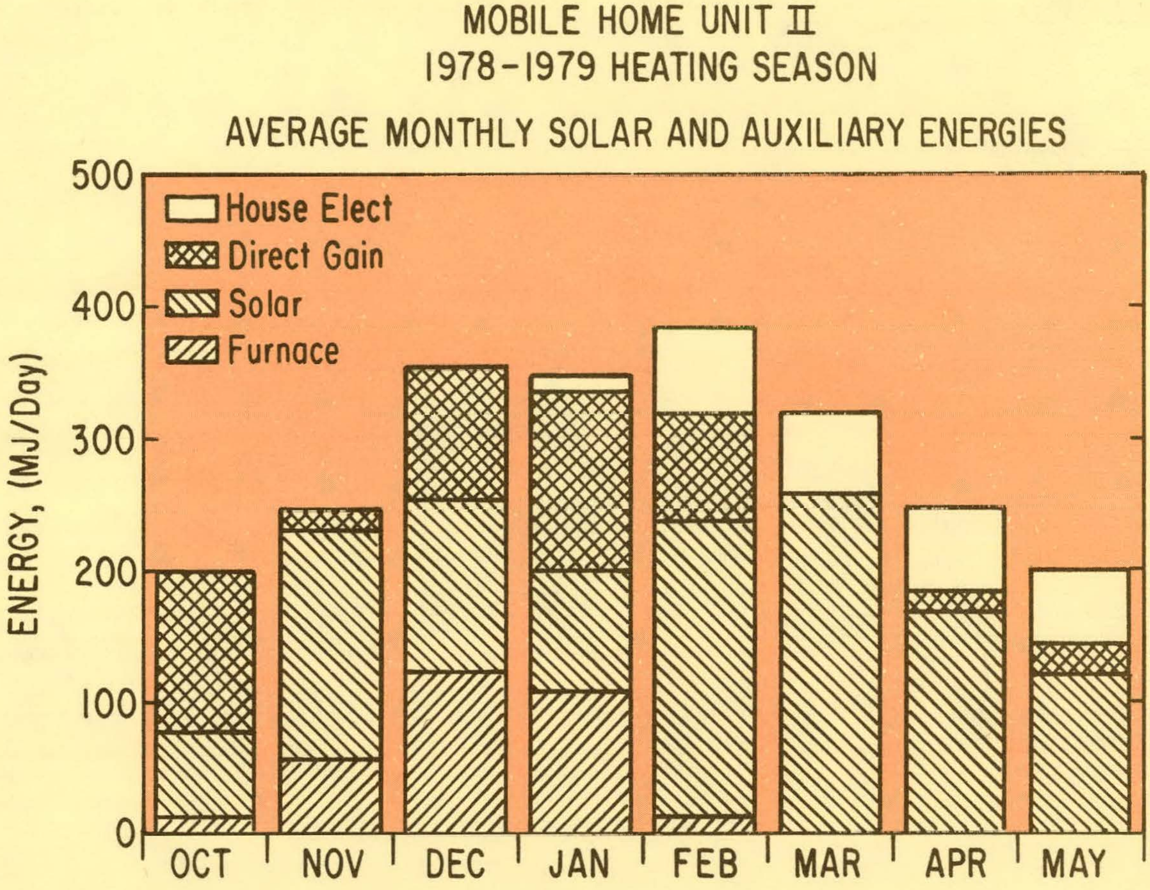
This home has been instrumented and monitored during two heating seasons. A detailed energy balance was performed, separating the solar contributions of the roof pond and direct gain components.

About 80 percent of the building's heat demand is supplied by solar energy. Both experimental tests and computer modeling show that about 30 percent of the demand is supplied by direct gain. However, when the south-facing windows are blocked by insulation, the thermal storage roof can still supply almost 80 percent of the somewhat reduced load, while overheating is reduced.

LASL plans to use the building in the future for more extensive parameter variations in support of computer studies leading to a general Solar Load Ratio method for thermal storage roofs of either water or masonry.



Photograph of LASL's passive modular home showing roof apertures that admit sunlight to the water bags lying on the ceiling.



Bar chart showing the solar and auxiliary energies used by the passive modular home. Starting in January, electric energy was supplied to the house to simulate normal use of lights and appliances.

PROJECT TITLE: **ECONOMICS OF PASSIVE SOLAR VERSUS CONSERVATION**

Institution: *Los Alamos Scientific Laboratory*
Los Alamos, New Mexico

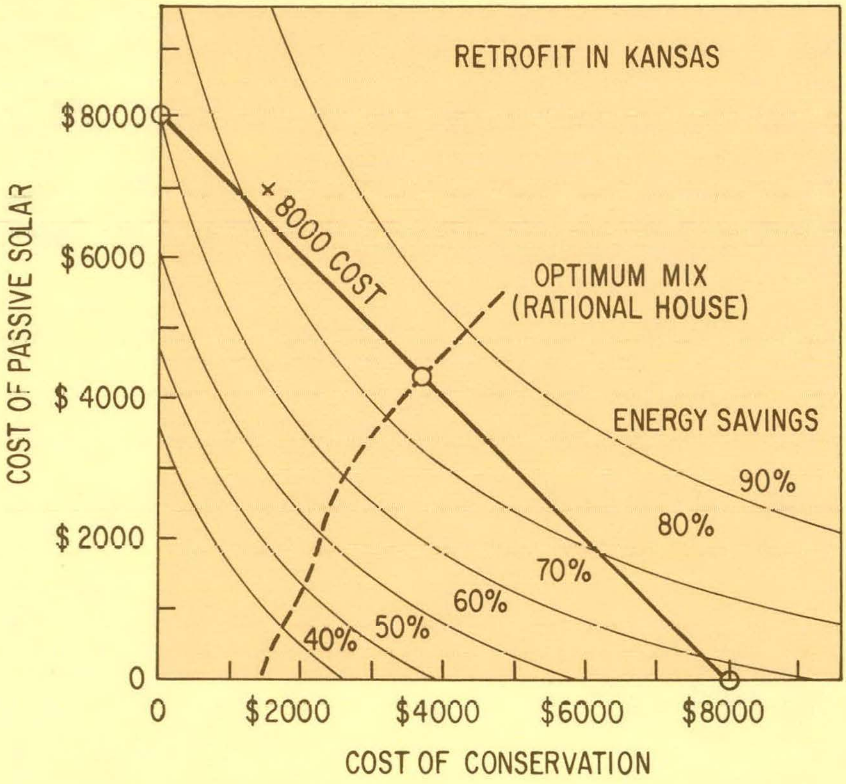
Principal Investigator: *Don Neeper*

Contract Number: *In-house*

LASL has performed calculations and developed a methodology for allocating resources or expenditures between passive solar and energy conservation in an optimum manner. Development of this methodology was possible because LASL's Solar Load Ratio (SLR) correlations enable a rapid estimate of the performance of a passive heating system in any climate.

The goal of continuing efforts is to develop simple tables spelling out the optimum mix of passive solar and conservation for many locations throughout the United States. These results will be especially valuable in retrofit situations.

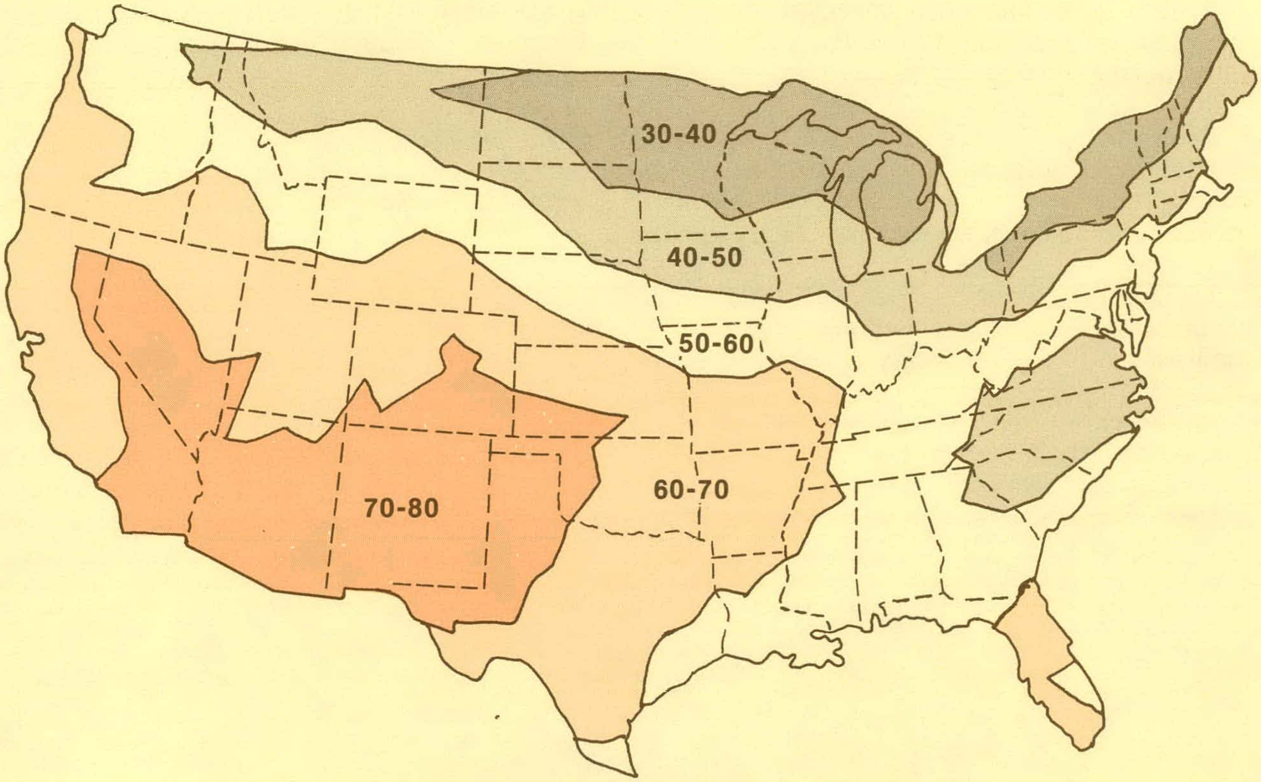
As an example, actual experience involving a residence in the Midwest was used. The cost of reducing the heating load coefficient of the building by a factor of three using external insulation, multiple glazing, etc., is \$8,000. The cost of a Trombe wall on the south side is \$8/ft^2. Based on these costs and the climate data for Dodge City, Kansas, LASL can predict energy savings for a range of expenditures on both conservation and passive solar.



Curves of constant energy savings are plotted as a function of cost of conservation and cost of solar. Any point on the solid line represents a combined \$8000 expenditure for solar and conservation. The locus of points representing maximum energy savings for any expenditure is shown by the dashed line.

A significantly larger energy saving is achievable with a mix of the two strategies compared with either one used alone. For investments up to about $1700, conservation alone is preferred. Beyond this amount, a mixed strategy is best for most situations.

In the northern, cloudier portions of the country, the emphasis is on conservation. The passive solar strategy is preferred in sunnier locales. However, it is profitable to use some amount of passive solar in all parts of the continental United States. Maps have been prepared showing the percent to be spent on passive solar throughout the United States, the energy savings, in barrels of oil, per house per year, that is saved by the mixed strategy; and the fraction of the building load, after conservation, that can be satisfied with solar energy.



SOLAR HEATING PERCENTAGE

Map showing the fraction of heat to be supplied by solar for a particular house design when the optimum mix of conservation and solar is used in each climate. Use of passive solar heating is profitable for the homeowner in all locations.

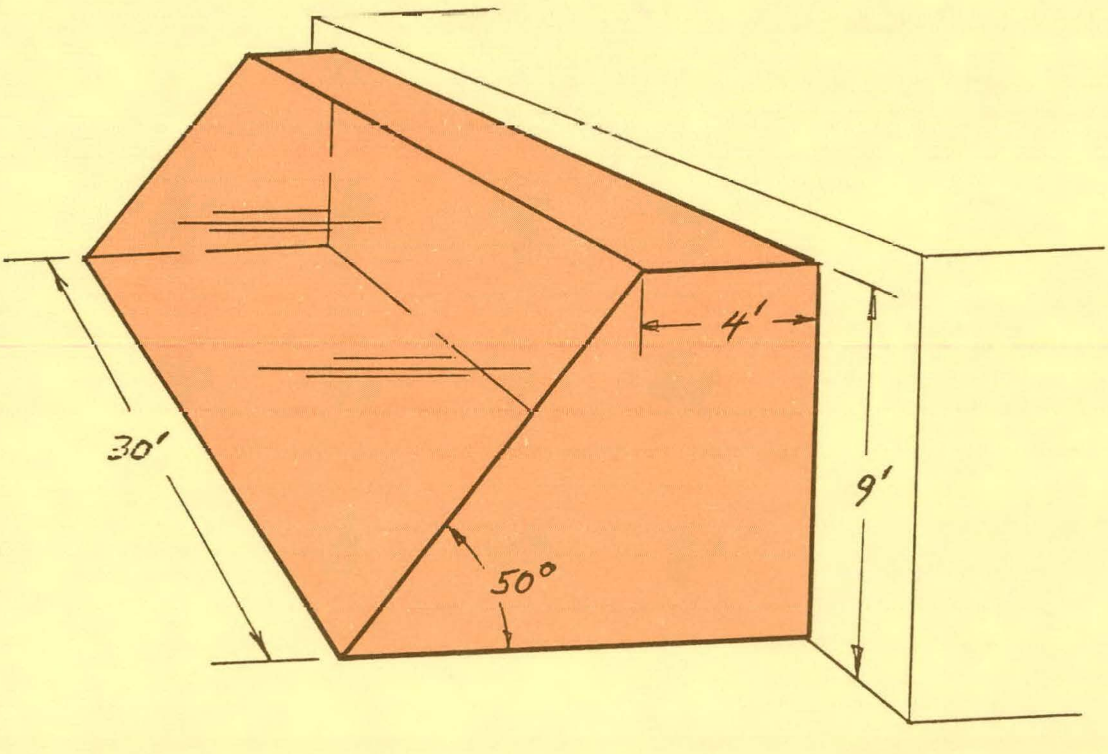
PROJECT TITLE:	**MONTHLY SOLAR LOAD RATIO FOR ATTACHED SUNSPACES**
Institution:	*Los Alamos Scientific Laboratory* *Los Alamos, New Mexico*
Principal Investigator:	*Don Neeper*
Contract Number:	*In-house*

A large and important facet of the LASL passive program involves the development of mathematical modeling techniques for passive solar buildings. Computer models based on thermal network analysis are validated with experimental data from test cells.

Detailed, hour-by-hour solutions of the system's differential equations allow correlation of the monthly and seasonal solar heating to be correlated with average weather characteristics and building heat demand. These simplified correlations, known as the Solar Load Ratio (SLR) method, permit building designers to make quick estimates of the performance of passive solar buildings.

The monthly solar load ratio method requires knowledge of the horizontal isolation and the heating degree-days for each month of the year at a particular location. From the LASL correlations the user can find the monthly or yearly solar savings fraction from graphs or with a hand calculator.

Having completed the SLR method for thermal storage wall and direct gain buildings, LASL is developing this design method for attached sunspaces (greenhouses, atriums, etc.). Initial results show that east and west end-walls of greenhouses should be insulated rather than glazed, and that a single sloping south-facing glazing is better than a design with a glazed roof and vertical glazed wall.



Schematic diagram of a typical attached sunspace for which Solar Load Ratio correlations have been developed.

PROJECT TITLE: **PASSIVE SOLAR DESIGN HANDBOOK**

Institution: *Los Alamos Scientific Laboratory*
Los Alamos, New Mexico

Principal Investigator: *Don Neeper*

Contract Number: *In-house*

This project, 2 years in the preparation, was undertaken by the LASL staff in cooperation with Bruce Anderson of Total Environmental Action, Inc. The original two-section, one-volume concept was expanded to two volumes when the bulk of the material and the disparate nature of the two sections were deemed too great for one document.

Volume One is entitled *Passive Solar Design Concepts* and was written by B. Anderson as a qualitative introduction to the use of passive solar energy. It is meant as a means of pointing out the role passive solar can play, along with energy conservation, active solar, and other options, toward reducing our use of conventional fuels and, thus, helping to solve the pressing energy problem we face.

Volume Two, written by the LASL staff, is entitled *Passive Solar Design Analysis* and is based on technical experimentation and analysis. This volume provides technical design aids for passive solar design, to demonstrate that solar can work well and to provide a means whereby performance of a passive solar building can be predicted in advance. Procedures have been provided to permit builders and architects to consider quantitatively the many complex aspects of such designs in a simple manner without losing the fundamental relationships. An economic analysis has also been included. The two volumes were completed in the spring of 1980 and distributed throughout the solar community. The document numbers are DOE/CS-0127/1 and DOE/CS-0127/2.

Future additions to the *Analysis* portion of the *Handbook* will include sunspaces, parameter studies for direct gain, internal convection in buildings, convective loops, and thermal storage roofs.

PROJECT TITLE: **PASSIVE TEST ROOM PROGRAM**

Institution: *Los Alamos Scientific Laboratory*
Los Alamos, New Mexico

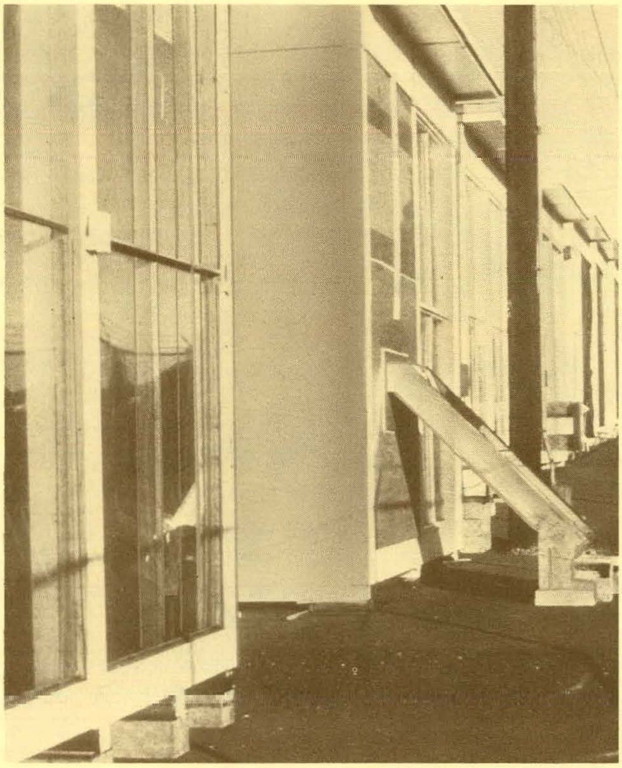
Principal Investigator: *Don Neeper*

Contract Number: *In-house*

The first two small test rooms were built by LASL in 1976 using standard residential construction techniques. They proved to be a very effective means of evaluating passive heating techniques and of obtaining accurate thermal performance data for validating computer codes and models.

LASL now has 14 test rooms (arranged in sets of two with a common wall) measuring 5 feet wide, 8 feet deep, and 10 feet high. The south-facing 5 feet X 10 feet sides are glazed. These test rooms have been designed to be reconfigurable to test many designs and many products; the side-by-side location permits easy comparison of solar heating performance.

Temperatures in the rooms are measured with Chromel/Alumel thermocouples connected to a data acquisition computer system. Weather data are taken at the same site and include horizontal, 45° and vertical-south solar radiation measurements, wind direction and velocity, and wet bulb temperature.



Photograph of the south faces of LASL's passive test rooms.

Rooms have been used to test thermal storage walls (both Trombe and water walls), convective loops, conditions of venting and nonventing, shading, night insulation, phase-change storage walls, multiple glazings, direct gain, and a number of proprietary products.

Before the 1979–1980 heating season, all 14 of the test rooms were converted to allow variation of the heating load and to measure auxiliary power use. Instrumentation and controls were updated to achieve higher precision and better control.

Test room behavior is not intended to be strictly representative of expected behavior of passive buildings. An occupied building would always be operated with auxiliary heating and ventilation to prevent overheating. The principal purpose of the test rooms is to provide comparative data between two approaches under identical conditions, and to provide data for validating computer simulation codes.

PROJECT TITLE: **SIMILARITY STUDIES OF INTERZONE HEAT TRANSFER BY FREE CONVECTION**

Institution: *Los Alamos Scientific Laboratory*
Los Alamos, New Mexico

Principal Investigator: *Don Neeper*

Contract Number: *In-house*

This study was undertaken to determine the influence of the size and geometry of interior doorways, vents, and room orientation on natural convection of thermal energy. As there is little quantitative information available on interzone transport by natural convection, LASL initiated a project to generate the fundamental data.

Generally, passive buildings receive solar radiation in the south-facing zones only. Clerestory windows can be used to admit sunlight to north zones, but this solution is expensive, especially for tract housing. Houses can be constructed only one zone deep, but this restricts the variety of floor plans. Some builders install ducts and fans to distribute warm air around the house, but this solution means higher initial costs and use of electricity to power the fans. If means can be found to enhance natural convection, much could be saved in terms of comfort, money, and electricity.

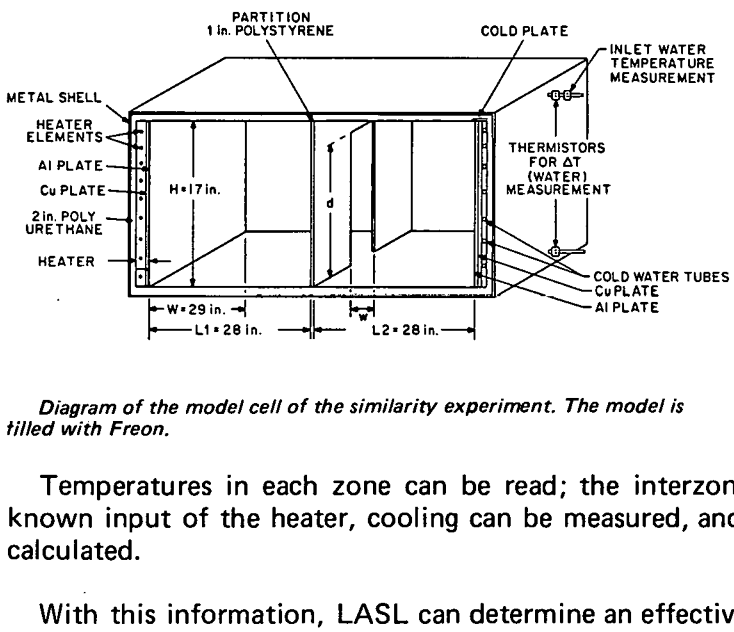


Diagram of the model cell of the similarity experiment. The model is filled with Freon.

The principles of similitude permit LASL to use a small-scale laboratory model to determine transport rates in full-scale prototypes. A two-zone test chamber connected by an aperture of variable geometry simulates two rooms in a house connected by a doorway or other opening of variable size. An electric resistance heater simulates solar gains and an air-water heat exchanger removes heat from the second zone, setting up a convective loop through the aperture. Use of Freon as the gaseous medium permits the model to be about one-fifth the size of the system being simulated.

Temperatures in each zone can be read; the interzone transport rate can be determined from known input of the heater, cooling can be measured, and losses through the chamber's shell can be calculated.

With this information, LASL can determine an effective conductance for interzone transport as a function of the difference between average room temperature and the geometric parameters of the aperture. Data already obtained indicate that heat transport through an ordinary door 7 feet high could be doubled if the door extended all the way to an 8-foot-high ceiling. Furthermore, the data show that the interzone transport rate in an actual building can be inferred by measuring the temperature profile in a doorway.

Measurements in one full-scale room agreed with predictions based on data from the similarity model, thus supporting the similarity method.

PROJECT TITLE: **PHASE-CHANGE THERMAL STORAGE EVALUATION**

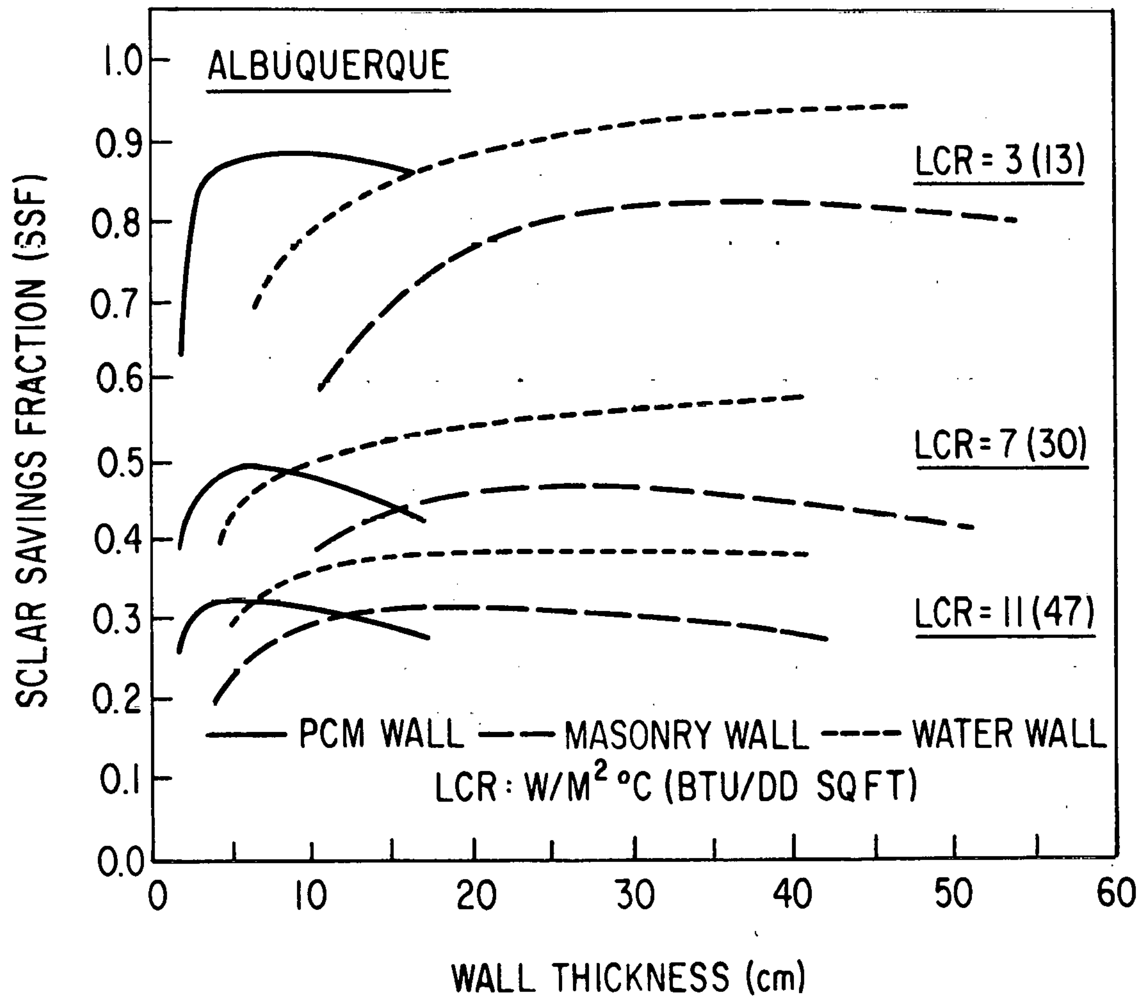
Institution: *Los Alamos Scientific Laboratory*
Los Alamos, New Mexico

Principal Investigator: *Don Neeper*

Contract Number: *In-house*

A phase-change material is one which changes form, or melts at a fairly low temperature, absorbing large quantities of heat. As it recrystallizes, it releases that heat. This type of material is used for passive thermal storage because of its ability to store thermal energy in a compact volume of lightweight substance.

Two test rooms have been configured with $CaCl_2$ phase-change storage walls in order to evaluate the performance of such walls over a heating season, and to compare their performance with concrete and water storage walls.



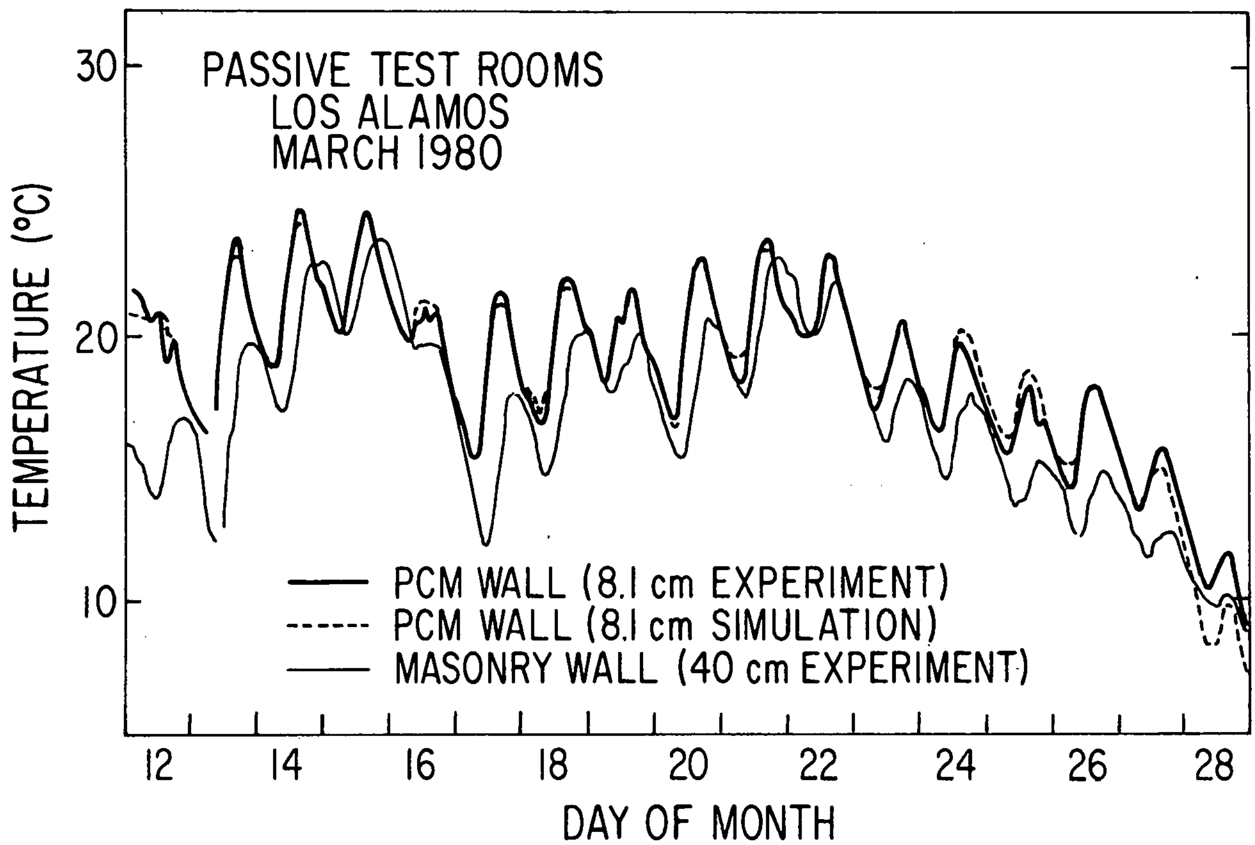
Calculated and measured time history of room temperature in the test cell with a storage wall of PCM boxes. The measured room temperature in a neighboring test cell using a 40 cm-thick masonry wall is shown for comparison.

One room was outfitted with a wall of Dow factory-made black tubes filled with $CaCl_2$ mounted in a rack behind the south-facing glazings. The space between the tubes permitted thermocirculation of room air around the tubes and against the glazing. The other test room was constructed with a slurry of $CaCl_2$ and diatomaceous earth, packed in black plastic boxes. The diatomaceous earth prevents phase separation and consequent irreversibility of the melting process. The boxes were arranged in shelves behind the glazing. Spaces between boxes were filled with foam insulation to prevent thermocirculation of air.

This study will allow LASL to determine if phase change walls perform better than traditional thermal storage walls of water or masonry. The effects of thermocirculation will also be studied.

A mathematical model of phase-change passive thermal storage is being validated with data from test rooms and test boxes.

Preliminary results indicate that the solar savings fraction of a phase-change wall is only slightly higher than that of a conventional storage wall. The major advantages of a phase change wall will be due to its small volume and increased thermal comfort.



Comparison of calculated seasonal solar savings fraction supplied by a PCM wall, masonry wall, and water wall as a function of wall thickness for Albuquerque. Each set of curves is for a particular Load/Collector Ratio (LCR), which is a measure of building heat demand and collector size.

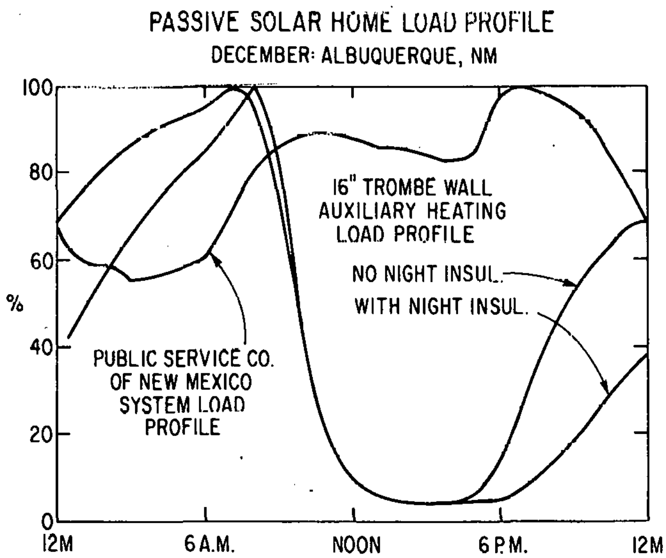
PROJECT TITLE:	**STUDY OF OFF-PEAK ELECTRICAL AUXILIARY HEATING IN PASSIVE BUILDINGS**
Institution:	*Los Alamos Scientific Laboratory* *Los Alamos, New Mexico*
Principal Investigator:	*Don Neeper*
Contract Number:	*In-house*

Most passive solar buildings require auxiliary energy during extended periods of cloudy weather. In many cases, electricity is this backup energy source because of its general availability and low initial cost to the homeowner.

Electric utility companies have feared that passive solar buildings could exacerbate the peak load while paying less revenue due to low annual consumption. However, LASL has noted that the auxiliary heat demand of a passive building falls largely during the off-peak early morning hours. This study is a joint effort with a housing developer and the utility (Public Service Company of New Mexico) to design and test an electric auxiliary heating system that operates strictly during off-peak hours.

Large heating mats are buried several inches below the floor of a direct-gain house in Santa Fe. The anticipated auxiliary heat generated by the mats slowly diffuses to the floor, and is subsequently released into the house. This anticipation of heat demand by up to 1 day requires optimized location of the mats and control by a microprocessor.

LASL has performed the calculations for optimized design and is preparing the controller. LASL has guided installation of monitoring equipment and will subsequently evaluate the data from this house.



Graph of the December monthly average demand for auxiliary heat by a passive house with and without night insulation, versus time of day. For comparison, the system demand for electricity supplied by the utility company is shown. All curves are shown as percent of peak. Note that the peak energy demand of the passive house occurs during the period of minimum demand on the utility.

PROJECT TITLE: **THERMAL PERFORMANCE OF PASSIVE COMPONENTS OR BUILDINGS**

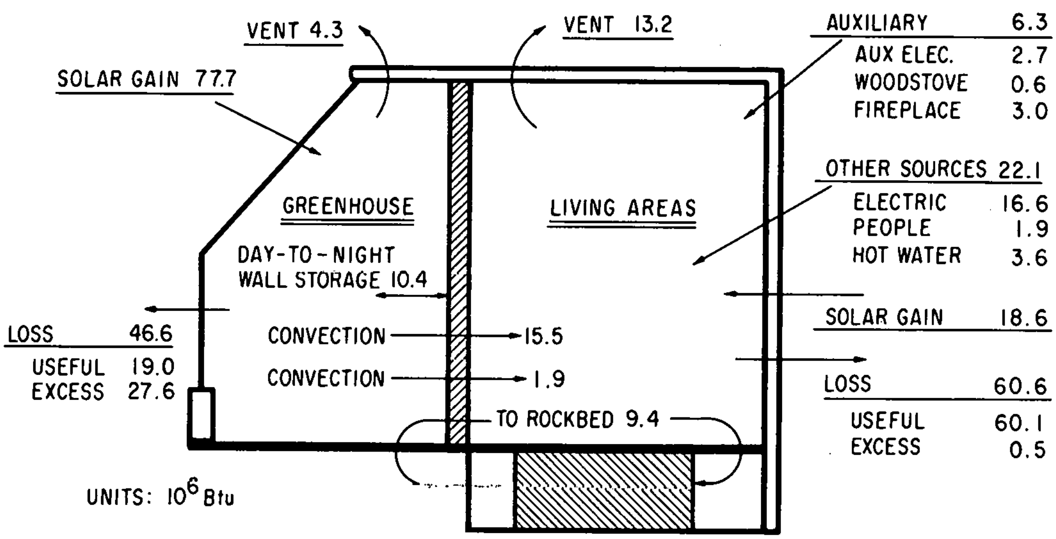
Institution: *Los Alamos Scientific Laboratory*
Los Alamos, New Mexico

Principal Investigator: *Don Neeper*

Contract Number: *In-house*

There are two main purposes to this program: to record the thermal comfort and energy savings characteristics of a variety of privately built passive solar buildings and to provide validation data for calculations of the behavior of the monitored components of the buildings.

Instrumentation installed in these buildings consists of thermocouples to measure temperature, a pyranometer to measure solar radiation, and an anemometer and wind vane to measure wind velocity and direction. Auxiliary energy use is measured where feasible and, if fans or movable insulation is present, changes in their state are recorded.



Schematic diagram of the seasonal energy flows in the Balcomb house with attached sunspace.

Because these buildings are of complex geometry and are occupied by the owners, calculations regarding behavior of passive buildings are more difficult to perform (than numerical modeling of test rooms). However, it is possible to observe certain key temperatures and to develop certain rules of thumb regarding effective passive design.

LASL has monitored 14 privately owned passive buildings over the past several years, and present efforts are concentrating on analysis of the data from monitored buildings, and on obtaining detailed data on sections or components of a few buildings.

PROJECT TITLE:	**MARKET RESEARCH/PROGRAM SUPPORT**
Institution:	*Market Facts* *Washington, D.C.*
Principal Contact:	*Dick Ross, Market Facts; Peter Ketals, SERI*
Contract Number:	*BO-9-8376-1 (under contract to the Solar Energy Research Institute)*

This project is for the purpose of achieving the following objectives:

- The design of a Program Area Plan for Market Research necessary to support the national passive solar effort in the residential market sector.
- Allow a representative from Market Facts to attend "Class C" energy audit review/coordination meeting to be held in Vermont, February 25–26, 1980.
- Implement the first research identified as part of the plan formulated in the first objective listed above: national passive solar market surveys.
- Review of the program plan and initial results of the preliminary research will be presented at a meeting to be held in Washington, D.C. March 4, 5, 6, 1980.

In order to accomplish the above objectives Market Facts will be required to meet with representatives of the RSEC's, SERI and DOE. In addition, the subcontractor will prepare recommendations for additional market research support for the national Passive Solar Program and initiate the design of the first research phase.

PROJECT TITLE: **PERFORMANCE EVALUATION PROGRAM SUPPORT**

Institution: *Memphremagog Group, Inc.*
Newport, Vermont

Principal Contact: *Blair Hamilton, TMG; Sharyn Towle/Dan Frey, SERI*

Contract Number: *AM-9-8223-1 (under contract to the Solar Energy Research Institute)*

The Memphremagog Group is a nonprofit research and educational organization concerned with the development and widespread application of appropriate technologies. Memphremagog is providing professional management, coordination and other support services for the performance evaluation program described in SERI's "Program Area Plan for Performance Evaluation of Passive/Hybrid Solar Heating and Cooling Systems."

Included are the following specific tasks:

- Organize, convene and report on periodic meetings of the System and Market Development Working Groups described in the Program Area Plan and coordinate performance evaluation efforts to meet System Development Group and Market Development Group data needs.

- Work with the organizations in the two Working Groups to plan new activities to be undertaken under the auspices of the Performance Evaluation Program and write supplementary material for addition to these activities. The contractor shall also modify and update the Program Area Plan as new information is developed and feedback is acquired during program implementation.

- Provide technical and administrative support to the organizations charged with task implementation under the Program Area Plan.

- Review activities conducted under the Performance Evaluation Plan of passive/hybrid systems in FY 1980 and recommend changes in the program for subsequent years.

- Provide coordination among the System and Market Performance Working Groups, SERI, NBS, LBL, LASL, the National Solar Data Network Program, the current national market research effort for passive systems and other programs and organizations conducting similar performance evaluation efforts.

PROJECT TITLE: **INSTITUTIONAL**

Institution: *Mid-American Solar Energy Complex*
Minneapolis, Minnesota

Principal Investigator: *David Pogany*

Contract Number: *In-house*

Solicitations will be sent to cities, counties, and Regional Planning Authorities within the MASEC region through the State Solar Offices to organize a solar subdivision development working committee and to submit a proposal to promote a solar subdivision. This committee (at a minimum) will consist of representatives from the mayor or city manager's office, the local codes department, the finance, real estate, and architectural industries, as well as local consumers and members of local trade unions and utilities. The subdivision to be developed will be described in a proposal containing a list of locally available support resources. A MASEC Source Evaluation Board will select the subdivisons to be funded, based on the quality of the proposal, personnel, geographic location, and population to be served. Committee members of both successful and unsuccessful proposal teams will be invited to attend workshops and seminars for a general discussion of solar codes, standards, consumer protection, land use, energy planning, financing, and utility needs. The workshops will consider available blueprint designs and future training sessions for architects and builders.

Proceedings from these workshops and seminars will be published and distributed.

The selected proposal teams will be funded for operating expenses, development work, and travel requirements. Communities will be asked to use local private funds and federal funds, such as the HUD Community Block Development Grants and CETA.

The proposal teams will submit progress reports and plans for future development to MASEC.

PROJECT TITLE: **MARKET TEST (DESIGN/BUILD TEAMS)**

Institution: *Mid-American Solar Energy Complex*
Minneapolis, Minnesota

Principal Contact: *David Pogany*

Contract Number: *In-house*

The primary objective of this effort is to establish and train design-build teams for solar buildings. Solicitations will be issued by MASEC and the recipients will be responsible for all aspects of designing and constructing passive solar structures. The solicitations will be issued for each of the following areas:

- Single-family retrofit
- Multifamily new construction townhouses and condominiums
- Multifamily new construction low income housing and apartments
- Multifamily retrofit
- Light commercial new construction.

Several awards per solicitation are anticipated.

Selected designs will be promoted and distributed through appropriate channels throughout the region.

PROJECT TITLE: **MASEC SOLAR 80 PROGRAM**

Institution: *Mid-American Solar Energy Complex*
Minneapolis, Minnesota

Principal Investigator: *David Pogany*

Contract Number: *In-house*

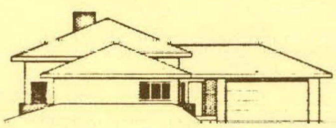
This project funded the designs of a series of passive solar homes as part of the MASEC SOLAR 80 program. MASEC selected and contracted with 10 design teams to design aesthetically appealing, livable homes that are highly energy efficient.

The illustration shows some of the designs generated. Additional information may be obtained by writing:

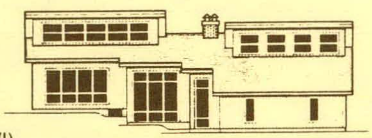
SOLAR 80
The MASEC Center
8140 26th Avenue South
Minneapolis, Minnesota 55420

SOLAR 80
Home Feature Comparison

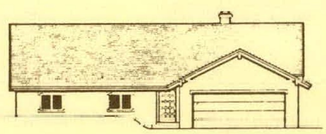
The RidgeWay/27001
- 1640 square feet
- 3 bedrooms
- 3 bathrooms
- 2 car, attached garage
- *$110,000 (Plymouth, MN)



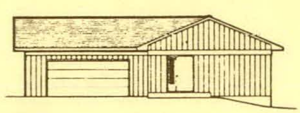
The ClaireMont/27002
- 1800 square feet
- 3 bedrooms
- 2 bathrooms
- 2 car, attached garage
- *$78,000 (Eau Claire, WI)



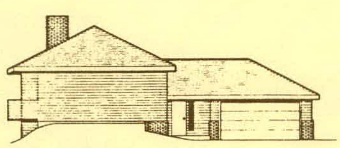
The SolarWay/27003
- 1433 square feet
- 3 bedrooms
- 2 bathrooms
- 2 car, attached garage
- *$64,000 (Indianapolis, IN)



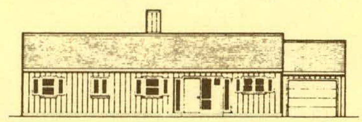
The KirkWood/27004
- 1200 square feet
- 3 bedrooms
- 2 bathrooms
- 2 car, attached garage
- *$56,000 (Cedar Rapids, IA)



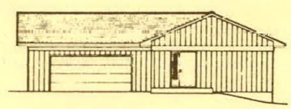
The SunSource/27005
- 1500 square feet
- 3 bedrooms
- 2 bathrooms
- 2 car, attached garage
- *$110,000 (Minneapolis, MN)



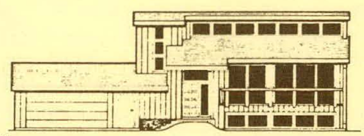
The ParkLand/27006
- 1400 square feet
- 3 bedrooms
- 2 bathrooms
- 1 car, attached garage
- *$65,000 (St. Louis, MO)



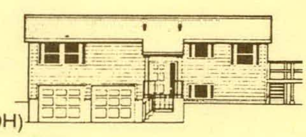
The CedarWood/27007
- 1200 square feet
- 3 bedrooms
- 2 bathrooms
- 2 car, attached garage
- *$56,000 (Cedar Rapids, IA)



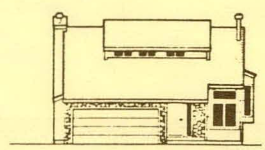
The SunRise/27008
- 2000 square feet
- 3 bedrooms
- 2½ bathrooms
- 2 car, attached garage
- *$80,000 (Eau Claire, WI)



The SunCrest/27009
- 1450 square feet
- 3 bedrooms
- 1 bathroom
- 2 car, attached garage
- *$55,000 modular (Vandalia, OH)
- *$65,000 conventional (Vandalia, OH)



The WaterFord/27010
- 1800 square feet
- 3 bedrooms
- 2½ bathrooms
- 2 car, attached garage
- *$85,000 (Waterford, MI)



**Construction cost estimates based on labor and material costs in cities indicated in spring, 1980. Lot price not included.*

PROJECT TITLE:	**PASSIVE SMALL WORKSHOPS**
Institution:	*Mid-American Solar Energy Complex* *Minneapolis, Minnesota*
Principal Contact:	*David Pogany*
Contract Number:	*In-house*

One of the most effective educational media is through well-planned seminars and/or workshops. As part of MASEC's overall commercialization activities for passive solar energy, a number of workshop programs are being established. The subject matter of these workshops will be oriented toward specific market application areas, e.g.:

- Agricultural – These programs are designed to familiarize agricultural engineers with solar agricultural structures for such purposes as swine confinement, tool sheds, grain dryers, and dairy applications. Information pertaining to financing alternatives with specific emphasis on Farmer's Home Administration Loans will also be presented.

- Model Codes – These programs will be directed toward building code organizations and public interest groups. Additionally, this effort will provide logistical support at state and local levels and facilitate acceptance and use of national concensus standards, codes, guidelines, and certification efforts.

- Distributors – These programs are in seminar format and oriented toward managers of lumberyards, HVAC distributors, and building supply wholesalers.

- Schools and Hospitals – This activity involves supporting solar planning and design of schools and hospitals contained with a federal grants program for building structures of that type.

- Financial – These activities support the development of financial workshops through press releases, cosponsorship, state/local liaison and on-site conference assistance. A program will also be developed describing passive solar funding need in the Mid-America region. This program will be oriented toward charitable Foundations and presented in tutorial format to the staffs of these organizations.

PROJECT TITLE:	**PASSIVE SOLAR VOCATIONAL-TECHNICAL TRAINING INSTITUTE**
Institution:	*Mid-American Solar Energy Complex* *Minneapolis, Minnesota*
Principal Contact:	*David Pogany*
Contract Number:	*In-house*

MASEC will work with schools of continuing education or similar organizations throughout the region to develop a one-week long passive solar training institute. The courses will be offered during the summer of 1980 within the MASEC region. This institute will focus on materials developed by the Advanced Solar Design workshops and the *SOLAR 80* homes programs conducted by vocational schools within the MASEC region during FY79. Schools under contract with MASEC will be responsible for writing and teaching passive solar courses to attendees. Twenty-five instructors chosen by MASEC on a competitive solicitation basis will attend the institute. In effect, this project will orient teachers and encourage the growth of passive solar construction courses within the community colleges and vocational-technical institutes throughout the region.

PROJECT TITLE: **PASSIVE SOLAR DESIGN/SINGLE FAMILY RESIDENCES**

Institution: *National Association of Home Builders, Research Foundation, Inc.*

Principal Investigator: *Ralph Johnson*

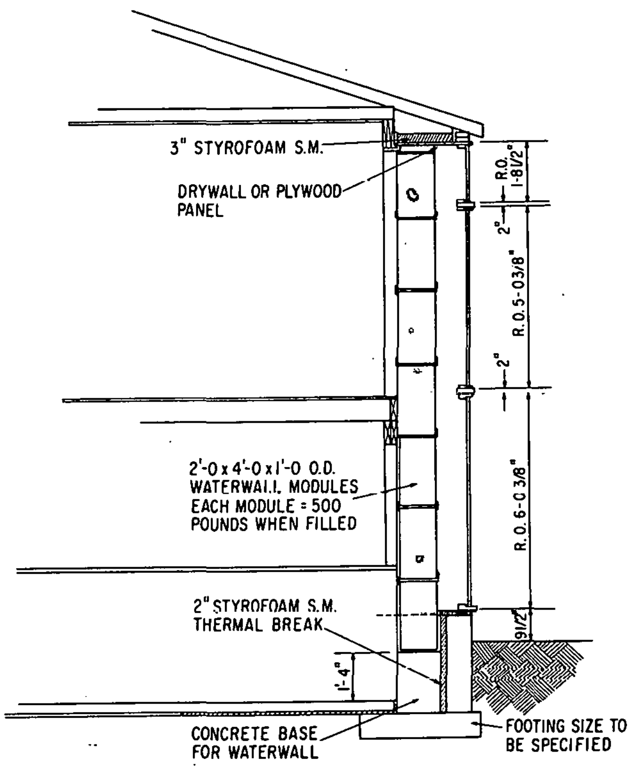
Contract Number: *DE-FG02-79CS30300*

This project represents the development of passive solar design single family residences. NAHB is serving as developer coordinating all facets of the design, construction and performance evaluation process with Ryan Homes, Inc. as a member of the project team.

The design approach, even in the conceptual stage, will attempt to incorporate the most innovative, meaningful and cost efficient features by surveying knowledgeable governmental and building industry personnel. To ensure designs of highest quality and market appeal, major decisions will be made by an Advisory Committee including an architect/engineer with extensive home building experience and representatives of large volume home building operations. Advice will also be solicited from the DOE technical representatives and the national laboratories.

Design criteria will include: estimated additional first cost and indirect effect, if any, on reducing or adding to related costs; reduction in operating cost as a result of passive solar energy collection; construction system feasibility; materials and labor, and appropriateness of the technique for the overall dwelling design. Presently four home designs are being developed:

- "base" house
- sun tempered/direct gain
- water wall
- phase change/selective surface.



The lots selected for the passive solar homes provide unobstructed access to the sun's energy. This will permit the use of a number of the builder's homes for visual comparison with the passive solar demonstration homes. In addition, this would permit DOE or one of its subcontractors to monitor a typical house along with the passive solar home.

The Foundation will develop the design and prepare the final working drawings and specifications for the passive solar dwelling to be similar in size and type to one of the selected builder's basic models.

The Foundation will also estimate construction cost differences and operating cost benefits that should result from the use of the selected passive solar energy features in relation to the builder conventional home. This information will be used to verify the selected passive solar features.

PROJECT TITLE:	**OPTIMIZING SOLAR UTILIZATION THROUGH GLAZING USAGE IN RESIDENTIAL BUILDINGS**
Institution:	*National Fenestration Council* *Topeka, Kansas*
Principal Investigator:	*Albert F. Lutz, Jr./William Birch*
Contract Number:	*DE-FG03-80CS30229*

The National Fenestration Council is a not-for-profit corporation which includes manufacturers of windows and doors, skylight and space enclosures, glazing materials, fenestration component suppliers, and trade and professional associations.

NFC will conduct a three-phase project to provide research data and practical handbooks on optimizing solar utilization through the southerly-facing glazing of low-mass residential buildings.

During Phase I, various computer analyses for typical low-mass residential buildings will be performed to determine the independent and interdependent effects of thermal mass, orientation, latitude, climate, shading, wind velocity and infiltration on heating and cooling loads related to southerly-facing glazing.

Phase II will involve analysis of the computer data from Phase I and determine optimum glazing areas for passive solar heating and natural ventilation for a range of low-mass residential buildings. One or more designs will be selected for detailed analysis and construction to verify design parameters.

During this phase, NFC will consult with the National Association of Home Builders (NAHB) to ensure a representative sampling of current residential styles and types are used to check design parameters. One or more residential building types will be constructed in cooperation with NAHB to verify the analysis methods. Temperatures and fuel usage will be monitored to verify experiences of homeowners with the design assumptions.

Phase III work will be to condense the collected data into various handbooks for architects, planners, home builders, engineers and code officials that will explain passive solar heating through conventional glazing, show example calculations, and provide suggestions for site planning and design. Necessary modifications of existing building codes and standards will be proposed so as to allow early application of the principles.

In this phase, NFC will work with the AIA Research Corporation and NAHB Research Foundation to produce a variety of design aids for site planning of south-oriented housing developments and for a variety of one- and two-story house plans with entry and street access in different locations.

PROJECT TITLE: **PASSSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**

Institution: *National Homes Manufacturing Company*
Lafayette, Indiana

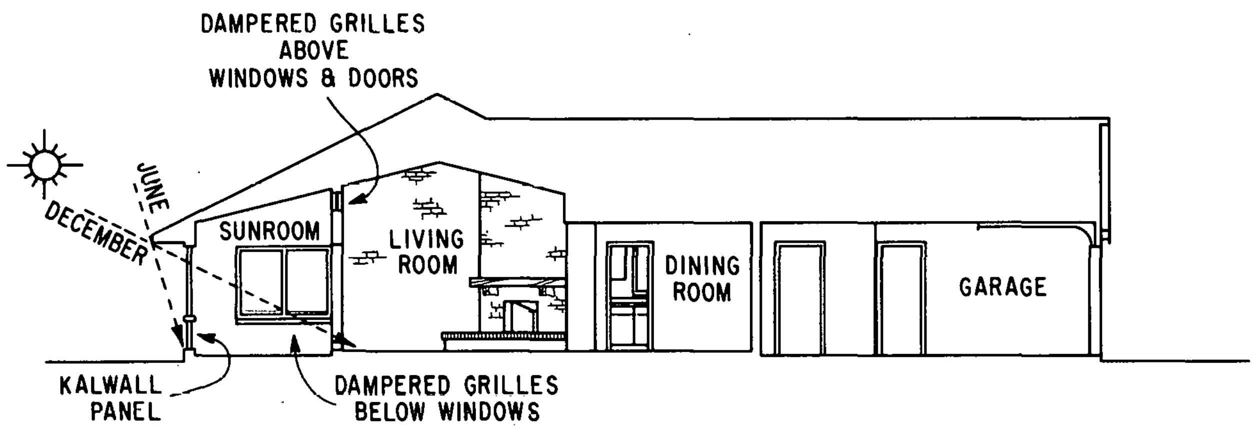
Principal Investigator: *Steve Wilson*

Contract Number: *DE-FC02-80CS30377*

National Homes Manufacturing Company of Lafayette, Indiana, is a large public firm engaged in the manufactured housing business. National Homes has proposed to develop three passive solar building designs:

- Model One will consist of a conventional model modified to optimize passive solar energy without using new materials and without adding extra cost
- Model Two will be a new model that will use new design concepts and/or new construction materials to increase the passive solar contribution at little or no extra cost
- Model Three will consist of new passive design concepts and/or materials to optimize the passive solar contributions at a moderate cost increase.

The models to be used for passive solar concepts will be designed for the Indianapolis, Indiana, area. Passive solar will then be adapted as necessary to accommodate other locations and climates.



SECTION THRU SUNROOM & LIVING ROOM

PROJECT TITLE: **CONSUMER EDUCATION**

Institution: *Northeast Solar Energy Center*
Cambridge, Massachusetts

Principal Contact: *Didier Thomas*

Contract Number: *In-house*

The accelerated commercialization of passive solar energy is directly dependent upon the knowledge of the potential users. Consumers, in general, are unfamiliar with the variety of solar applications available and the ways these applications can be applied towards reducing energy needs.

The purpose of this program is to develop the educational channels to increase public awareness of passive solar energy by supporting the preparation and promotion of passive solar energy course materials. Current work emphasizes a cooperative effort with the region's state department of adult education, energy offices, and the full range of institutions offering courses to the general public. The work plan involves the following tasks:

- Dissemination of the passive solar/conservation *adult education* curriculum in New Jersey and Maine (the pilot states of the FY79 Program) as well as distribution to the other states in the region and general coordination of the overall program
- Circulation of the grade level 4 to 8 "Solar Works" kits developed in FY79 and preparation of similar kits for grade levels 9 to 12 for incorporation into the DOE solar curriculum package
- Assistance to community groups and citizens' associations by providing funding, material and technical support, for their solar-related activities.

Accomplishment will be measured via quantitative evaluations and analyses of data submitted by project participants and key user groups.

PROJECT TITLE: **INCENTIVES**

Institution: *Northeast Solar Energy Center*
Cambridge, Massachusetts

Principal Contact: *Didier Thomas*

Contract Number: *In-house*

Existing statutes, regulations, building codes, consumer protection measures and governmental financial incentives have generally related to active solar systems. The rapid emergence of passive solar technology has created a need for placing greater emphasis on working to implement similar legislation for passive systems. This project activity will be to provide support to state regional and federal efforts to eliminate institutional barriers and develop incentives to promote more widespread application of passive solar systems. Pertinent tasks include the following:

- Working with state governments to develop legislation and regulations that remove legal barriers to the use of passive solar systems; establishing tax and other financial incentives to complement this effort
- Providing assistance to local governments in removing barriers that exist in subdivision regulations, planning documents, and zoning and building codes
- Assisting the financial community in establishing programs for builders and buyers of passive solar buildings
- Efforts to reconcile the differences between passive solar systems and energy conservation codes.

The output of these efforts will include reviews and suggested amendments to Federal and state laws and regulations as well as local ordinances and codes; testimony before various government boards; and suggestions on types of incentives.

PROJECT TITLE: **PASSIVE MARKET DESIGN DEVELOPMENT**

Institution: *Northeast Solar Energy Center*
Cambridge, Massachusetts

Principal Contact: *Didier Thomas*

Contract Number: *In-house*

The objective of this project is to make available the most noteworthy of the award-winning regional designs for passive single-family and multifamily buildings to the home-buying public and housing developers.

This project will publish a book of house and multifamily development plans which appeal to home buyers, homebuilders, and potential housing developers in the Northeast Region. It is anticipated that 5 multifamily prototype designs, 5 residential designs meeting BEPS standards, and 10 residential design build teams will be established before the end of 1980.

PROJECT TITLE: **PUBLIC INFORMATION**

Institution: *Northeast Solar Energy Center*
Cambridge, Massachusetts

Principal Contact: *Didier Thomas*

Contract Number: *In-house*

A major function of the Regional Solar Energy Centers is to foster an awareness of the seriousness of the energy problem to the general public as well as business, industry and labor organizations. This involves supplying information on the viability of passive solar technology as an alternative to depletable energy sources. The main objective of this task is to promote an awareness and better understanding of passive solar technology and the benefits it offers over traditional energy sources. Primary emphasis will be made on cost and energy savings to positively influence public attitudes.

Promotional activities will involve the following numerous work tasks:

- Assessing regional passive solar information needs by monitoring general and trade publications and by identifying opportunities for placement of news and feature articles
- Preparing announcements on economic and financial incentives and performance characteristics of passive solar systems for use by various media
- Writing public service announcements, holding passive solar press conferences, and distributing radio and television news releases
- Sponsoring educational seminars and speakers bureaus.

Monthly reviews will be conducted to ascertain the effectiveness of current efforts and formulate direction of future promotional activities.

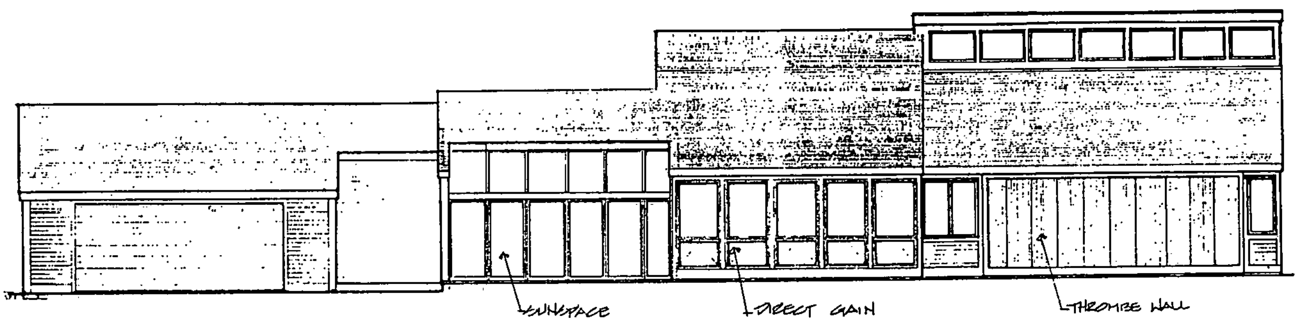
PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Northern Homes of Pennsylvania, Inc.* *Chambersburg, Pennsylvania*
Principal Investigator:	*Joseph R. Carusone*
Contract Number:	*DE-FC02-80CS30378*

The objective of this program for Northern Homes is to prepare a home design package that will include the development of a modular passive solar energy system concept that can be readily adapted to the customer's varying requirements. This design package will be ready for manufacture and can be used in conjunction with Northern Homes' already established estimating procedures, providing an accurate cost estimate for the structure.

Design Approach

During design, the following passive solar applications will be considered:

- Energy analysis of present line homes — The purpose of which is to determine the effectiveness of various conservation techniques
- Establishment of an energy budget for the new structure
- Establishment of design requirements that includes comfort level, incremental cost for passive systems, architectural capability, functional use, maintenance and security, site and orientation, and modularity
- A multilevel screening process of the various design alternatives to select the most cost-effective systems.



SOUTH ELEVATION

Northern Homes has selected its basic two-story model as the product line for incorporating cost-effective passive systems. Pennsylvania has been selected as the target area for the passive solar home. This prototype building will be used for a minimum of 1 year for the purpose of prototype testing and preliminary market promotion.

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Pan Abode, Inc.* *Renton, Washington*
Principal Investigator:	*Pete Perez*
Contract Number:	*DE-FC02-80CS30379*

Pan Abode Cedar Homes, Inc., is a privately owned company located in Renton, Washington. Pan Abode, Inc., has 26 years experience in designing, producing, and building energy-efficient solid wall cedar units.

Pan Abode, Inc., proposes to introduce a passive solar energy system in one of their basic building models known as the "Cavalier." This unit currently sells from $30,900 to $38,700 and contains 1,540 sq. ft.

The design approach is to determine the design modifications desired to convert each side of the building model into the south side of a passive solar house. The design system will include:

- Modifying building windows to allow each side (in turn) to be the south side of a direct gain house
- Adding to each side of the building (when that side is on the south) an energy wing
- Tests to measure air infiltration in the model house.

Marketing and Testing

Pan Abode units are sold throughout the United States, but a prototype unit will be constructed in the Seattle area, and the building will be completed by one of Pan Abode's construction crews.

Test marketing can be accomplished in a large variety of markets. The selection of these markets will depend on the final design, its costs relative to alternate building methods, and the availability of dealer capital to undertake purchase and construction of these models.

PROJECT TITLE:	**PASSIVE WATER WALL AND FOCUSING ROOF APERTURE SOLAR HEATING BUILDING EXPERIMENT**
Institution:	*Princeton Energy Group* *Princeton, New Jersey*
Principal Investigator:	*Harrison Fraker, Jr.*
Contract Number:	*EG-77-G-04-4149*

This project involves the design, construction, instrumentation, and monitoring of a building experiment using a passive focusing roof aperture system operating with a passive water wall with movable insulation/reflectors.

Using computer simulation, a preliminary network model analysis of critical nodes for both focusing roof aperture and water wall has been performed. Design parameter optimizing has been conducted, resulting in recommended design configurations for the focusing roof aperture.

A modified version of an existing "Omnibus" instrumentation package has been installed in a novel passive solar house near Winchester, Virginia. The data acquisition system was installed in November 1978, and has been operated successfully since that time.

PROJECT TITLE: **ANALYSIS OF THE PASSIVE SOLAR/ELECTRIC UTILITY INTERFACE**

Institution: *Public Service Company of New Mexico*
Albuquerque, New Mexico

Principal Investigator: *O. W. Wehlander*

Contract Number: *DE-AC04-79CS30173*

The Department of Energy has identified "passive" as a solar technology slated for early commercialization. Technical feasibility has already been proven in many structures and, as design techniques are continually refined, applications, particularly at the architectural design level, will grow. What is necessary for rapid commercialization is development of builder/developer and consumer confidence in reliability of performance and economic viability. Another aspect of commercialization that must also be considered is the more far-reaching impact the technology will have on electric utilities. Most utilities, although promoting the use of solar technologies, are concerned about electricity being used for the backup systems. This is a real concern with passive solar since the lowest initial cost backup system is usually some form of electric resistance heater.

The major thrust of this project is to study passive solar design with electrical backup systems and the resultant impact on the utility network. Study of advanced water conservation techniques is also included as part of the scope of work of this effort.

Some of the objectives of this project are to:

- Demonstrate that owner/utility compatible heating systems, in this case, passive design with electric backup, can be implemented.
- Quantify the energy-saving potential of passive solar element incorporation in homes constructed by a builder/developer.
- Identify benefits or potential problems utilities may encounter in distribution and supply of electrical energy to a large number of this subclass of structures.
- Measure effects of community water conservation design and relate that to potential energy savings from decreased pumping requirements.
- Disseminate findings and information learned from the project in a timely fashion, both at the local and national level, to potential home buyers, builder/developers, architects, and utility companies.

Through the joint efforts of Public Service Company of New Mexico (PNM), Los Alamos Scientific Laboratory (LASL), and the builder/developer (Communico), the DOE-funded instrumentation and monitoring system can provide the proving ground for commercialization enhancement.

One home of the 19-home passive solar community will have designed into it a load-managed electrical backup system. The home and its system will be monitored for solar performance and energy consumption. Other homes within the development will be monitored for their energy consumption and limited space conditions. The community will be monitored as a whole to analyze diversified electrical demand. Advanced water conservation techniques will also be implemented and monitored to quantify the impact of conservation of this resource. Documentation and dissemination of data and information will follow as findings are compiled.

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Ryan Homes, Inc.* *Pittsburgh, Pennsylvania*
Principal Investigator:	*Richard H. Tracey*
Contract Number:	*DE-FC02-80CS30380*

Ryan Homes, Inc., of Pittsburgh, Pennsylvania, was founded in 1948 and is one of the nation's largest home builders. Production and marketing operations are conducted in 22 different metropolitan areas in the eastern half of the country. The Ryan Homes are low-rise primary residences which are pre-sold directly to consumers by the company's own sales force. Panels and some components are made in their own manufacturing plants and delivered to the site where the houses are assembled by subcontractors supervised by the company employees.

Ryan Homes intends to develop three passive solar designs around the largest selling type of structure presently offered, the 40 ft X 26 ft bi-level or split-entry type home. With some variation, this type home is common to every market presently served by Ryan Homes.

This model has living space ranging from 1,027 to 1,593 sq. ft. The house may be constructed with factory fabricated panels which are shipped without siding materials, or the house may be constructed by Ryan's closed wall concept, which includes factory panels complete with windows, insulation, and wiring. The closed wall concept includes a mechanical core, plant fabricated with all plumbing, wiring, fixtures, and finished interior walls.

All models have a standard energy package that includes insulation levels and sealing techniques with proven results in reducing energy use. This package includes ceiling insulation; full wall, ring joist, and basement wall insulation; double glazing; insulated doors; hot water conservation devices; and a tested infiltration value of less than one-quarter air change per hour (unoccupied).

Design Approach

The basic design approach will be to incorporate passive solar features into the selected model without dramatic change in appearance or floor plan. Materials selected for collection and storage will be evaluated for availability, ease of erection, cost, and construction during a 12-month building season. Of special interest will be the selection of methods that will allow the same basic house to be built on lots or in areas where optimum orientation may not be available. This may suggest a greenhouse concept where collection and storage may be shifted by option to any side of the structure.

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Silvercrest Industries* *Buena Park, California*
Principal Investigator:	*Charles Williams*
Contract Number:	*DE-FC02-80CS30381*

Silvercrest Industries of Buena Park, California, produces a product line of low-cost housing, including mobile homes for park developments and private land and factory-built modular homes sold to developers.

Increasing energy-conserving features to three model homes built by Silvercrest Industries is expected to increase future sales. The three models range from 1,400 to 1,800 sq. ft. and will be selling between $20,000 and $45,000. In addition to upgrading insulation, energy-conserving features, and options, the models offer water-flow control on bath and shower outlets, night-setback thermostats, electronic ignition devices, and dual-glazed windows.

These model homes have been marketed primarily in California, Arizona, Utah, and Nevada. This area typically has high daytime and relatively low nighttime temperatures.

Design Approach

In the design approach, computer models will be used to evaluate the overall passive solar components. The energy use for heating and cooling will be calculated by a version of the National Bureau of Standards Load Determination Computer program. This program determines heating and cooling loads on an hour by hour basis for an entire "typical" year. Because this program considers the variables affecting heating and cooling loads, it is a tool for assessing relative design changes upon fuel requirements. Only those changes in models that offer significant energy savings and are cost-effective will be included in the final design.

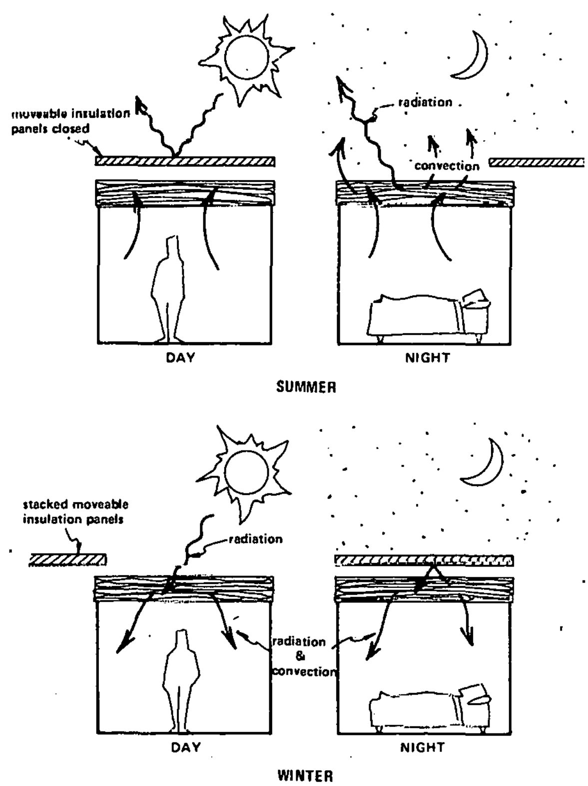
PROJECT TITLE: **SKYTHERM DESIGN EVALUATION/PHOENIX**

Institution: *Skytherm Processes and Engineering*
Los Angeles, California

Principal Investigators: *Harold R. Hay and Daniel A. Aiello*

Contract Number: *ET-78-G-03-1842*

Skytherm is a proprietary passive thermal conditioning system with minimal mechanical requirements. Panels of insulation over thermoponds supported by a metal ceiling are manually or automatically moved to provide natural air conditioning. Through panel movement, the thermoponds receive isolation for solar heating during a winter day and are covered at night to prevent heat loss. In summer, reversing panel positions retards daytime heating of the thermoponds but allows cooling to the night sky.



This project has two objectives: (1) to arrive at a design that will combine minimum cost with maximum operations results through analysis and experiment, and (2) to provide professional designers and engineers with concise information on Skytherm.

Professionals strongly oriented and experienced in low-cost housing and passive systems will assess current but untested Skytherm roof designs and select two for ground-level accelerated testing. The design will then be installed on a full-scale house, which is available in Phoenix, Arizona, for this experiment. The information and design details resulting from this effort in Phoenix will be combined with previous experience with Skytherm, and the data will be compiled into a manual for low-cost Skytherm applications.

PROJECT TITLE: **SKYTHERM PRODUCTION RESEARCH/ATASCADERO**

Institution: *Skytherm Processes and Engineering*
Los Angeles, California

Principal Investigator: *Harold R. Hay*

Contract Number: *EM-78-G-03-1825*

Skytherm is a proprietary passive thermal conditioning system developed by Harold Hay. The system uses a roof pond with movable insulation. Advanced conceptual designs for the Skytherm System will be evaluated by professional personnel to analyze seismic, acoustical, fire, and lightning standards. Research will be undertaken on sliding seals and plastic film components in the thermoponds. The cost and operation efficiency of the "attic thermopond" will be determined, as well as whether stagnation temperatures adversely affect the plastic glazing materials.

Obstacles to construction and commercialization of the Skytherm System will be reviewed, including union jurisdictions, possible material shortages, use of unskilled labor, and safety and liability considerations. Long-term observations of the Skytherm System will be made in a house constructed in Atascadero, California.

In January 1980, implications of the Skytherm on building codes were reported:

- *Structural Safety* – The vertical load imposed by the weight of water on the roof is important. Designers must take this uniform load into account in the design of roof, walls, and foundations of the building. The thermoponds (made from ultraviolet-resistant plastic) will be replaced upon any evidence of damage from aging
- *Fire Safety* – The Skytherm System provides no unusual problems for the building occupants in the event of fire. Any collapse of the thermopond could act as a fire suppressant. The potential for external fire is minimal since the entire roof is essentially a water pond contained in plastic bags
- *Accident Safety* – All mechanical equipment should have shields to prevent catching of clothing or body parts in gears and pulleys. Since the Skytherm is installed in accordance with the National Electric Code, the potential for electrical malfunction or shock hazard is minimal
- *Health Issues* – The thermoponds are contained in sealed plastic and hold calcium hypochlorite or other algicides. No health hazard in the disposal of the water was foreseen, though the installation of a plumbing vent on the roof was recommended.

PROJECT TITLE: **BASIC PHYSICAL STUDIES**

Institution: *Solar Energy Research Institute*
Golden, Colorado

Principal Investigator: *Ken Ortega*

Task Number: *In-house*

The general objective of the task is to introduce, investigate, characterize and optimize innovative building materials, components, systems and designs that will significantly reduce the energy requirements of buildings and communities. Currently the task is concerned with methods and systems that provide passive hybrid thermal control, and improved thermal performance of building systems.

The work involved in this task is to investigate and evaluate the thermal performance characteristics of a passive thermal control system and two different storage wall systems:

- Louver thermal control system (see Figure 1)
- Transfer wall
- Water wall

The louver thermal control system utilizes louvers to improve storage wall performance and to regulate heat transfer from storage walls. The transfer wall contains high conductivity covering plates and connecting fins within the wall to propagate more rapid heat transfer. The water wall is a system design to take advantage of the high conductivity of water and potential as a heat storage device.

Alternative designs to each of these systems will be evaluated using numerical simulation techniques and laboratory experiments. Promising systems will be physically constructed and field tested.

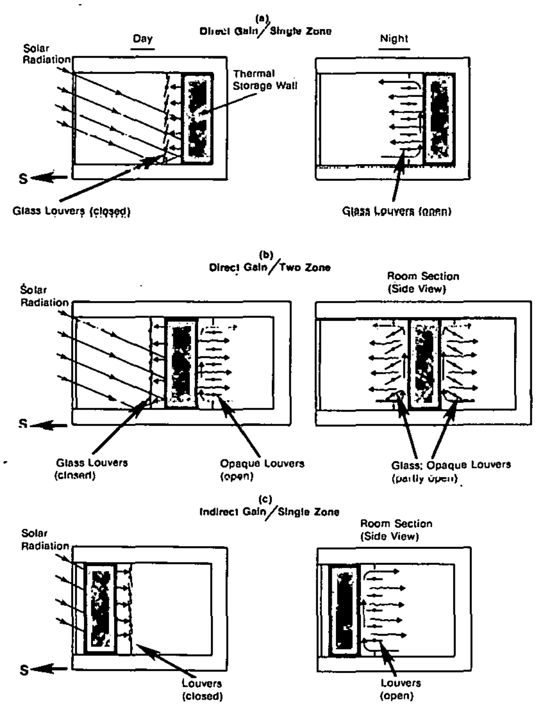


Figure 1. (Generic Types)

PROJECT TITLE:	**DENVER METRO HOME BUILDERS PROGRAM**
Institution:	*Solar Energy Research Institute* *Golden, Colorado*
Principal Investigator:	*Bruce Baccei*
Task Number:	*In-house*

The primary objectives of this program are to:

- Assist 13 selected home builders in the Denver Metro area in developing continuing abilities to design, build and market energy conserving homes which utilize passive solar heating and cooling and solar domestic hot water technologies
- Increase public awareness and appreciation for energy conserving solar homes
- Encourage and assist RSEC's State Energy Offices, and progressive utilities to utilize the successful model this program affords for working with industry.

The program is a cooperative effort between Western SUN, the State of Colorado's Office of Energy Conservation and SERI. Announcement of the solicitation from SERI inviting home builders to participate resulted in 47 proposals. Thirteen no cost agreements with builders were subsequently negotiated.

SERI has provided technical assistance to the selected builders through design reviews and technical seminars. SERI also assisted Western SUN in conducting a workshop for home builders not selected to participate in the program. The workshop was co-sponsored by the Home Builders Association of Metro Denver. 450 people attended the workshop.

All of the builders have completed final designs and ten are beginning construction.

The homes being constructed will be instrumented for thermal performance monitoring. A parade of solar homes will be conducted in February 1981 in conjunction with the local Home Builders Association to publicize these homes and passive solar.

PROJECT TITLE:	**PASSIVE BUILDING PERFORMANCE EVALUATION AT THE CLASS B LEVEL**
Institution:	*Solar Energy Research Institute* *Golden, Colorado*
Principal Investigator:	*Donald Frey*
Task Number:	*In-house*

The objective of this task is to install low cost data acquisition systems in 80 passive solar homes around the country and gather data to support commercialization and market development through approximate determination of the thermal performance of these buildings. Secondarily, the program will evolve universal software for the analysis of data from low cost data acquisition systems and provide data for validation of passive solar design tools.

This SERI managed project is a joint effort between SERI, DOE, the four regional solar energy centers, NBS and a number of contractors.

Initial building monitoring will begin in January 1981. The program will assess both passive heating and cooling and is expected to be an ongoing effort for the next two to three years.

PROJECT TITLE:	**PASSIVE BUILDING PERFORMANCE EVALUATION AT THE CLASS C LEVEL**
Institution:	*Solar Energy Research Institute* *Golden, Colorado*
Principal Investigator:	*Sharyn Towle*
Task Number:	*In-house*

A national program to evaluate the performance of passive and hybrid solar heated and cooled residential buildings has examined the data and information needs of both system development and market development activities. The implementation of this program involves a coordinated program of both quantitative and qualitative evaluation efforts. Class C performance evaluation is the collection and analysis of the qualitative, noninstrumented data. While the results will be useful to system development efforts, the primary purpose of this level of evaluation is the support of market development activities.

Inclusion of qualitative factors adds an important dimension to thermal performance evaluation by including the occupants' interaction with the building as part of the evaluation. It is impossible to analyze the thermal performance of most passive solar buildings without taking into consideration the occupants' interaction with the building. The factors commonly used in most evaluation of passive solar system performance are quantitative factors such as Btu's delivered, fuel savings and temperature maintained. The occupants' perceptions of performance may provide equally important indices of thermal performance such as overheating, heat distribution and overall thermal comfort.

PROJECT TITLE:	**PASSIVE SOLAR MANUFACTURED BUILDINGS**
Institution:	*Solar Energy Research Institute* *Golden, Colorado*
Principal Investigator:	*Bruce Baccei*
Task Number:	*In-house*

The primary objectives of this program are to:

- Give technical assistance to 23 building manufacturers under contract to DOE/Chicago Operations Office to design (Phase I), construct and test energy performance (Phase II) and test market (Phase III) energy efficient passive solar manufactured buildings
- Encourage and assist, through workshop/seminars conducted with national industry associations, other building manufacturers to develop and produce energy conserving passive solar buildings
- Increase market/consumer awareness and appreciation for passive solar manufactured buildings.

Management and technical support to the 23 manufacturers in the DOE program have been the primary activities to date. A workshop initiating the program and the manufacturers design activities was held in November 1979. Since then technical assistance and feedback to manufacturers and their solar consultants have been primarily through reviews of manufacturers designs and proposals for subsequent phases. Thus far reviews have been conducted for 17 preliminary designs, two final designs and one Phase II proposal and one combined proposal for Phases II and III.

Two prototype buildings are complete and will begin monitoring soon. Several manufacturers are expected to complete final designs and initiate Phase II activities within the next three months. Four manufacturers have indicated that they will propose to commence Phase III activities within the next four months.

PROJECT TITLE:	**SOLAR INDEX**
Institution:	*Solar Environmental Engineering Company*
Principal Investigator:	*Loren Lantz*
Contract Number:	*DE-AC02-78ET-20090*

The Solar Index is simply a number between 0 and 100 which tells you what percentage of your hot water could be supplied by a solar water heating system on a given day.

For example, if the Solar Index today is 84, then roughly 84 percent of the energy required to heat your household water to 120°F could be provided by the sun.

The Solar Index is reported by radio and television stations and newspapers, usually given with other weather data like the air quality index, pollen count, and wind chill factor.

The Solar Environmental Engineering Company calculates the Solar Index each day by computer for numerous geographic areas. Data are then transmitted to 200 Standard Metropolitan Statistical Areas over the UPI wire.

PROJECT TITLE:	**CODES AND STANDARDS**
Institution:	*Southern Solar Energy Center Atlanta, Georgia*
Principal Contact:	*Kal Turkia*
Contract Number:	*In-house*

SSEC has developed a residential codes workbook to examine the effects of new conservation standards used throughout the south on passive solar designs. SSEC is surveying each state and major construction market to assess the impact of building codes and standards on passive design features.

The workbook on residential codes is divided into three parts. Part I contains general information on types of passive solar techniques and a method for estimating passive solar performance.

Part II describes the important codes and standards that are later referenced in Part III of the workbook. Each of the code descriptions cites the items in the code that could have a potential impact on a passive solar design and concludes with an overall analysis of the effect the code has on the use of such techniques.

Part III summarizes state and local codes and code agencies. In addition, the local summaries name contacts in the enforcement agency to whom specific questions may be addressed. Synopses of statements by the building officials on the use of passive solar in their jurisdictions and descriptions of related programs (such as those of utility companies) are included. The synopses include requirements for filing building permits. The code workbooks are being distributed to designers and developers throughout the south by SSEC.

PROJECT TITLE:	**PASSIVE MARKET ANALYSIS**
Institution:	*Southern Solar Energy Center* *Atlanta, Georgia*
Principal Contact:	*Kal Turkia*
Contract Number:	*In-house*

This project will measure the effectiveness of passive program activities at demonstration and market test sites. SSEC will perform market penetration studies and coordinate with the building community and design professionals, as well as representative home buyer groups, to obtain data and guidance on these activities.

A subcontractor will monitor program performance and perform market penetration analyses at the market test/demonstration sites. In addition, SSEC personnel will interview various target groups to assess project effectiveness and take corrective action as needed.

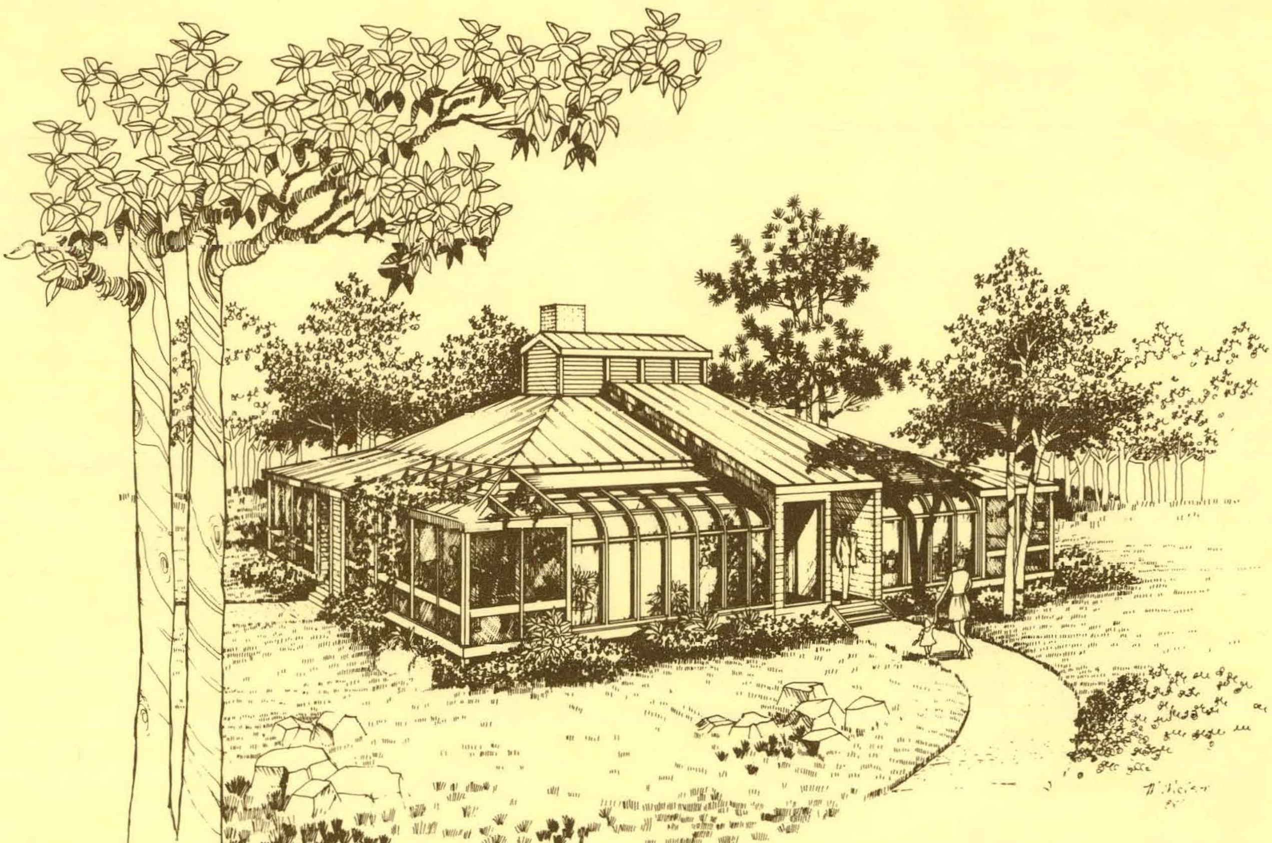
The related objectives of this project are to measure passive effectiveness and to retain continual contact with the marketplace.

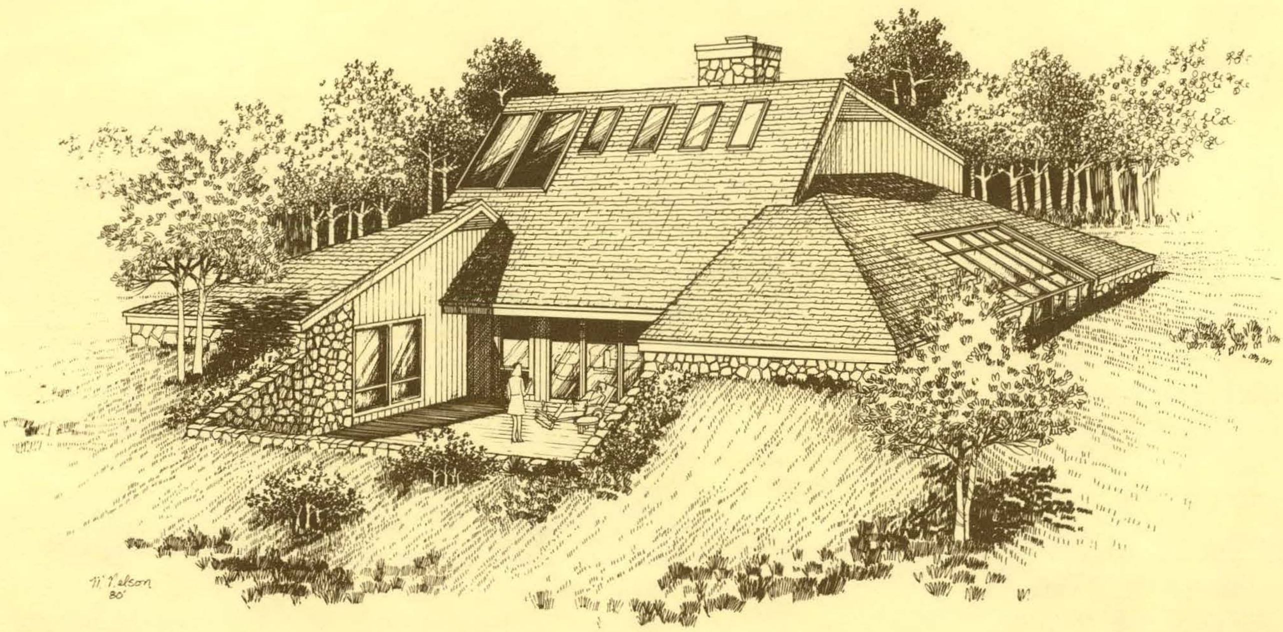
PROJECT TITLE:	**REGIONAL COOLING DESIGN**
Institution:	*Southern Solar Energy Center* *Atlanta, Georgia*
Principal Contact:	*Kal Turkia*
Contract Number:	*In-house*

This project is a continuation of a pilot started in FY79 to develop innovative passive techniques for low-energy cooling at SSEC's four locations. Cooling design efforts are being initiated at six new sites, and awards for 12 selected designs will be made. Special attention is being given to areas with more severe cooling and humidity conditions, to focus the best available talent on this problem.

An evaluation board of local professionals, realtors, builders, and city code officials working with SSEC technical staff is selecting the most appropriate designs. Local and state-level publicity has been to heighten public awareness of the project. These publicity efforts will be increased when the structures are available for occupancy.

Efforts have been taken to invite design participation from all segments of the building community, such as A/E firms, builders, manufactured housing firms, and the mobile homes industry.





This project intends to increase public awareness and understanding of passive solar systems and to encourage builders to use passive systems as marketing tools. As the project proceeds, data will be collected on the cost and performance of passive techniques in hot, humid climates. An inventory of passive techniques that are adapted for the Southern Region will be assembled and made available to architects, builders, and designers within the SSEC area.

PROJECT TITLE: **RESIDENTIAL PASSIVE MARKET TEST PROJECT**

Institution: *Southern Solar Energy Center*
Atlanta, Georgia

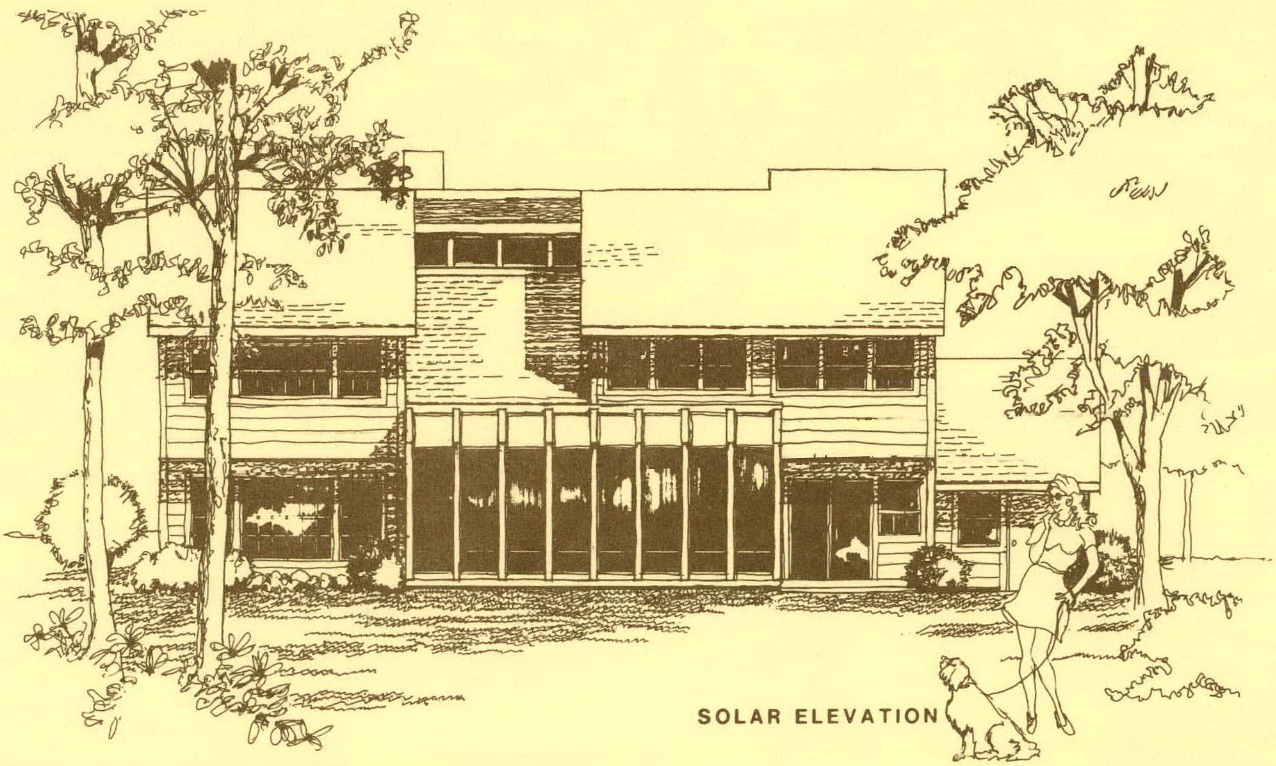
Principal Contact: *Kal Turkia*

Contract Number: *In-house*

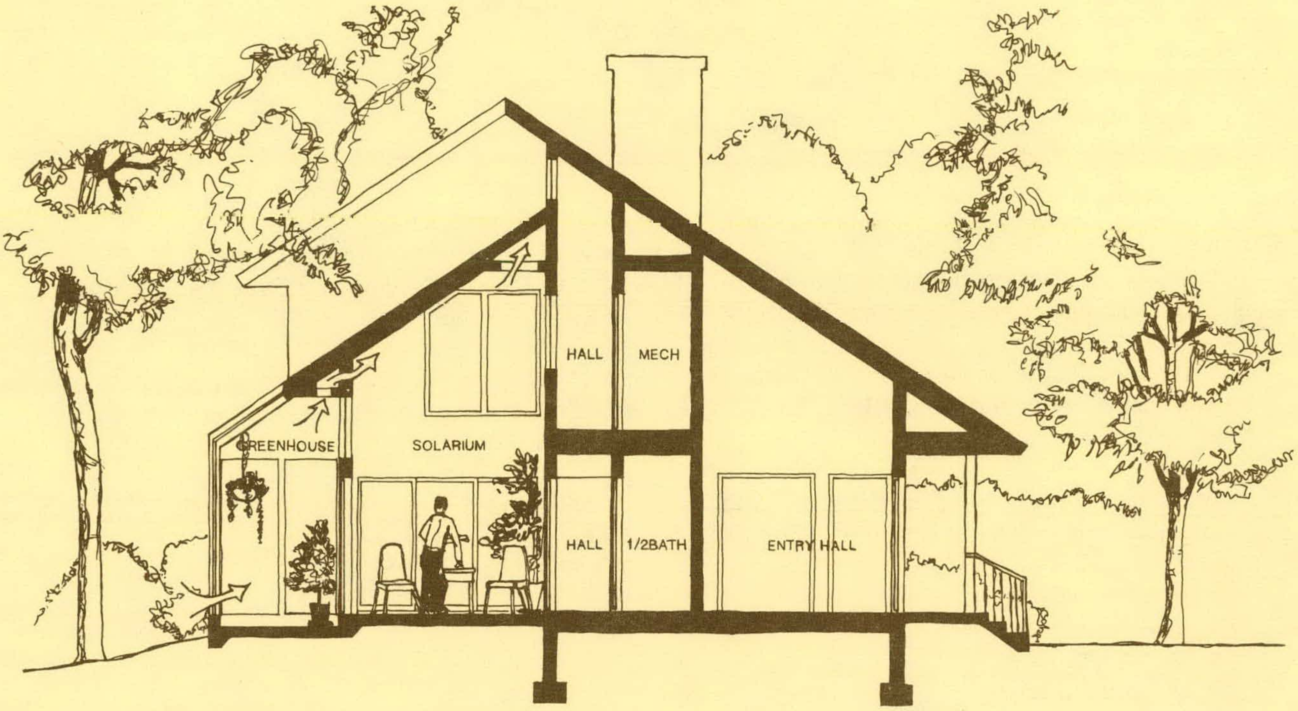
This project involves residential single-family and multifamily design/build structures. SSEC is generating eight marketable passive homes in eight different climate zones, providing pilot "design aid" assistance to four new homes and five multifamily dwellings.

An ambitious testing program, along with major coordinated marketing and educational initiatives, is being conducted in each target area. The project will further efforts to form a meaningful, working relationship between solar design professionals and the building community. It will also acquaint typical tract builders throughout the Southern Region with passive designs.

Four of the single family demonstrations are now in various phases of construction in Atlanta, Houston, Louisville, and the greater D.C./Baltimore area. Two multifamily demonstration dwellings are also underway, as well as a manufactured housing project. In each city, a local builder and architectural firm have collaborated on the design/construction. Their goal is to construct a building that will yield major energy savings and will also sell readily in the local market. A local advisory team of a lender, realtor, code official, and utility representative has provided additional guidance for the single-family projects. Local NAHB affiliates also are giving valuable assistance.



SOLAR ELEVATION



Projected energy savings for these structures are significant. The thermal envelope in each house will meet or exceed the proposed Building Energy Performance Standards (BEPS). The solar input (solar heating fractions range from 45 to 65 percent) will reduce conventional energy demand to about one-half that called for in BEPS.

Prices on these homes are projected in the range of 2 to 5 percent over similar homes without passive features. All homes will be open to the public upon completion, and specific events for builders and the media are planned in each city.

PROJECT TITLE:	**DETERMINATION OF PASSIVE SYSTEM COSTS AND COST GOALS**
Institution:	*Total Environmental Action, Inc. Harrisville, New Hampshire*
Principal Investigator:	*Paul Sullivan*
Contract Number:	*EM-78-C-01-5233*

This project was solicited by DOE in order to provide information to the in-house DOE planning and commercialization process. Project results, to be released this year, will also be useful to other groups, particularly designers and builders.

Two specific objectives of the study are (1) to provide a variety of user groups with passive heating cost information and (2) to establish goals to increase the cost-effectiveness of passive heating systems.

In general, costs were distilled by analyzing "standardized" passive system designs applied to "typical" tract, nonsolar buildings. The passive systems considered were:

- Trombe wall
- sunspace
- direct gain
- thermosiphoning.

Typical passive system designs were developed based on an audit of over 200 existing designs.

Four types of "base case," nonsolar buildings were selected for eight regions of the country. Specific city locations chosen in each region were:

- Boston, MA
- Chicago, IL
- Atlanta, GA
- Albuquerque, NM
- Denver, CO
- Seattle, WA
- Baltimore, MD
- Sacramento, CA.

Each of the "base case" buildings was developed from schematic design to preliminary working drawings with details and specifications. Working drawings, details and specifications for the passive system types were also developed. These passive systems were then applied to each of the base case buildings in order to determine the *incremental* costs of the passive system.

Besides area and the specific building to which they were applied, significant variables within each passive system type included:

- Direct Gain

  - amount and type of additional thermal mass
  - fixed vs operable sash
  - number of glazing layers
  - movable insulation

- Sunspace
  - manufactured vs site-built units (in both cases a premium glass unit was assumed) and type
  - amenities and finish selection
  - movable insulation

- Thermosiphon
  - ducted or nonducted versions
  - one or two stories high
  - interior trim

- Mass Wall
  - vented and nonvented
  - double or triple-glazed
  - movable insulation
  - mass wall material and thickness
  - footing depth
  - interior finish.

Cost information was then developed for each building, with and without each passive system type, in each region for the following categories:

- materials
- labor
- operation
- maintenance
- life cycle.

Two professional cost estimating firms were selected to provide detailed construction cost estimates in the Uniform Construction Index format.

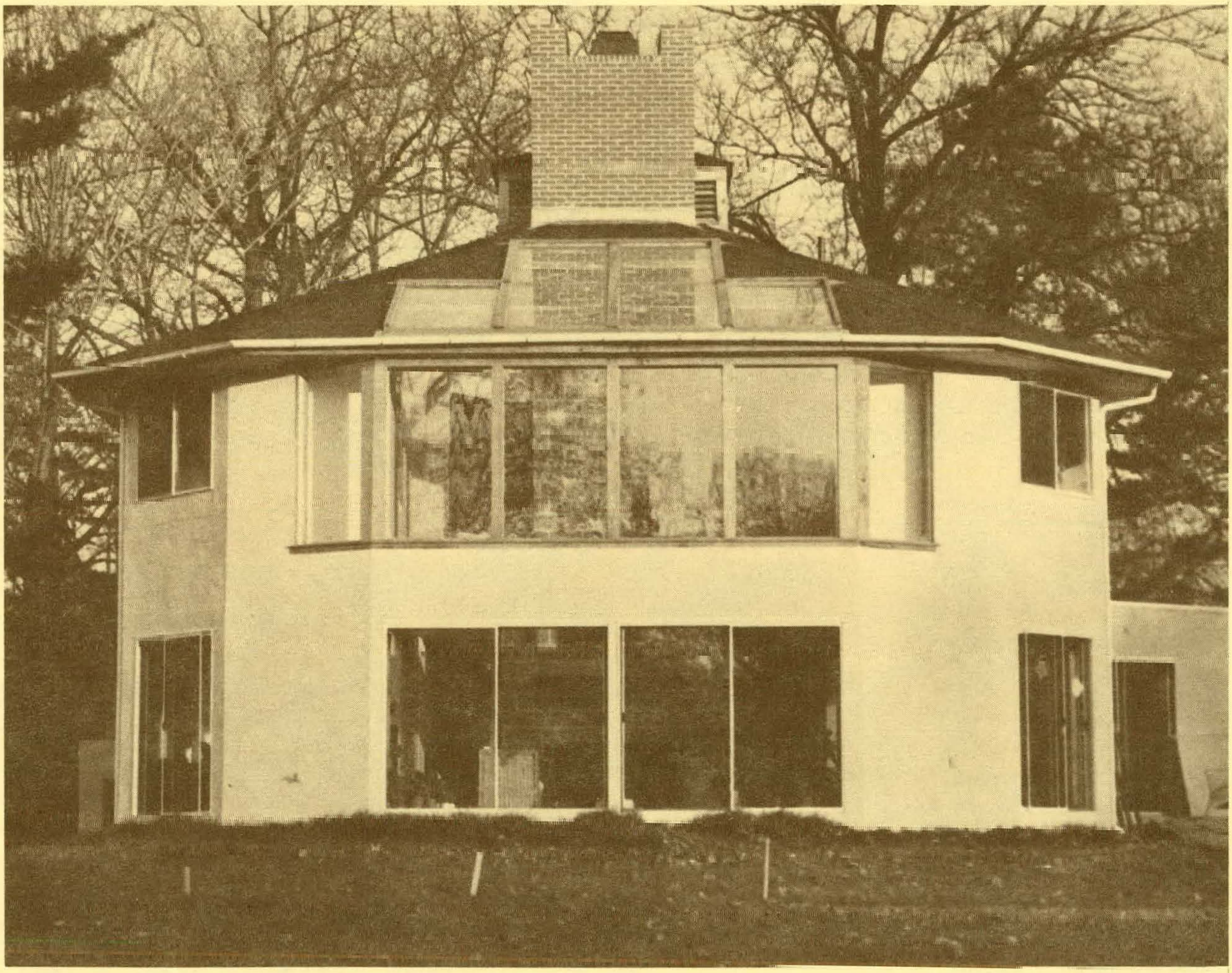
The final results and detailed methodology of this study will be presented in a format useful to a wide variety of user groups: consumers, architects, engineers, builders, developers, and lenders. Others interested in a long-term perspective on passive heating costs, and especially those aspects impacting future improvements in cost-effectiveness, will benefit from the presentation of passive system cost goals.

PROJECT TITLE:	**SOLAR ATRIUM: A HYBRID SOLAR HEATING AND COOLING SYSTEM**
Institution:	*Ueland and Junker Philadelphia, Pennsylvania*
Principal Investigator:	*Mark Ueland*
Contract Number:	*EG-77-G-04-4135*

The major objective of this project is to design, construct, and monitor an innovative concept of solar heating and cooling called "solar atrium."

The solar atrium concept is adaptable to residences and smaller commercial and institutional buildings. It is designed to be constructed of materials and equipment that are economical and readily available. Cost-effectiveness of installation and operation is a primary design objective.

The solar atrium is a further development of efforts begun in the 1930's and 1940's to design houses which would obtain a major portion of their heating from the sun.

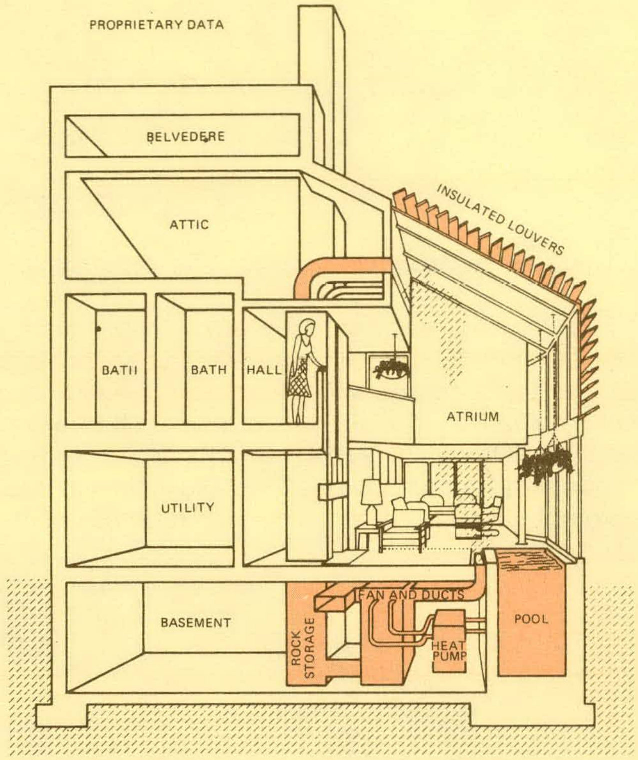


The early "solar house" experiments proved the benefits of large glazed areas for trapping solar energy. However, they were not equipped to collect and store surplus solar energy, nor were they equipped to control heat losses through glass areas at night or during cloudy days.

The solar atrium incorporates the large glass areas of the earlier houses and adds facilities for heat storage and control of heat losses through glass.

The solar atrium has been designed and will be constructed for testing within a demonstration model single family residence. This solar system has a two-story atrium with operable internal insulated shutters for controlling heat loss and gain, passive heat storage in a small water pond and the atrium floor, and a fan to pump heated air from the top of the atrium to a rock bed in the basement.

PROPRIETARY DATA



SECTIONAL VIEW OF SOLAR ATRIUM

The atrium and residence will be instrumented and monitored to obtain data on the system operation and electricity costs over a full year heating and cooling season.

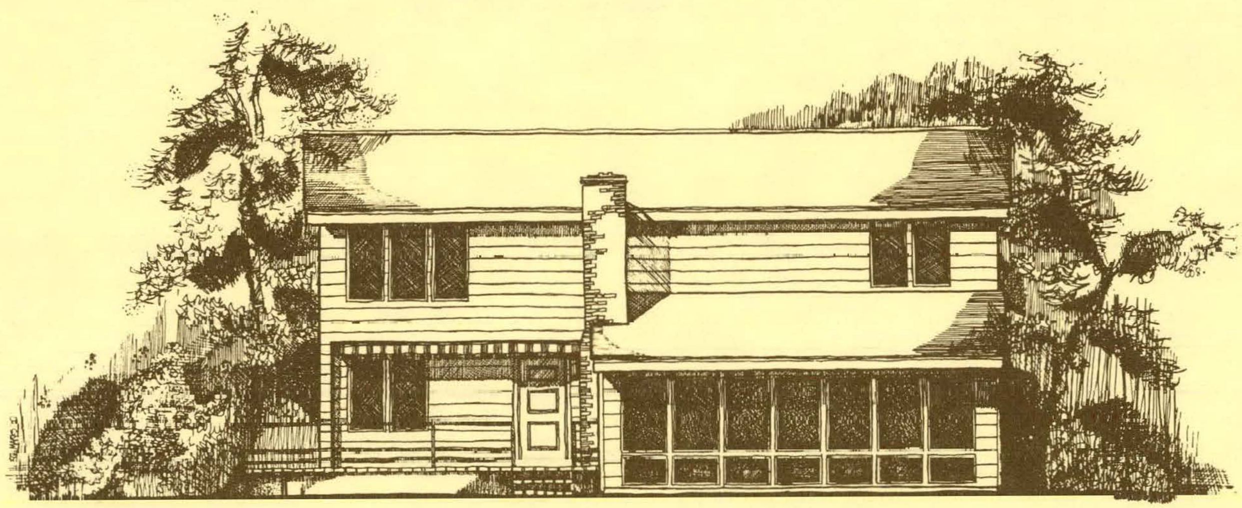
Life-cycle costs will be produced, including costs of installation, operation and financing. Cost-effectiveness will be measured by comparing the life-cycle costs generated for the experimental residence with those of a similar residence of conventional design without the solar atrium.

Comparisons will also be made with other existing passive and hybrid solar homes.

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Unibilt Industries, Inc.* *Vandalia, Ohio*
Principal Investigator:	*Doug Scholz, President*
Contract Number:	*DE-FC02-80CS30384*

Unibilt Industries of Vandalia, Ohio, has been producing modular home units since 1968.

The standard modular home currently produced by Unibilt Industries consists of two modules set side by side. The basic modules are 12 to 14 ft wide and up to 54 ft long. To more easily accommodate passive solar components, Unibilt Industries will increase the size and height of the home to 1-1/2- and 2-story models. The new design will be site independent, so that the new modules will be adaptable for a wider range of site shapes, slopes, and orientations. Passive solar components will include water walls, attached greenhouses, and rock-storage areas. The passive solar design is intended to focus on infiltration prevention and heat-recovery components to supplement water heater source.



Design Approach

During design, architectural sequences will establish schematic designs for the 1-1/2- and 2-story modular homes of approximately 1,500 to 2,500sq. ft. Using this as a base, Unibilt Industries will initially evaluate each model to determine sizes and types of various passive solar techniques that would be required to provide a reasonable solar-heating fraction. A reasonable solar heating fraction is considered to be 70 to 80 percent. Various hand-held calculator routines will be used for this evaluation.

The integration of a variety of passive solar techniques into the base models will be investigated. The techniques to be explored include:

- *Direct solar gain through glazing* using skylights, clerestory lighting, and solar-facing vertical glass

- *Attached indirect solar gain/storage* using masonry and water, by the dynamic characteristics of various high-mass materials

- *Remote solar gain/storage* with greenhouse structures; glazed, exposed crawl spaces; and rock bed storage

- *Insulation schemes* will be evaluated for the wall, floor, and foundation and roof/ceiling components

- *Good construction practices* such as caulking, weatherstripping, and other methods of reducing air infiltration.

Several evaluation tools are currently under consideration by Unibilt Industries. One is a passive solar analysis by Douglas Balcomb of Los Alamos National Laboratory. There are a number of less sophisticated programs which are adapted to hand-held calculators.

PROJECT TITLE: **CONTROLS FOR PASSIVE SOLAR HEATED HOUSES**

Institution: *University of California — San Diego*
San Diego, California

Principal Investigator: *Professor Anthony V. Sebald*

Contract Number: *DE-AC02-80CS30260*

This project is a continuation of U. S. DOE support in the area of controlled passive solar heated houses. Two years of effort are presently being completed. During the first year, under contract, controls for single passive techniques* in a given house were individually evaluated.

During the current year, controlled integration of Trombe wall, direct gain and rock bin is being studied. Furthermore, a comfort index is being developed and optimal controls for totally off peak backup demand are being generated.

Future objectives are to:

- Provide a better understanding of the complex interactions present in controlled passive solar houses
- Develop specific guidelines for the passive solar industry in the area of controls for passive buildings.

Camera ready copy of a manual including weather zone guidelines is one of the deliverables of the proposed contract. In addition, the UCSD Energy Center will have a reasonable number of copies printed and available for direct dissemination. The availability of this manual will be advertised through an article in Solar Age or a similar journal.

Other proposed deliverables include:

- A comparison of simulated and empirical heating season results for a passive building containing a fan cooled Trombe wall and a passively discharged radiant floor rock bin. The empirical results will include a comparison of the comfort indicators of the above building with those of an adjacent, actively solar heated one. It is understood that the comfort indicators will be determined by work in the current contract and that limited occupancy will be used to complement computer measurements with human sensations.
- A thermal network model will be generated for a controlled two zone structure incorporating direct gain into either zone, a Trombe wall in the south zone, a rock bed under the floor in the north zone and convective/conductive coupling between zones.
- An alternative conceptualization to determine whether controlled passive buildings are well matched to their climate zone/occupancy characteristics will be attempted. A frequency domain approach will be attempted and the results reported. At least one example will be computed.

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*Trombe wall, water wall, direct gain, roof pond, greenhouse, convective loop.

PROJECT TITLE:	**PASSIVE RETROFIT PROJECT**
Institution:	*Southern Solar Energy Center* *Atlanta, Georgia*
Principal Contact:	*Kal Turkia*
Contract Number:	*In-house*

This project will continue retrofit activities initiated by SSEC during FY79. Work includes defining design concepts and offering construction incentives for market testing a minimum of 50 regional residential retrofit applications.

A retrofit handbook is scheduled for completion this summer and will be widely distributed to builders and homeowners. This handbook will contain precise working drawings and specifications for several passive retrofit techniques on direct gain, space, wall, and solar attic. Each technique will be modified to work in various southern climates.

A section of the retrofit book will explain how to evaluate existing buildings for retrofit potential and will assist in selecting the best retrofit techniques for homes. This section will also help buyers choose homes most suitable for retrofit.

The retrofit handbook will be distributed throughout the Southern Region in conjunction with a widely publicized small grants program. The grants program will identify suitable projects to illustrate the wide variety of approaches and applications for various climatic regions. Grants will be allocated to ensure an even distribution of funds throughout the region in areas with high visibility or uniquely difficult energy or housing problems. The small grants will not exceed 20 percent of construction or $800. These will be made to qualified applicants to assist in defraying the incremental cost of adding passive retrofit heating and cooling systems to their property. In return, the SSEC will have monitoring rights for a period of one heating and cooling season.

Regional workshops will be promoted to aid in the understanding of the handbook and grant application process and to increase general public awareness of the potential savings of passive retrofit techniques.

PROJECT TITLE:	**APPLICATION OF PHASE CHANGE MATERIALS IN PASSIVE SOLAR SYSTEMS**
Institution:	*University of Delaware* *Newark, Delaware*
Principal Investigator:	*Joseph Slikowski*
Contract Number:	*DE-FG04-79CS34146*

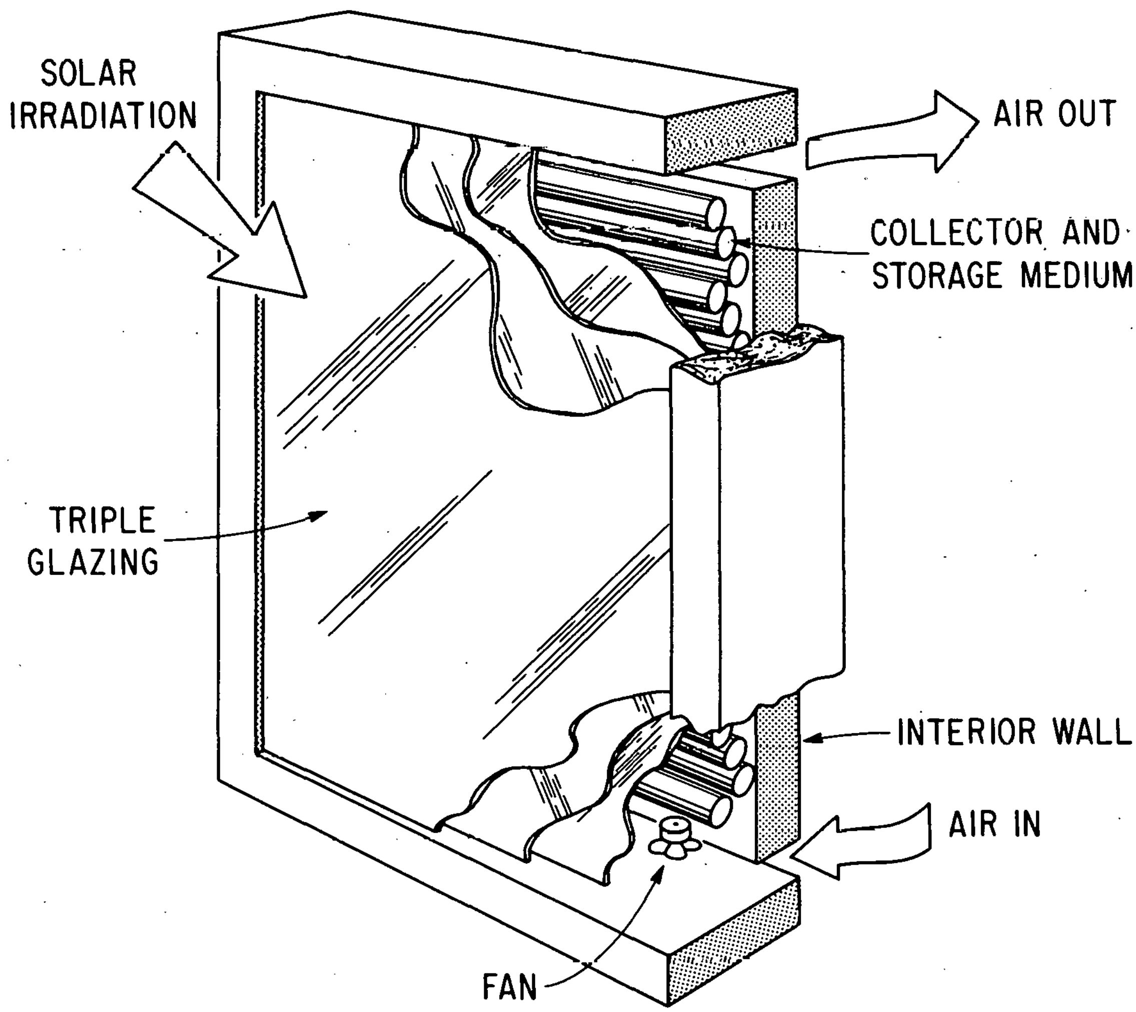
The Institute of Energy Conversion of the University of Delaware has designed and constructed a modular, hybrid passive solar energy collection and storage unit called the Thermal Wall Panel. The Thermal Wall Panel (TWP) uses a packaged Phase Change Material (PCM) to collect and store the incident solar energy. In the winters of 1977–1978 and 1978–1979, the Thermal Wall Panel was tested in Solar One, the Institute's solar house and laboratory. In addition, various configurations of phase change materials were studied to determine the effect on system performance as compared to specific heat storage systems. With the cooperation of regional builders, configurations using the TWP concept were analyzed for appearance, cost and performance.

During the period of the program, 2000 pounds of phase change material were packaged in plastic containers. Analysis of the performance of the packaged material itself, over the past two years, has provided a basis for developing a specification for packaging the material.

The major results and conclusions from the program are:

- Based on measurements, a Thermal Wall Panel with movable nighttime insulation (R=6.80) can retain and deliver, as heat, an average of 45 percent of the insolation during any given day.
- Based on calculations, 300 sq. ft. of Thermal Wall Panel can provide about 25 percent of the heating needs for an 1800 sq. ft. house. When this Thermal Wall Panel is combined with direct gain in a passive solar energy system, 56 percent of a home's heating needs can be provided.
- A Thermal Wall Panel can be installed in a typical home in the Mid-Atlantic region for an incremental cost of less than $10 per square foot of glazing.
- In climatic conditions similar to the Mid-Atlantic region, a triple glazing system is a cost-effective method for glazing and reduction of heat loss.
- Due to its modularity, narrow cross section, potential low cost and high efficiency, the Thermal Wall Panel shows promise as a passive solar heating system for both new construction and retrofit applications. The Thermal Wall Panel system can be manufactured as a factory-built module or it can be site-built from components.
- The wall thickness of the polyethylene tube should be 0.050 in. or thicker to prevent excessive failures due to "dimpling" during the extrusion process. It is recommended that tube diameters be in the range of 1.5 in. to 2.0 in. so as to provide the desired performance when considering the trade-off of surface area available for irradiation, surface area needed for proper heat transfer and the overall contained volume.
- With a phase change material having a transition temperature in the range of 90°F to 120°F, a storage capacity design value of 850 Btu/ft^2 of glazing is sufficient to provide good performance.

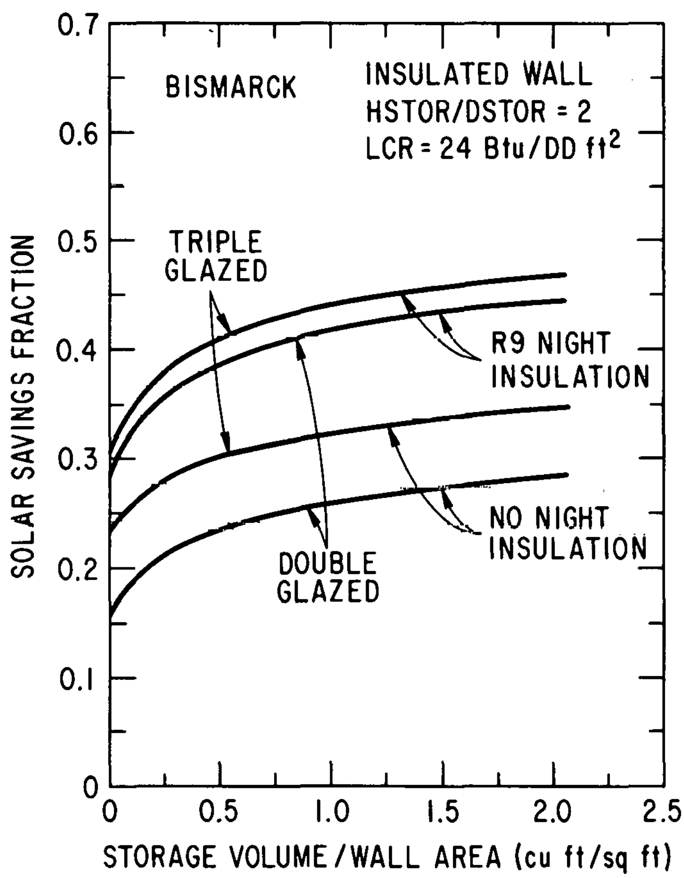
- For an effective value of h_c (i.e., overall heat transfer coefficient) in the range of 1 to 3 Btu/hr ft² °F, modeling of this class of phase change material system can use lumped parameter assumptions and obtain reasonably good agreement with experimental results.



PROJECT TITLE:	**PASSIVE SOLAR HEATING OF BUILDINGS WITH AN ATTACHED GREENHOUSE**
Institution:	*University of South Dakota Vermillion, South Dakota*
Principal Investigator:	*R. W. Jones*
Contract Number:	*DE-AC02-79CS30242*

Research is being conducted on the attached greenhouse type of passive solar heating system in the north-central region. General goals of the research are:

- To evaluate attached greenhouse passive solar heating in terms of the expected fraction of the total heating load provided by solar energy
- To investigate the constraints imposed on performance by traditional, wood-frame design and construction practices, especially for use of an insulated frame wall between the greenhouse and the residence
- To develop specific design guidelines for an attached greenhouse incorporated in new construction, or in a retrofit to an existing building, of traditional design and construction; and
- To investigate nontraditional designs appropriate to optimum performance, and to develop specific guidelines for any such designs.



The analytical method is dynamic computer simulation using a thermal network model of the building. Actual hourly meteorological and solar radiation data from selected cities in the north-central region will drive the computer simulations. The principal progress in this, the third quarter, of the project is additional computer simulations for certain attached greenhouse designs using the hourly typical meteorological year (TMY) data for Bismarck, North Dakota. Details about the models used and the definitions and values of certain reference design parameters are referenced in the second quarterly progress report for the period November 20, 1979, to February 28, 1980, document number DOE/30242.2.

Research to date permits some preliminary conclusions on the cited goals:

- Expected Solar Savings Fractions as a function of the load/collector ratio for areas similar to Bismarck, North Dakota.

- There are no severe constraints imposed on performance by traditional, wood-frame design and construction practices. In particular, the use of an insulated frame wall between the greenhouse and the residence, with thermocirculation vents for heat transfer, has a comparable performance to other types of solar walls.

- Specific design guidelines for the following parameters:

  - Storage volume
  - Glazing system
  - Glazed end walls
  - Storage shape
  - Color of wall and storage container
  - Color of floor, walls and ceiling
  - Wall conductance
  - Vent area
  - Glazing tilt
  - Sunspace geometry
  - Ceiling depth
  - Resistance of night insulation.

- Nontraditional designs appear to be unnecessary for good thermal performance, meaning primarily that an insulated wall with vents performs almost as well as a thermal-storage wall.

Many more parametric studies of the type reported here are needed before reliable and general design guidelines can be advanced with confidence. Of the greatest need are studies using locations and loads other than Bismarck. As many such studies as possible will be performed in the next quarter.

A design tool of great importance is the Los Alamos Scientific Laboratory (LASL) Solar/Load Ratio (SLR) method of performance estimation. This method allows a designer to estimate the performance of a design on the basis of just one parameter – the Solar/Load Ratio. This method has been extended to include attached greenhouse systems, as one aspect of the present project, jointly with LASL. Progress in this aspect was presented at the 25th Annual Meeting of the American Section of the International Solar Energy Society, June 2–6, 1980, Phoenix, Arizona.

PROJECT TITLE: **PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**

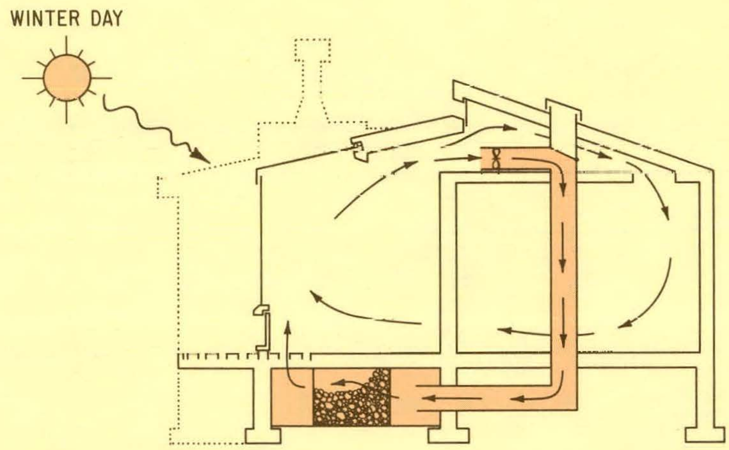
Institution: *Usry, Inc.*
Richmond, Virginia

Principal Investigator: *J. Durwood Usry, President*

Contract Number: *DE-FC02-80CS30385*

Over the past 40 years, Usry, Inc. has become one of the larger mobile homes firms in Virginia. The types of mobile facilities have included classrooms, bank units, dental facilities, university housing, and construction buildings.

The model building proposed by Usry, Inc., for incorporation of passive solar features is 1,344 sq. ft. and is used primarily for housing, with some commercial and educational applications. Heat pumps are standard as the primary heating and cooling devices. Wood stoves may be installed as a backup heating unit. Fireplaces are optional. Usry, Inc., anticipates that inclusion of passive solar into these mobile units will increase considerably their market potential.



USRY SOLARIUM

Design Approach

During design, Usry will begin with an analysis of existing capabilities and limitations that characterize modular homes. The design team will identify processes and assemblies that could contribute the most to passive heating and cooling. Especially, wall and roof assemblies will be studied for thermal characteristics. A survey of climatic conditions will be made in the marketing area of Maryland, Virginia, West Virginia, and North Carolina. This will entail researching, assembling, and reviewing data on wind and sun movements and identifying the full range of climatic conditions to which the mobile homes will be adapted.

Rules of thumb will be applied to preliminary designs that will be subjected to cost analysis and performance calculations. Those designs considered the more promising will undergo more detailed development. Computer modeling of the unit's performance as a whole, as well as its components, will be made. The most promising designs will then enter the final design and evaluation phase.

PROJECT TITLE:	**PASSIVE COOLING OF PLANTS**
Institution:	*Utah State University* *Logan, Utah*
Principal Investigator:	*Greg McPherson, Utah State; Mark McDade, SERI*
Contract Number:	*AM-9-8261-1 (under contract to the Solar Energy Research Institute)*

The Utah State University will quantitatively explore the cooling effects of plants on a house. Two identical scale model homes (one-tenth the size of a typical 1600 sq. ft. unit) will be built for the experiment. Two major variables to be considered in the design of the models are thermal resistance and thermal diffusivity. Thermal resistance is the ability to resist heat transfer from the exterior to the interior and can be increased by adding insulation. Thermal diffusivity is the tendency to absorb, store, and then release heat. The two models will have the same thermal resistance per square foot of wall, floor, ceiling, roof, and window space as a typical home in Utah. Each model will reflect accurately the direct thermal resistance (as well as the heat lag characteristics) of a typical home.

The models will be mounted on wheels to facilitate transport. Components of the models will be tested against construction materials of the typical home to verify the accuracy of the heat transfer calculations. Models will be located on test sites facing south. Thermocouples (to record temperature fluctuations) will be placed along the inside and outside walls and roof. One model will be under a shade tree, while the other will receive full sunlight. Plants for shading a model will be selected that are representative in size, form, and shading coefficient of their species. Experimental sequences of house/plant configurations will allow comparison of heat gain and lag time caused by trees of different foliage densities.

The overall objective of the Utah State University in this project is to identify the best location for trees, shrubs, and vines around a home to minimize heat gain. This requires calculations for (1) the yearly overheated periods when shading is critical to restore temperatures to the comfort zone; (2) the position of the sun when shading is needed; and the height, spread, and (3) the position of the plant between the sun and home during the over heated period. After learning where plants should be placed, the next step is to select the most appropriate plants. A list of commonly used ornamental and native plants of the region will be compiled. Each plant will be given a shading coefficient, as determined by energy transmission through the leafy canopy. This will indicate the shading effectiveness of the various species.

The results of this experiment will be written, so that they can be easily understood by the technical designer and average homeowner. The project will benefit the professional designer and any laymen interested in a more effective use of plants around residential structures, thereby reducing dependence upon highly technological and energy consumptive solutions to survival in the arid west.

PROJECT TITLE:	**NATURAL CONVECTION SOLAR HEATING SYSTEMS**
Institution:	*W. Scott Morris* *Santa Fe, New Mexico*
Principal Investigator:	*W. Scott Morris*
Contract Number:	*DE-AC02-79CS30243*

This project involves continuing research on passive solar heating systems which use natural convection collectors and the dissemination of results of the research to workers in the field and the general public. Work is proceeding in three areas:

- *Experimental Research* — Although natural convection collector systems offer a large advantage over other passive systems, by isolating the glazing from the area to be heated, the actual performance of these systems varies from poor to excellent depending on general and specific design factors. The purpose of this research is to determine experimentally the effects of many of these design factors, including:

  — Basic geometry of collector-storage loop
  — Length of collector
  — Tilt of collector
  — Internal geometry and proportions of system
  — Restrictions to flow within the system
  — Parameters of storage (operating temperatures and transfer areas).

  This experimental evaluation will be accomplished through the use of one or two very flexible closed-cell test units, built for the purpose and monitored under a variety of conditions. The end result will be a broad data base on natural convection collectors which will enable the establishment of computer simulation techniques, and provide the basic groundwork for designers of such systems in the future. This portion of the work will be performed mostly at the Los Alamos Scientific Laboratory in Los Alamos, New Mexico.

- *Monitoring and Evaluation* — Several full-scale house space heating systems using natural convection collectors have been built and are operating in the southwest. Only two of these systems are presently being monitored. One is by W. Scott Morris and the other by Los Alamos Scientific Laboratory. Funds from this DOE contract will be used to continue monitoring and evaluating both systems, plus others as time permits.

- *Predictive Techniques* — The study will incorporate the experimental results of the first two parts of this proposal as a guide with which to verify or modify existing mathematical approaches to natural convection designs. The goal will be to develop a simple working technique to estimate systems performance for natural convection collection systems.

The deliverables from this project will be a series of papers reporting on all levels of research being conducted, including:

- Establishing a data base for computer simulations of convection collectors
- Development of a simple performance estimating techniques
- Results of the monitoring and evaluation task.

PROJECT TITLE: **EDUCATION PROGRAM**

Institution: *Western Solar Utilization Network*
Portland, Oregon

Principal Contact: *William Davis*

Contract Number: *In-house*

Western SUN's education project is designed to reach general audiences, as well as those within educational institutions. To promote public awareness of solar energy, educational curriculum materials are being prepared, surveyed, evaluated, and distributed. Seminars and workshops are being conducted; publications, exhibits and displays are being assembled; and consumer education media materials are being designed. Tasks are addressed to educators at all levels: K-12, community colleges and universities, professional architects, bankers, realtors, builders, small business entrepreneurs, local public officials, community organizations, as well as the general consumer.

Western SUN's education program will coordinate ongoing education efforts within the states. Curriculum materials that are successful in the region (or elsewhere) will be promoted for use. Teacher training workshops for both administrators and teachers will be conducted to accommodate the need for flexibility and the use of curriculum in a variety of teaching settings.

Western SUN also will coordinate with other DOE programs and with solar energy and educational organizations actively working on solar energy education projects. Support is provided for the National Park Service Energy Resource Awareness Centers. Western SUN supports the education efforts at the upcoming AS/ISES "Solar Jubilee" Conference and plans to sponsor several smaller conferences directed toward community libraries, local media contacts, homebuilders, and members of the financial community. This project will involve the following tasks:

- Survey, evaluate, and use curriculum materials enabling teachers to address solar energy applications; to provide teacher training on solar energy

- Acquaint lenders, appraisers, realtors, and other professionals with solar energy applications and their investment potential, so that they might make effective business decisions concerning solar energy

- Support effective, visible solar greenhouse demonstration installations within public school systems

- Facilitate the use of former military installations as converted education and training centers for solar energy.

PROJECT TITLE:	**INSTITUTIONAL**
Institution:	*Western Solar Utilization Network* *Portland, Oregon*
Principal Contact:	*William Davis*
Contract Number:	*In-house*

Western SUN's commercialization strategy includes specific emphasis on consumer protection through a variety of projects at the state and local level.

In the *Model Solar Consumer Assurance Project*, Western SUN extends through the State Solar Offices (SSOs) policy guidance, technical assistance, and seed money for development of consumer assurance programs. Western SUN assesses different state and local legal situations, administrative arrangements, and resources that affect the implementation of model consumer assurance efforts. These efforts focus on the prevention of complaints, as well as providing procedural and technical safeguards.

A *Regional Complaint Exchange* gathers information on consumer problems for dissemination to all 13 states in the region of Western SUN. This information will be made available to each state, SERI, and DOE through the SEIDB network and computer terminals in each state.

The *Residential Conservation Service (RCS)* project has the objective of ensuring that the opportunities of the RCS are understood by the solar industry, utilities, and homeowners. Western SUN works with SERI through the SSOs to produce accurate and applicable training materials. Workshops are arranged in selected locations to educate RCS auditors in the potential benefits and shortcomings of renewable energy technologies in the home, using materials from SERI and local sources.

A *Schools and Hospitals* project has the goal of increasing the number and variety of renewable energy applications for these institutions in the region. Education workshops are conducted, bringing together potential users and suppliers of the necessary services and hardware. Through Western SUN's state network of SSOs, assistance is offered to ensure that the state plans reflect the potential for renewable energy technologies. Target audiences of this project include architectural and engineering firms, contractors, schools and hospital administrators, and state energy office program managers.

In an *Analysis/Status of Codes and Standards*, Western SUN has the project objective of monitoring and evaluating (in cooperation with SERI and other Regional Solar Energy Centers) model code development. Particular attention is devoted to the potential for enforcement and the ability to incorporate new products and practices. Published reports will analyze the national experience and indicate the impact of widespread model code use in each region.

Through *Local Government Technical Assistance*, Western SUN offers technical solar assistance to local agencies for energy planning, solar access, model ordinance development, and solar code implementation. The League of California Cities (in conjunction with the California Energy Commission) has conducted several solar workshops for local government officials. A *Solar Handbook for Local Government Officials* has been prepared and a *Solar Systems Code Review Manual* is being published. Western SUN assisted in the publication of *Capturing the SUN: Opportunities for Local Governments*.

Western SUN (in cooperation with DOE) will coordinate a series of public meetings designed to generate a thorough review of the proposed model code. The code will encourage the development of solar energy and be a safeguard for the public's welfare. The code can represent a uniform and self-sustaining set of guidelines for the newly formed solar industry. Western SUN also funds technical advisors in selected cities. Each technical advisor works directly with building code officials in obtaining approval for solar designs and aids in the compilation of solar ordinances. One responsibility of technical advisors is to train inspectors and planners for future in-house capability to perform these tasks.

Under *Innovative Institutional Arrangements and Legal/Regulatory Issues*, Western SUN has the project objective of assessing the impact of various regulatory actions and institutional arrangements. Western SUN identifies means by which the use of solar energy can be accelerated through such innovative arrangements as municipal solar utilities or other local government or private utility programs. The Bonneville Power Administration (BPA) is currently involved in plans for a substantial solar effort. Western SUN is preparing a memorandum of understanding with BPA to clarify the relationship of the two organizations and to delineate responsibilities in dealing with utilities and consumers in the region. Western SUN analyzes current federal and state criteria for participation in market incentive activities, such as tax credits and the Residential Conservation Service operations (e.g., standards, warranty, and installer qualification requirements). Western SUN offers technical support to states and assistance in the development of legislation to alleviate institutional barriers or establish institutional incentives to use solar energy.

The *Analysis of Passive Construction Costs* project has the objective of identifying the most effective means for determining the energy-regulated contributions and cost impact of passive solar systems. Existing cost data will be analyzed on generic passive systems being constructed (e.g., Trombe wall and direct gain) in relation to the energy contributed by the system and materials used. This assessment will be compared to building regulations to recognize the potential for certification of passive system construction techniques.

PROJECT TITLE:	**MARKET TESTING AND APPLICATIONS**
Institution:	*Western Solar Utilization Network* *Portland, Oregon*
Principal Contact:	*William Davis*
Contract Number:	*In-house*

Western SUN's market testing and applications project is aimed at establishing the commercial viability of solar systems and products. The approach involves working with manufacturers, solar organizations, and consumers to demonstrate performance under actual market conditions. The nature of these activities warrants the involvement of the Regional Solar Energy Centers in a lead planning capacity.

Specific activities include:

- *Market Testing Planning* — To establish a mechanism through which future market testing tasks can be conducted under actual market conditions
- *Demonstration Projects* — To re-orient existing data gathering and dissemination activities at demonstration projects to reflect the data needs of the solar industry in the region
- *Solar Update Conference* — To attract participants to the annual Solar Update Conference, provide information about DOE, Western SUN, and related solar projects and solicit comments in determining future, federally sponsored solar programs
- *Manufactured Building Project* — To assist SERI in contract monitoring, identifying additional markets in the Western Region, and disseminating results of the current DOE/SERI program to appropriate target audiences
- *Solar Federal Buildings Project* — To obtain information on federal solar projects within the Western SUN region and assist in the dissemination of design tools to architects/engineers in federal facilities.

PROJECT TITLE:	**TRAINING, INFORMATION, AND EDUCATION PROGRAMS**
Institution:	*Western Solar Utilization Network* *Portland, Oregon*
Principal Contact:	*William Davis*
Contract Number:	*In-house*

Western SUN's technical training program imparts professional level skills on passive and active solar energy, wind and wood technologies, with a special emphasis on the residential and commercial solar markets. Training tasks are designed to benefit installers, skilled trades people, architects, engineers, builders, developers, lenders, and state and local government, code, ordinance, planning, and tax officials. Projects have been planned for the entry-level participant as well as for the advanced student, and many will provide professional certification for apprenticeships, or otherwise recognized forms of professional training.

Western SUN's training projects will be coordinated with those of trade associations and unions; local, state, and federal governments; community colleges; vocational/educational institutes; and colleges and universities. Those training programs already in existence and sponsored by these organizations will be evaluated for Western SUN cosponsorship and support where appropriate. Western Sun will fully utilize, evaluate, and widely distribute the curriculum and training materials currently available, identifying needs for the writing of new materials and sponsoring their preparation. Flexibility to devise new training projects and approaches in response to state and regional priorities will be preserved.

Western SUN supports the training tasks to be conducted at the AS/ISES "Solar Jubilee" Conference and will sponsor several "Jobs from the Sun" conferences to address the specific training needs and opportunities for the unemployed. Also, conference support will be granted to local groups operating small, specific training projects. This will be coordinated with technical assistance training on active, passive, wood, and wind technologies for local government officials. Specialized training in solar businesses and installations will take place on Indian reservations in the southwestern portion of the Western SUN region. Direct hot water installation training is designed for low-income communities in conjunction with federally sponsored CETA and other agency solar and weatherization programs.

Western SUN will publicize training programs through regular information channels (e.g., the SEIDB). Western SUN will also participate in the promotion of Voluntary Solar Certification through building trades and HVAC industry representatives, retaining competency on the questions of contractor licensing and examinations. Western SUN works directly with and in support of the Solar Training Institute funded by DOE and DOE's Correctional Institution Program. Other activities will involve:

- Increase the number of solar installer courses offered through community colleges and vocational schools
- Encourage building trades, contractors, and mechanics to participate in the development of a national bureau for voluntary solar certification
- Offer solar installer training classes at federal and state correctional institutions
- Assist trade organizations in identifying and developing curricula for use in their own training projects
- Provide design and construction assistance for solar greenhouse installations in low-income rural communities in the Western Region.

PROJECT TITLE: **PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**

Institution: *Wick Building Systems, Inc., Marshfield Homes Division Chillicothe, Missouri*

Principal Investigator: *Ron McCaslin*

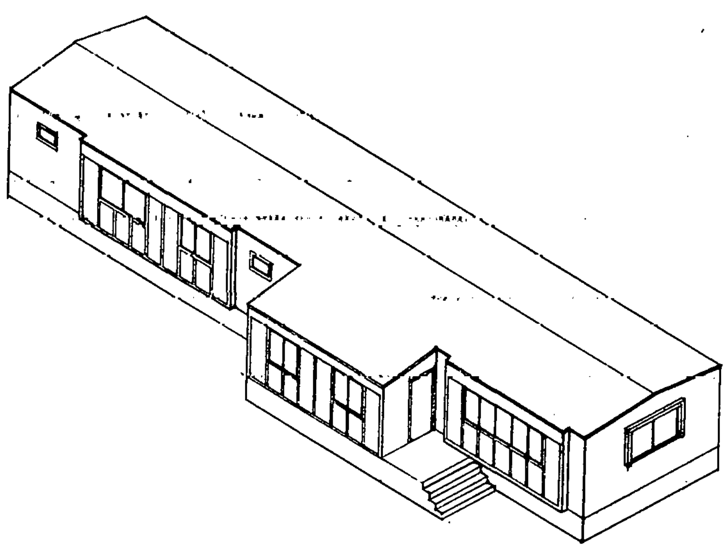
Contract Number: *DE-FC02-80CS30387*

The Wick Building Systems, Inc., of Chillicothe, Missouri, was founded in 1954. Mobile home operations began in 1960 with purchase of Marshfield Homes. These are marketed through a network of 660 independent dealers located primarily east of the Continental Divide. Wick Building Systems is currently the nation's sixth largest manufacturer of housing units (both custom panelized and manufactured/sectional homes).

This project examined various passive solar design concepts and energy management opportunities for improving the energy performance of single and double wide units manufactured by Marshfield Homes. The results provided Marshfield with potential design opportunities which do not significantly increase the cost of present units and which may be incorporated using current Marshfield construction techniques.

Three single wide models were compared: a standard unit; a fine-tuned model utilizing Marshfield's "Extra Measure 3" insulation package and additional energy conservation features; and a model referred to as Marshfield 1 incorporating passive solar design and energy conservation features. Both the standard unit and the fine-tuned unit have 105 square feet of glazing. The standard unit has 50 percent of the glazing oriented south, 25 percent north, 12.5 percent east and west. However, the fine-tuned unit is designed to have all glazing facing due south. From computer analysis, the solar contribution in meeting total heating energy for the three models was estimated as follows:

- Standard single wide unit — 11 percent
- Fine-tuned unit — 27 percent
- Marshfield 1 — 66 percent



Two double wide solar designs were examined based on an "affordable" 24 ft by 36 ft mobile home now manufactured by Marshfield Homes. Both designs involved modifying an existing double wide unit to include low-cost passive technology in a 12 ft sun space. Marshfield 2 added a sun space to the end of the home and would be more economical to manufacture than Marshfield 3 where the sun space is incorporated along the major axis. Computer analysis indicates an estimated solar contribution for these two models as follows:

- Marshfield 2 – 58 percent
- Marshfield 3 – 68 percent.

Comparative performance for all five mobile home models and the impact on heating costs assuming use of a gas furnace are summarized in the following table:

COMPARATIVE PERFORMANCE
MARSHFIELD STANDARD MODEL AND
ALTERNATIVE DESIGNS

	Area ft^2	Percent Solar	Auxiliary Heating Cost (Gas)$/Year
Standard (single wide)	924	11	520
Fine-tuned (single wide)	924	27	180
Marshfield 1 (single wide)	1,152	66	110
Marshfield 2 (double wide)	1,152	58	93
Marshfield 3 (double wide)	1,152	68	86

CHAPTER V: COMMERCIAL BUILDINGS

The overall objective of the work reflected in the projects in this chapter is the same as for Chapter IV except that the buildings involved are for nonresidential uses (i.e., office, institutional, industrial, commercial, etc.). Buildings for these applications are usually more complex and larger than residential buildings and must rely on different design criteria. For example, commercial structures must contend with energy flows dominated by internal heat gains caused by factors such as lighting, occupants, and equipment – factors which may normally be considered negligible in residential buildings.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Alaska Department of Transportation* *Fairbanks, Alaska*
Principal Investigator:	*Leroy Leonard*
Contract Number:	*DE-FC02-80CS30321*

Alaska's Department of Transportation and Public Facilities (DOT&PF) has responsibility for all state-owned rural schools in Alaska. DOT&PF is the owner-manufacturer of school facilities for rural Alaska where fuel costs often exceed $2.50 per gallon for a No. 2 stove oil.

The DOT&PF proposes to develop a passive solar building component that can be designed, prototype tested, and integrated into the routine design and construction of rural school facilities in Alaska. The passively designed building will be approximately 20 ft. X 30 ft. in size. The size is strategic because of the requirement that it be transportable by air (C-130 Hercules aircraft) to remote Indian or Eskimo villages in rural Alaska.

The objective of this Alaskan school effort is to reduce the cost of heating borne by the consumer (which in this case is the local school district), often in poverty-level areas. This building will serve as a model for future school construction in other northern latitudes of the United States and Canada.

DOT&PF expects to continue this project into the Phase II and Phase III stages. Partial funding for Alaska's portion of necessary Phase II funding has been programmed into the FY 1980 budget to provide for a continuation.

Design Approach

- Constraints imposed by building use:
  - Thermal mass storage easily transportable
  - Building will have daytime use
  - Unavailability of technicians and maintenance, as well as high fuel costs, dictates complete passive solar energy applications.

- Design features and analytical elements are:
  - Heating degree days
  - Total (heat and hot water load) load requirements for heat
  - Average monthly solar radiation
  - Use of variables in F-CHART
  - Windows — south facing
  - Shuttering — time variable shuttering
  - Mass storage within building
  - Insulation (conservation options)
  - All associated economic optimizations.

PROJECT TITLE:	**NATIONAL PASSIVE PROGRAM SUPPORT RESEARCH**
Institution:	*AIA/Research Corporation* *Washington, D.C.*
Principal Investigator:	*Duncan S. Bremer*
Contract Number:	*DE-AC02-79CS30120*

The scope of work under this contract involves three major tasks:

- *Passive Education Program and Model Workshops* — This effort charges AIA/RC to develop a program of workshops relating to passive solar design. In addition to developing the content and all materials for the workshops, they are responsible for evaluating their effectiveness, recruiting and training staff to conduct them as well as coordinate their programs' content with those developed by the Regional Solar Energy Centers

- *General Management Support and Information Dissemination* — This activity includes assisting in the development of architectural graphic standards, consulting with DOE as required, regarding the National Passive Program, and preparing and distributing information on all types of aspects of passive solar design

- *Architectural Design Competition* — This task supports the development of passive solar design competitions and involves advising DOE on content and criteria to be included in the competition.

PROJECT TITLE: **LONG-TERM ICE STORAGE FOR COOLING APPLICATIONS USING PASSIVE FREEZING TECHNIQUES**

Institution: *Argonne National Laboratory*
Argonne, Illinois

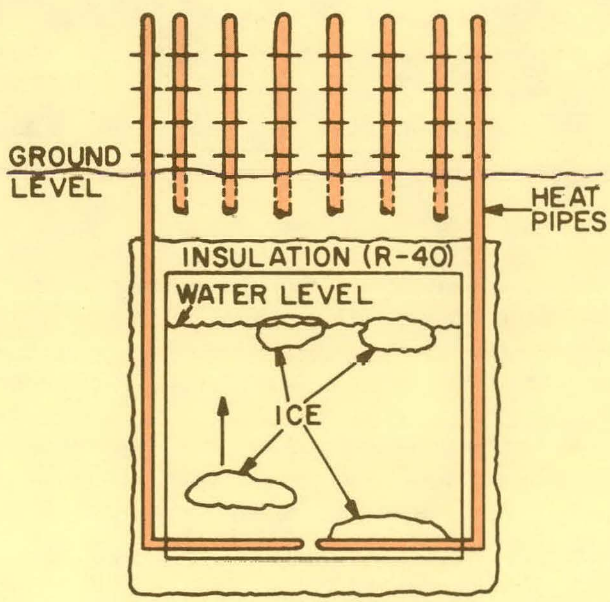
Principal Investigator: *A. J. Gorski*

Task Number: *49583*

This program is developing a cost-effective method of solar cooling using ice passively grown and stored during the winter. The cooling system will generate large volumes of ice without any expenditure of external energy or labor. This passive method of freezing ice has the potential to provide cost-effective summer cooling.

The concept of freezing ice in the winter and using it to provide cooling in the summer is not a new idea. This method has been used for food refrigeration for many years, and is still used in remote parts of the country. The major disadvantage of conventional ice storage techniques is the prohibitively high labor costs involved in cutting, moving, and insulating ice in an "ice house." However, if ice can be frozen in large volumes in the same container in which it will be stored, without any expenditure of energy or labor, long-term ice storage has the potential to provide cost-effective cooling.

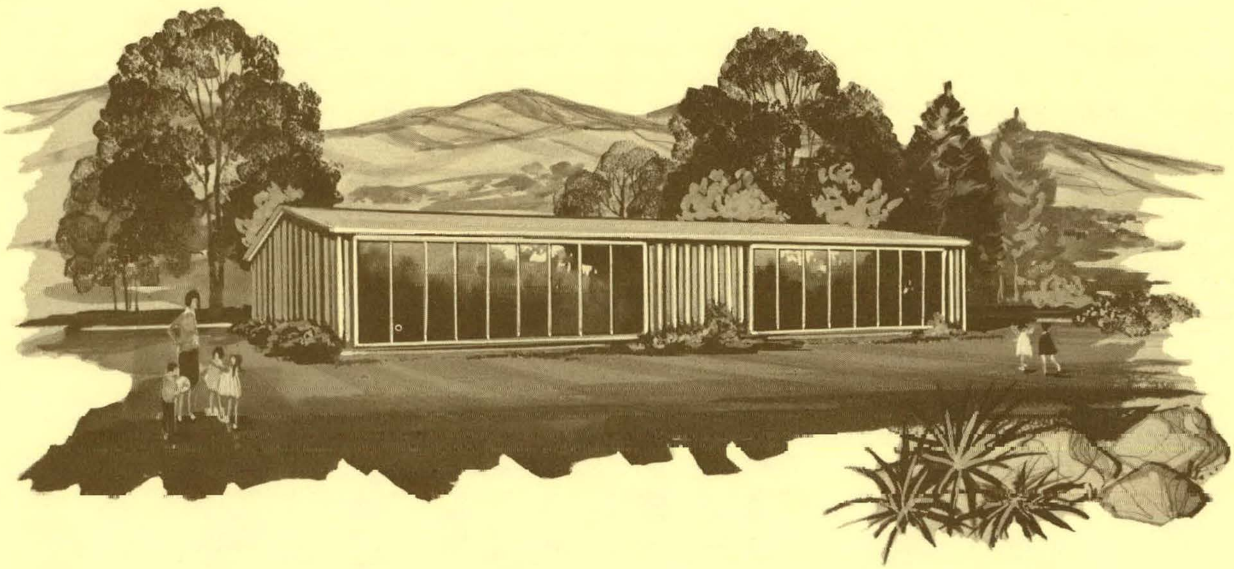
The basic elements of the passive cooling system proposed are shown below. A large insulated tank of water is buried underground near (or under) the building to be cooled. Specially designed heat pipes extend from the bottom of the tank to the soil surface and project above the ground. These heat pipes act as one-way conductors of heat. Along the underwater length, heat from the water causes thin film evaporation of the working fluid within the unit. The resulting vapor travels upward and condenses in the above-ground radiator section, releasing the transported heat to the air. During the winter months extraction heat freezes ice along the submersed portion of the heat pipes. When the air is warmer than the water in the tank, the evaporation-condensation cycle stops automatically. Thus heat can be easily removed from the water, but it cannot be readily transferred from the environment to the water.



PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Banes Company, Inc.* *Albuquerque, New Mexico*
Principal Investigator:	*Doyle Seymour*
Contract Number:	*DE-FC02-80CS30364*

The Banes Company, Inc. proposes to implement passive solar, thermal storage, and daylighting systems into their 28 ft. X 60 ft. manufactured buildings. Although primarily used as classrooms, the buildings also function as office space and warehouse storage areas. Including solar heating features into these buildings is expected to increase their market potential. The proposed building is a standard, double-wide portable classroom unit. The average price is $36,000.

The test facility will be located in Albuquerque, New Mexico. Maximum summer temperatures are generally in the high 90s, and low humidity makes evaporative cooling an attractive alternative. The high probability of sunshine on cold days makes solar space heating a natural candidate for energy conservation. Daily minimum temperatures are below the comfort range even in the summer. Both high and low temperatures tend to occur during periods of intense bright sunshine.



Design Approach

The design approach will focus on effective integration of passive solar features (such as thermal storage) into the modular building. Implementing passive techniques will consider several options:

- Passive solar heating options – Trombe wall, direct gain, roof clerestory, radiation/convection wall, greenhouse
- Passive cooling options – Roof pond, night cooling, and evaporative cooling
- Daylighting options – Windows, clerestory, and skylighting
- Other design options – Fuel selection, space conditioning back-up system, window fenestration, and heat recovery systems.

Design tools for these buildings include programs that have been used by Los Alamos Scientific Laboratory and the University of New Mexico to study passive solar applications' cost effectiveness.

PROJECT TITLE: **SECONDARY SCHOOL SOLAR CURRICULUM**

Institution: *Bureau of Science Education*
Albany, New York

Principal Investigator: *Tom Boehm*

Contract Number: *DE-AC01-77-CS34039*

In 1977, DOE funded the New York State Education Department and the S.U.N.Y. Atmospheric Sciences Research Center to develop and disseminate a secondary school solar curriculum. Written by teachers and field tested nationally during the 1979–80 school year, the curriculum is designed to be integrated into existing science classes. The core of the curriculum are the 43 activities for junior high science, earth science, biology, chemistry, and physics. The activities cover all forms of solar energy, from passive design to wind biomass. Support materials include a Teacher's Guide, a text covering scientific, technical, and social aspects of solar energy, and a reader of current articles on energy from popular periodicals.

The Regional Solar Energy Centers (RSECs) are assisting DOE disseminate the curriculum. During the 1979–80 school year, the Northeast Solar Energy Center sponsored over 75 workshops reaching more than 3000 teachers.

Plans for 1981 include revision of the solar science curriculum and expansion of the curriculum to include activities in industrial arts and home economics.

PROJECT TITLE: **WHITE MOUNTAIN SCHOOL FACULTY HOUSING AND DORMITORY**

Institution: *Banwell White & Arnold*
Hanover, New Hampshire

Principal Investigator: *C. Stuart White*

Contract Number: *EG-77-G-04-4139*

The White Mountain School Faculty Housing and Dormitory Project is designed to use a solar assisted heating system to minimize fuel consumption and to provide an environment for teaching the principles of solar energy and how to use them more efficiently.

The building's program began with the premise that the dormitory should be something more than just a place to sleep. It was felt that a system using solaria and greenhouses would extend the student's learning experience beyond the classroom by confronting them with a naturally-powered environment. In terms of solar design approaches, the "living center" explores the basic functional differences between greenhouses and solarium solar systems.

The architects felt that active solar collectors could and, in fact, should be avoided because they don't offer any aesthetic enhancement to the kind of spaces they had intended for the dormitory living center. Active collectors are efficient but they do not necessarily allow sunlight into the building and thus can deprive occupants of the abundant natural lighting that is a principal advantage of most passive solar systems.

The building, which was completed and occupied in Spring 1979, is a linear, single-loaded structure oriented on an east-west axis. The south elevation – which actually faces 10 degrees west of south – consists of a series of interconnected two-story solarium units and a central greenhouse for year-round food production experiments. The building design called for five nearly identical bays. The two extreme east and west units were faculty apartments, and the two units flanking the greenhouse, student quarters. (Because of financial limitations, however, the east wing faculty apartments have not been built.) The middle unit houses the center's community room on the lower level, and a resource/library/monitoring space above.

The Center's greenhouse is a high-mass structure, with dark masonry walls and floors and a large capacity to store heat within itself, and in so doing, dampen temperature fluctuations. The prime purpose of the greenhouse's passive features is to supply solar heat to the greenhouse itself, not to the rest of the building.

The solaria, on the other hand, are low-mass structures, with as little capacity to store heat as is practical and still be usable.

Because of the low mass used and the large expanse of glazing (over 2000 square feet) these solaria periodically overheat. It must be remembered that these spaces are literally solar collectors for the living spaces behind them. The floor area for community activities and circulation that they provide is above and beyond the building program requirements. As collectors, the solaria receive no auxiliary heating beyond that escaping from the living spaces, which are heated partially by conventional means. The interior temperatures are, however, high enough for the solaria to act as an additional insulation layer – or an intermediate temperature zone – between outside and inside, effectively minimizing heat loss from the south side of the building proper.

Monitoring shows that the design has been most effective, and heat loss from the south side of the building will most likely be reduced ultimately by 70–80 percent. During the measuring period a number of problems – some contributing substantial heat losses – existed, but have been corrected, or specific corrective measures recommended. The 35 percent solar heating fraction has been achieved in spite of these problems, which included the lack of nighttime insulation in the solaria. Performance is expected eventually to be close to the 50 percent solar contribution established in simulations prior to building construction. At that time the simulations indicated an annual energy requirement of 229 million Btu's per year without the solaria, but only 118 million Btu's with them.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Bessemer Board of Education* *Bessemer, Alabama*
Principal Investigator:	*Dr. Jack Hale, Superintendent*
Contract Number:	*DE-FC02-80CS30324*

The Bessemer Board of Education plans to abandon one of its elementary schools because of population shifts and the poor condition of the old building. A new elementary school building will be constructed on extra land at the site of an existing high school campus. The new building is expected to service 600 students and will include grades kindergarten through fifth. Energy conservation is the major concern in this project, which will embody passive solar design.

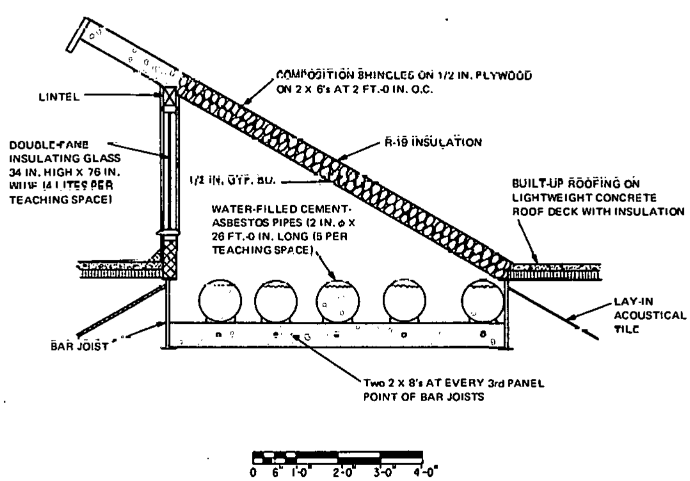
Design Team

- Architecture and Solar Desinger: Cobb/Adams/Benton, Inc., Architects
- Mechanical Engineer: McWilliams Associates, Consulting and Mechanical Engineers
- Lighting and Electrical Engineer: Cater and Parks, Inc.

Design Approach

Architectural variables to be investigated during the design process include:

- Building shape, building orientation, glazing and shading devices, mass of construction, insulation, and color
- Use of natural daylighting to replace a portion of the artificial lighting that will assist in cooling
- Design of mechanical systems for heating, ventilating and air conditioning, and passive solar design.



SOLAR 1 ROOF MONITOR/THERMAL STORAGE SCHEME

Various cost analyses evaluated the relative costs and returns of different design alternatives, including differences in first cost, utility cost, maintenance cost, and a pay back period which influences the passive solar features designed into the building.

Design Tools

- Physical modeling useful for evaluating natural daylighting characteristics; scale models will be constructed
- Hand calculations and computer calculations
- Computer simulation and economic analysis for evaluations of the passive solar design in relationship to total construction cost, total annual energy usage and utility cost, and annual maintenance cost.

Evaluation

Evaluation will be based primarily on comparison of costs with similar projects not enhanced by passive solar energy design.

PROJECT TITLE: **PASSIVE AND HYBRID SOLAR MANUFACTURED BUILDINGS**

Institution: *Butler Manufacturing Company*
Kansas City, Missorui

Principal Investigator: *Marvin Snyder*

Contract Number: *DE-FC02-80CS30366*

The primary goal of this project is to develop, in greater detail, passive heating, cooling and daylighting concepts which will be consistent with Butler's goal of providing a completely integrated set of building components for energy conservation in all climates throughout the United States.

The Design Team consists of Butler Manufacturing Company, Princeton Energy Group as Solar Architect, and the Desert Research Institute as cooling consultant.

Complete construction documents, encompassing more than three design alternatives to be tested have been submitted to DOE. Work is presently underway to install selected systems to the Butler Research Facility for analysis and testing.

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED BUILDINGS**
Institution:	*Butler Manufacturing Company* *Kansas City, Missouri*
Principal Investigator:	*Marvin Snyder*
Contract Number:	*DE-FC02-80CS30367*

The scope of work of this project addresses the design, construction, and testing of a manufactured building incorporating passive cooling concepts. Two prototype design systems will be incorporated into a test building to be constructed at Boulder City, Nevada. These systems are:

- Air Conditioning by Forced Convection through a narrow roof duct plenum (heat rejection accomplished by night sky radiative and spray evaporative cooling of the roof surface), with and without coupling to remote storage (the most promising possibility being below-slab rockbed)
- Cooling by Slab-Roof Radiative Coupling (heat rejection by the same means described above), with and without intermediating convective barrier or phase change storage.

A proposal to construct the facility is presently being reviewed with construction ready to begin immediately upon notice to proceed.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Carnegie-Mellon University* *Pittsburgh, Pennsylvania*
Principal Investigator:	*Volker Hartkopf*
Contract Number:	*DE-FC02-80CS30326*

Carnegie-Mellon University in Pittsburgh, Pennsylvania has proposed to redesign its central administrative building and retrofit the building using passive solar design concepts. The central administration building is a typical representative of the "glass box" building approach of recent years. The building is 10 years old, and it consists of rectangular floors, one basement, one entrance level, and five upper floors. Principal uses of the building are:

- Basement — Unloading, loading, storage, mechanical, minor offices
- Entrance floor - Reception and offices
- Upper floors - All upper floors are primarily used for offices.

Approximately 85 percent of the building is aboveground, and this part of the building is basically all glass.

Design Team

- Physical Plant Personnel of the University will have responsibility for control of fund commitments and for reporting financial and design progress of the project.
- Advanced Building Studies (ABS) will prepare the design program describing user requirements, site analysis, and urban neighborhood context analysis.
- Dubin-Bloome Associates of New York support an integrated design approach involving planners, architects, and engineers.

Design Approach

The goals in the redesign of the building are to reduce fossil fuel consumption and other existing energy demands on the building. These elements will be studied in relation to local climatic conditions, building use, configuration, and construction as they relate to energy consumption.

Design Tools

- Static load calculations will be used to evaluate energy conservation measures; static heat loss/gain calculations will be based on ASHRAE.
- Shading coefficients for summer and winter solar heat gain will be set by scale models.

- Passive heating programs will be measured on the TEANET TI-59 program.

- Cooling alternatives will be evaluated by ASHRAE static, hand calculations concerning natural ventilation and heat exchange of masonry materials.

Evaluation

Carnegie-Mellon University plans to install the systems modifications and solar retrofit measures. The University also plans to instrument the building to evaluate the system's performance after changes are made and to compare this performance with previous consumption records.

PROJECT TITLE:	**PASSIVE SOLAR CALCULATION METHODS**
Institution:	*CCB/Cumali Associates* *Oakland, California*
Principal Investigator:	*Zulfikar O. Cumali*
Contract Number:	*EM-78-C-01-5221*

CCB/Cumali Associates is a consulting engineering firm concentrating in the energy conservation field. Their work in the Passive and Hybrid Solar Energy Program presently involves two major efforts.

Analysis of Commercial Buildings for "BEPS"

A large number of existing buildings have been analyzed to determine their energy consumption characteristics. For the most part these buildings represented conventional structures and did not display any innovative design or passive solar features. Inclusion of a class of commercial buildings with such features is very important so that required supporting analyses and justifications can be made for the final BEPS ruling.

Obviously, not all building types and configurations lend themselves to passive solar applications. In selecting candidate buildings for the prototype set, numerous considerations must be satisfied. This may be done either by selecting those buildings that lend themselves with design modifications to passive solar applications or by developing new prototype solar designs. In either case, an extension of the building data base accumulated for BEPS needs to be expanded.

Initial data bases to be investigated are the 170 buildings which have been subjected to detailed analyses by AIA/RC, the 42 buildings that have been analyzed by DOE contractors for passive solar applications in the 1979 Program Opportunity Notice, 9 buildings CCB-Cumali Associates have developed for the California Energy Commission on which the state energy budgets are based, and a subset of over 100 buildings which CCB has analyzed over the last five years.

The prototype building preparation work will be done in close cooperation with SERI and the passive solar group at LBL, primarily; and to the extent possible, will be related to the work being done by other BEPS contractors.

Interzone Balance Techniques for Building Energy Analysis

The thermal coupling of zones and the systems serving them is a difficult computational problem when analyzing energy use in buildings. Approximate methods for solving this problem have been attempted in some of the recent public domain computer programs, i.e., DOE-1 and -2, BLAST, etc. The approach taken usually breaks the analysis into two parts, a thermal load calculation part and a system stimulation part.

The use of the thermal balance or the weighting factor technique also determines the coupling method employed for the thermal load and system performance calculations. For example, in the implementation of the thermal balance technique, the availability of heating or cooling and the capacity of the system serving the spaces need to be known when the controlling thermostat equation is included in the load calculations. However, if the assumed capacities are not correct, no mechanism is available to correct this in the system section except to ignore the implications of the different resulting temperatures. Such is the case in BLAST. In DOE-1 and -2, the zone-to-zone coupling is, exact in the loads section since constant temperatures are used, and the zone/system coupling is obtained by generating temperature weights. However, the zone-to-zone coupling in the systems section is approximate, as past hours temperatures are used to avoid a simultaneous type solution. In both implementations, if zone-to-zone and zone-to-system couplings are strong as in passive solar systems which depend on extensive use of interzone heat transfer and use of natural or forced ventilation to control zone comfort, the results obtained are very likely not reliable enough to evaluate design alternatives.

It is therefore important in all cases to account for these interactions so that the benefits derived from them can be ascertained and the negative effects produced in certain cases be qualified.

This proposed approach results from work done by CCB/Cumali Associates on Passive Solar Calculation Methods, implementation of a coupled technique in the residential package for DOE-2 for the State of California, and a study of the optimum window sizes for residences, suggestions on the use of the radiosity concept in Load Calculations by T. Kusuda of NBS, and a similar but more approximate technique described by George Walton of CERL.

The work is to extend the development of this common base to passive solar systems which can be used in either the weighting factor or the thermal balance techniques including their variants.

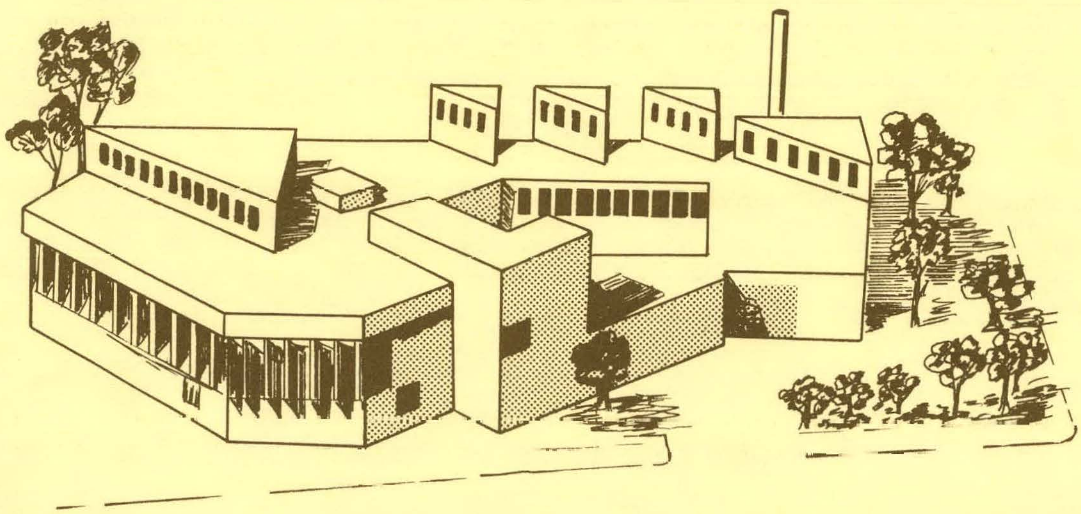
PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *City of Boston*
Boston, Massachusetts

Principal Investigator: *Patricia Bjorklund*

Contract Number: *DE-FC02-80CS30327*

The Public Facilities Department of Boston, has proposed a district police station for the City of Boston. It will be located in a neighborhood called "Jamaica Plain," approximately 6 miles southwest of the downtown and waterfront areas of Boston. The building will be approximately 13,000 square feet of new construction in a two-story arrangement.



Design Team

- Architect: Hill Miller Friedlaender Hollander, Inc.
- Solar Design Consultant: Timothy E. Johnson, who also teaches at M.I.T.
- Mechanical Engineer: Scorziello Associates of Boston, MA
- Electrical Engineer: Lottero & Mason Associates of Boston, MA
- Structural Engineer: Souza & True, Inc. of Cambridge, MA.

Design Approach:

The design methodology will follow the traditional architectural process of programming and conceptual to schematic and final design, taking into consideration the application of passive solar concepts throughout. Incorporation of passive solar features will be based on the following studies and analyses:

- Heating, cooling, and lighting requirements by functional area
- Site analyses including topography orientation and microclimate
- Performance simulation studies
- Study of physical models.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*City of Mount Airy* *Mount Airy, North Carolina*
Principal Investigator:	*Tom Webb, Grants Admin.*
Contract Number:	*DE-FC02-80CS30329*

Mount Airy, North Carolina, is located near the North Carolina/Virginia border approximately 10 miles east of the Blue Ridge Mountains. The city proposes to build a public library for the use of its citizens. The library is to be an integral part of the governmental/civic portion of the city and will be adjacent to a recently completed City Hall.

The proposed new library structure will contain 13,750 square feet. In addition to normal library functions such as book lending and periodicals, the building will offer space to be used as a public forum/exhibition area for the use of the townspeople. Another major function of the library will be to provide an example of solar energy design and use.

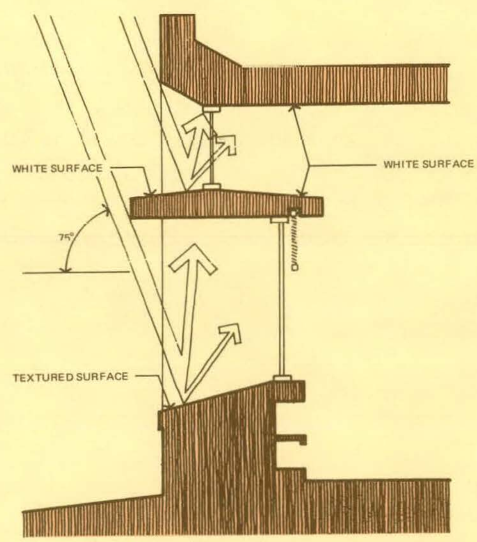
Design Team

- Architect/Engineer: J. N. Pease Associates of Charlotte, North Carolina
- Architect Solar Designer: Edward Mazria and Associates of Albuquerque, New Mexico

Design Approach

The programming phase will define the functional criteria for a solar design and will support the proposed functions of the building. Site studies will include such factors as: solar access, wind protection, site topography, and visual access and views.

The schematic design phase will result in scale-design drawings, basic decisions about the location of the building on the site, layout of interior spaces, and choice of an appropriate passive solar system. Upon approval, these concepts will provide the basis for the final design of the building.



Design Tools

- Scale model and sundial
- Heating Load/Collector Area Ratio developed at Los Alamos Scientific Laboratory
- Various computer analysis programs.

Passive solar systems will be installed as an integral part of the project as it is constructed. During construction, monitoring devices will be put in place as a permanent part of the building controls, allowing monitoring and evaluation throughout the life of the building.

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *City of Lincoln*
Lincoln, Nebraska

Principal Investigator: *V. C. Seth*

Contract Number: *DE-FC02-80CS30328*

The city of Lincoln, Nebraska, proposes to design and construct a 21,000 square foot (gross) facility which will be jointly used for a fire station, health station, and library.

Design Team

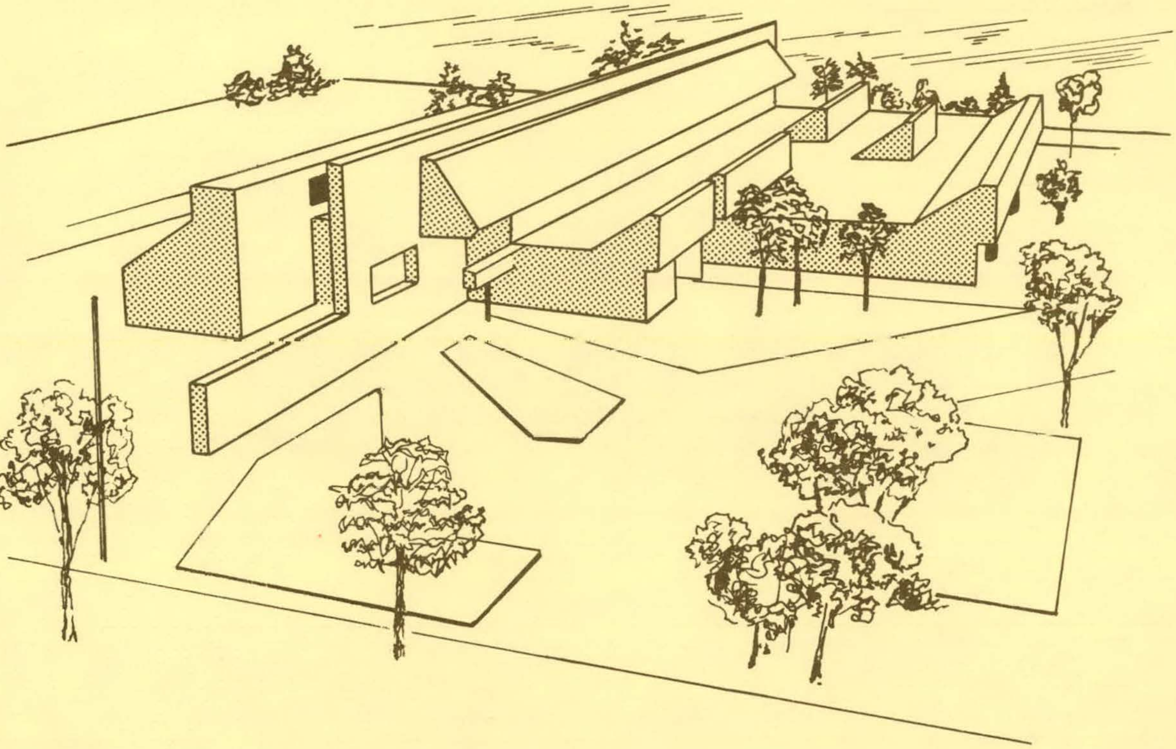
- Architectural Design Coordinator: John E. Sinclair
- Principal-in-Charge of Engineering: Charles L. Thomsen
- Mechanical Engineering Coordinator: Ravinder Maniktata
- Electrical Engineer: James Phillips
- Civil Engineering Coordinator: Randall E. Kumm
- Site Planning Coordinator: Lawrence A. Anersen.

Design Approach

The passive solar system will provide a major portion of the annual space heating and lighting requirements. In the library and health stations, this passive solar system consists of Trombe wall elements on portions of the south face of the building and light scoops in the roof for areas not adjacent to the Trombe wall elements. The light scoops are glazed with diffusing glass to dispense the solar radiation and light throughout the space. This eliminates the harsh glare of direct undiffused solar radiation. The diffused natural light will permeate most of the interior building spaces and will minimize the need for artificial lighting during the daylight hours.

Storage of heat from the light scoops is provided by localized dark masonry floor areas and movable standing water tubes. The Trombe wall consists of a dark masonry wall behind clear glazing. The wall serves both as collector and storage. The wall heats up on a sunny winter day and radiates heat into the room during the night. Both the light scoops and the Trombe wall are insulated by automatic insulated shades that roll down in the evening. Summer shading of the light scoops and other glazed areas is provided by roof overhangs. The south facade will also be shaded in summer by deciduous trees which drop their leaves to allow full sun to the south facade during the winter.

An active solar heating system has been studied, which would allow the use of the heavy masonry divider wall as a storage element for solar heat to augment the passive solar system and to preheat domestic hot water. Supplemental heat will be provided by natural gas.



In the design approach, the first step in considering energy utilization will be energy conservation. This first step leads to well-insulated, well-detailed buildings with shapes that minimize the area of exterior exposure relative to the volume of space enclosed. The second step integrates passive solar facets, such as building orientation, fenestration, planting, and other passive solar devices with the site requirements. After all energy conservation measures and all practical passive solar devices are included, active solar systems can be considered. The passive energy elements are superimposed on the building site so that the location and orientation of the building can respond to these criteria. The specific passive energy criteria include winter and summer sun angles and direction of winter winds and summer breezes.

Design Tools

- Rules of thumb developed at Los Alamos Solar Energy Laboratory
- Use of programmable calculator techniques.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*City of Philadelphia* *Philadelphia, Pennsylvania*
Principal Investigator:	*Thomas McKay*
Contract Number:	*DE-FC02-80CS30330*

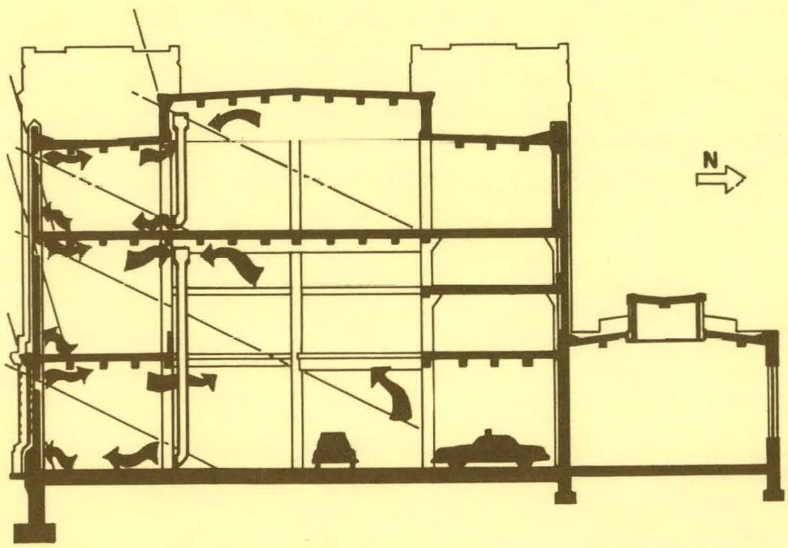
The City of Philadelphia proposes to add passive solar heating and cooling elements to the Automotive Maintenance Shop located in the southern section of the city. The building, approximately 65 years old, is used as an automotive shop primarily for police vehicles. It has a gross area of approximately 43,000 square feet on four floors. The structural frame is of reinforced concrete, and the exterior walls are of brick and terra-cotta. The building has five sides and is shaped like an elongated pentagon. The long axis of the building has a northeast-southwest orientation. This gives the long south side of the building an ideal orientation for passive solar heat collection.

Design Team

- Chief Design Engineer: James M. McKay, Department of Public Property (Philadelphia)
- City Project Architect: Richard Tustin, will provide technical development by resolving questions of design
- Solar Consultants: Charles Burnette and Associates.

Design Approach

- The primary design approach is to replace the windows on the south side of the building with a partially translucent water-filled fiberglass mass storage thermal wall shielded by shatter-proof high-impact resistant fiberglass. The intent of the design is to create a translucent replacement window that provides both heat and illumination during daylight hours and insulation at night when the facility is closed.
- The use of a heat trap (a down-facing insulated chamber) at the top of the water storage elements will be studied to determine to what degree heat leaving the water storage at night could be captured and held for early morning discharge.



- Based on the heat trap idea, a closely related greenhouse design will be developed around the main automotive doorways on the first level of the south wall. In this concept, a glazed canopy will be built above and projected around the large automotive entrances. The canopy roof will be sloped in a way to trap heat rising as it escapes from the open doorway.

Design Tools

- TEANET and TI-59 programmable calculator for analyzing passive thermal storage walls of the water wall type

- Calculations from an actual model.

Evaluation

- The City of Philadelphia will record the energy savings achieved through its Utility Monitoring and Forecasting System. The system allows rapid comparison of actual versus projected utility costs as well as historical versus current costs

- This proposed project will give added credibility to the planning and feasibility studies now in progress by demonstrating a practical use of solar energy in Philadelphia.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Colorado Mountain College* *Glenwood Springs, Colorado*
Principal Investigator:	*F. Dean Lillie, President*
Contract Number:	*DE-FC02-80CS30331*

Colorado Mountain College is a public, two-year community college located at Glenwood Springs, Colorado, in West Central Colorado on the western slope of the Rocky Mountains. It is a local district college, governed by a board of elected representatives from each of the five counties that comprise the College District.

Colorado Mountain College proposes to build a multiuse building to be a prototype for incorporating passive solar design in future campus buildings. The passive solar building to be designed will house the following entities:

- A community education center for Glenwood Springs
- Central administration and business offices for the Colorado Mountain College District
- Central administration offices for Colorado Mountain College District community education.

This structure will be built into the hillside and maximize the benefits and minimize the detriments of its microclimate. The design, orientation, fenestration, and siting will use natural means to achieve a significant portion of its heating, cooling, lighting, and ventilation requirements.

Design Team

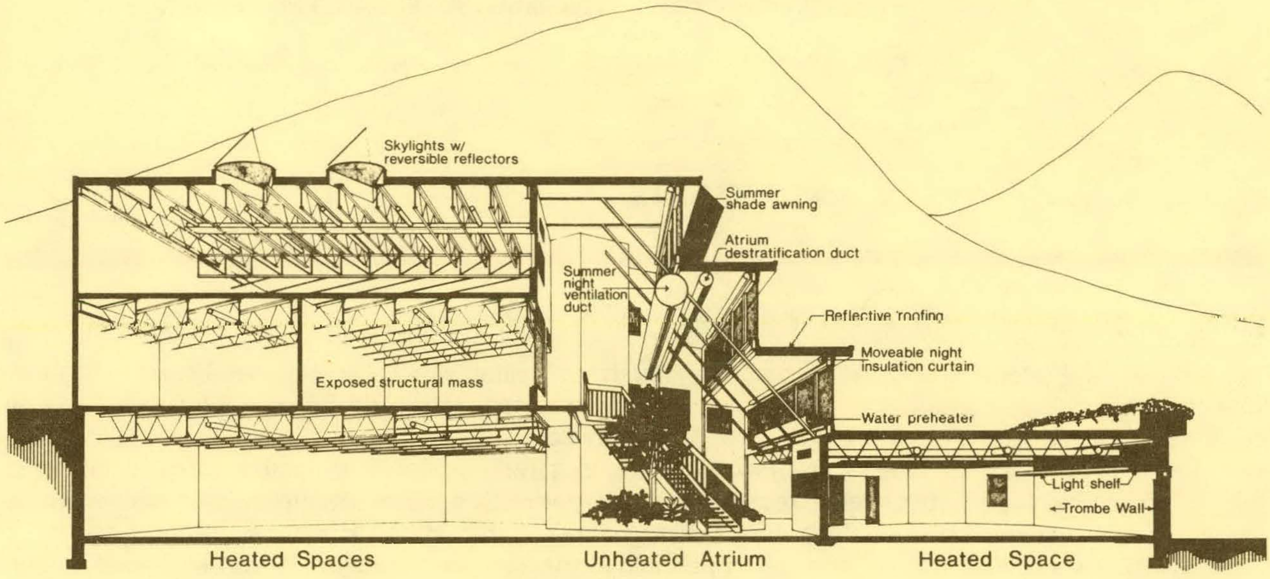
- Architect: Peter Dobrovolny, Sunup Architecture Firm
- Solar Consultant: Thermal Technology Corporation
- Structural Engineer: James R. Van Liere, P. E.
- Construction Manager: Construction Management Consultants, Inc.

Design Approach

- Energy efficiency has been identified as a primary design component
- Site analysis and local topography encourage a structure built into the hillside
- Exposed envelope components will be thermally tightened with double glazing, movable insulation systems, high resistance wall and roof sections, and an atrium buffer zone
- Variety of energy conserving and passive techniques, such as direct gains, thermal storage walls with integral and remote storage, solar greenhouse, and natural daylighting, will be used.

Design Tools

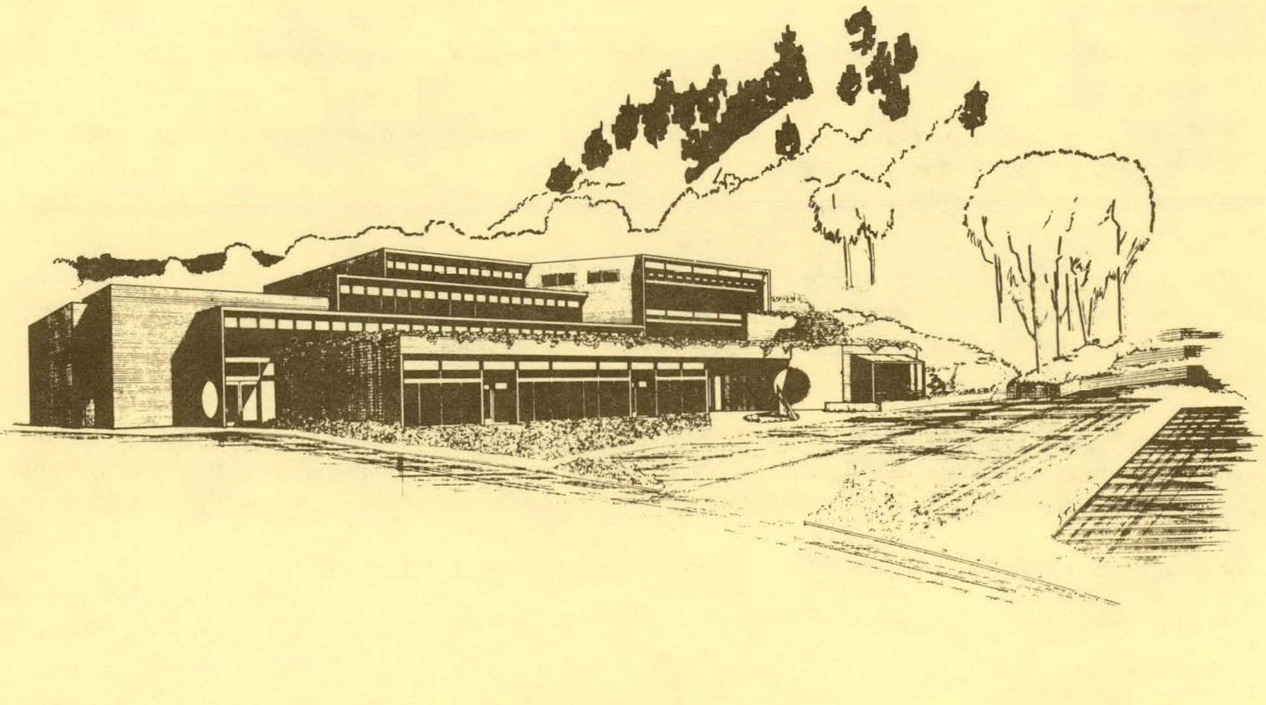
- Site analysis – surveying instrumentation, soil analysis, National Weather Service data pools
- Schematic design – based primarily on experience of the design team
- Design development – modifications of the LASL method for system performance and life cycle costing procedures; a second aspect of the thermal analysis involves instantaneous thermal environment calculations
- Computer model used to finalize design procedure – the program to be used is entitled *A Quantitative Method for the Design of Buildings with Comfortable Microclimates by Passive Control of Solar Effects*, developed by Mr. M. F. Agha.



BUILDING SECTION

Evaluation

- In essence the passive system or systems become the building; the building will function as a solar collector, energy storage battery and thermal trap
- Due to the educational nature of the project, Colorado Mountain College will develop a plan for evaluating the passive solar building both from a technical and social perspective
- Records will be kept to monitor the daily climatic conditions and both electrical and natural gas consumption figures.



PROJECT TITLE:	**REPEAT FACILITY** **(Reconfigurable Passive Evaluation Analysis & Test Facility)**
Institution:	*Colorado State University, Solar Engineering Applications Lab. Fort Collins, Colorado*
Principal Contact:	*Byron Winn*
Contract Number:	*DE-AC02-80CS30259*

Background

Although the overall discipline of heat transfer is well established, certain specific areas such as free convective heat transfer and radiative heat transfer within building structures are not completely understood. Investigations of free convective heat transfer have centered around two-dimensional, steady, laminar motion which is not representative of convective motion in a passive structure. Simple turbulent free convective systems scale from one system size to another as length to the one-third power. With minor disturbances within scaled spaces, air motion and heat transfer processes should not change appreciably for similar systems. However, when major disturbances are introduced in a passive solar building (partial walls, radiative interactions) the observed "behavior" of temperatures and air movement for one size room to another may no longer be similar since the irregularity in the geometry will eventually assume a controlling role. Therefore, it is important to obtain data for passive systems from full-scale buildings and preferably under controlled conditions. Questions of scale apply to radiative heat transfer within the building as well as to convective motion and there have been virtually no investigations to determine scaling effects.

A full-scale structure allows testing of combinations of passive elements since a linear combination of individual passive features for multiple systems is questionable and because there are complex interactions between systems (e.g., the hot air of a partial direct gain system interacts with the back surface of a mass wall and transfers heat into the wall from both surfaces).

The performance of passive solar systems is often a function of: first, the characteristics of the entire building; second, the interface between the solar system and the building; and, third, the specific parameters of the particular solar system being used. As a result, a full-scale passive solar test project should be able to:

- Deal with a variety of building configurations, interface configurations, and passive solar sytems; and
- Perform analyses to readily and accurately discern important parameters and the functional relationships existing among them.

Objectives

The primary objective of this project by the Colorado State University is to establish a controlled facility for testing passive system concepts in an efficient and cost-effective manner. The scope of work includes the design and construction of a building that can accurately simulate free convective heat transfer mechanisms.

The testing proposed by Colorado State University consists of two side-by-side, full-scale units separated by a basic research building and data analysis using the microprocessor and optimal observer techniques. The synergistic effects result in:

- A program which has the credibility of multiple, side-by-side facilities
- The reduced funding requirements of fewer facilities

- The speed and accuracy of microprocessor based observer techniques which allow for system identification in weeks and months instead of years.

The full-scale passively-heated test buildings are reconfigurable and provide control of three levels of complexity:

- The thermal properties of the buildings may be varied by changing the number of insulation panels in the walls and insulation in the ceiling, the amount of thermal mass in the floors and walls, and the amount of infiltration through vents and heat exchangers.

- The interior configuration may be changed by moving floors, ceiling, and the walls (to include mass walls) within the structure. This is done by removable floor panels and joists and a custom-designed concrete basement floor which can take the loads imposed by the mass walls.

- The passive solar system can be changed due to the various locations of apertures and the fact that these apertures are variable in size by means of masking.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Community United Methodist Church* *Columbia, Missouri*
Principal Investigator:	*William H. Miller*
Contract Number:	*DE-FC02-80CS30334*

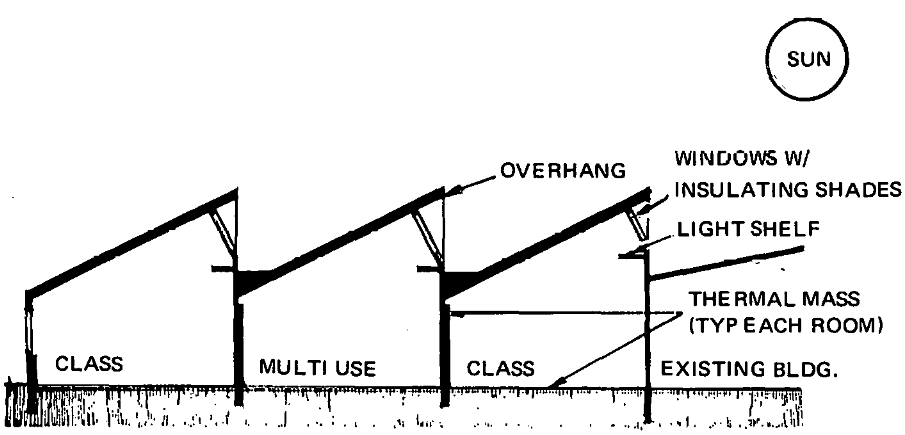
The proposed building of the Community United Methodist Church is a passive solar-heated and solar cooled structure dedicated to classroom space and will be a new addition to the existing complex. The building will be approximately rectangular in shape (with a length of 100 feet by 50 feet wide) and will use an open planning concept. The long axis of the building will have an east-west orientation to provide maximum exposure to the sun.

Design Team

- Architect/Project Manager: Peckam and Wright Architects, Inc., will provide leadership for the design team
- Architectural Consultant: Douglas Hoffman, Director of Architectural Services of the Board of Global Ministries of the United Methodist Church.

Design Approach

- Several passive solar systems will be evaluated for incorporation to the building:
  - A masonry thermal storage wall
  - The use of Eutetic Salt for additional heat storage
  - A greenhouse as a solar heating device and educational tool
  - An earth contact cooling pipe for summer cooling
  - An active domestic hot water heater.
- Other systems being considered include:
  - A heat pump for backup heating
  - An active solar hot water heater
  - One story to eliminate an elevator.



FINAL DESIGN SECTION

Design Tools

The design phase will require two sets of design tools — preliminary and final design models:

- Tools for preliminary work will use simple, hand calculator-type calculation; these procedures include those in the work of Mazria or the TEANET, 7-node thermal network model

- Final design calculations will use the Los Alamos Scientific Laboratory developed "Simulation Analysis of Passive Solar Heated Buildings"

- Other computer models that are available to the design team

Evaluation

To evaluate the effectiveness of the design, a simple monitoring of gas and electricity rates for the proposed building and the other buildings of similar size will be employed. Another mode of evaluation involves the use of extensive microprocessor data monitoring equipment.

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *Comal County Mental Retardation Center*
New Braunfels, Texas

Principal Investigator: *David M. Way*

Contract Number: *DE-FC02-80CS30333*

The Comal County Mental Retardation Center, located in New Braunfels, Texas, plans to design, install, and evaluate passive heating and cooling techniques into the retrofitting of an underutilized and deteriorating school building. The building to be retrofitted is the Stephen F. Austin Elementary School in New Braunfels. The building is owned by the New Braunfels Independent School District and leased by the Comal County Mental Retardation Center. The school will receive passive heating and cooling modifications as well as internal renovation. Upon completion, it will serve as a sheltered workshop for approximately 32 mentally retarded clients in a seven-county area surrounding New Braunfels.

Design Team

- Owner/Developer: Comal County Mental Retardation Center
- Architect: Joe Hubblefield Architects and Planners, Inc.
- Solar Design Consultant: Southwest Research Institute, a not-for-profit corporation in San Antonio, Texas
- Mechanical Engineer: JUD Plumbing and Heating Company, Inc., of San Antonio, Texas

Design Approach

Passive solar design considerations will include:

- Conservation - methods of minimizing the uncontrolled effect of the outside environment on the inside environment; to reduce heat gain in summer and heat loss in winter
- Cooling Load Reduction - In the South Texas area, electrical consumption by vapor compression air conditioners is a greater financial resource and expense than space heating; techniques to be investigated to counteract the heat gain are shading, thermal walls, berming and others.
- Heat Load Reduction - Meeting the heating load by passive means will be easier than for the cooling load; the primary alternatives to be explored are radiation through glazing, thermal storage, Beadwall/IR reflectors, Greenhouse effect, and movable ceiling panels.

Design Tools

- TEANET - To be used with hand-held programmable calculators with printer
- DEROB - An hourly load simulation program developed by The University of Texas to model passively heated and cooled buildings
- NBSLD (Modified) - Developed by Trinity University in San Antonio, Texas.

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Consolidated Properties, Inc.* *Berryville, Virginia*
Principal Investigator:	*Frederick L. Spencer, Jr.*
Contract Number:	*DE-FC02-80CS30369*

Consolidated Properties, Inc. is a holding company for four domestic corporations from the State of Virginia:

- USCO Structures – a manufacturer of prefabricated modular homes
- H. N. Ritter, Inc. – a general contractor
- Ritter Buildings, Inc. – a developer in Northern Virginia
- Spectrum Properties, Inc. – a realty company, licensed for the State of Virginia.

Through its subsidiary USCO Structures, Consolidated Properties, Inc. manufactures 13 models of modular homes for the eastern U. S. market. They range in size from 960 to 1,512 sq. ft., with one tri-level model containing 1,674 sq. ft. One model is a three-bedroom, 1-1/2-bath, single-family detached home of 1,168 sq. ft. and conventional wood frame construction. There is an external movable insulation system which in the attic space allows solar collection by a waterwall. When the winter sun is not available, the homeowner and the thermal mass are protected by an insulation blanket. By incorporating standard colonial features and accessories, such as shutters, weathervane, replica gaslight, entry light and picket fence, the homeowner does not forego the symbolic elements that they expect in a traditional home.

The single-family detached modular units can be shipped at a competitive cost within 200 to 300 miles of the factory at South Hill, Virginia. The cost objective of Consolidated Properties, Inc., is to produce passive solar modular units at $21 per sq. ft., FOB factory in South Hill. These units could be sold, transported, and sited in the $35,000 to $50,000 range.

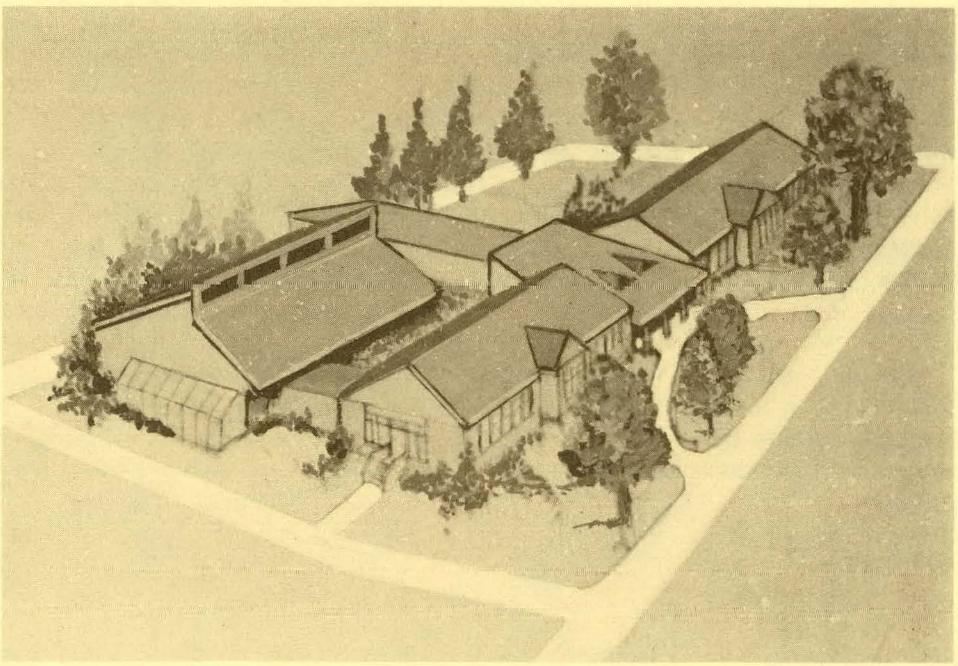
In applying passive solar concepts to their product line, energy conserving features to be considered are:

- Heavy insulation
- Continuous reflective vapor barrier
- Foam caulking around all openings and seams
- Perimeter insulation
- Double glazing
- Movable insulation on windows
- Waterwall heating and cooling
- Reflective south terrace
- Evergreen wind breaks
- Vestibule front door (garage serving as vestibule on rear door)
- Automatic set-back thermostat on back-up and hot water heater
- Interconnection of refrigerator waste heat and water heater
- Water heater as back-up space heating system via single fan coil unit in crawl space
- Solar plenum summer ventilator via traditional-appearing "chimney."

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Department of Aging, Baltimore County Towson, Maryland*
Principal Investigator:	*Gregory Mitchell*
Contract Number:	*DE-FC02-80CS30323*

The Department of Aging, Baltimore County, Maryland, is initiating a 7-year program to construct senior citizen centers. This proposal will remodel two buildings of 3,025 sq. ft. each. The two one-story buildings were erected originally in 1915, and the latest renovation occurred in 1968. The two buildings are on concrete foundation supports with wooden floors and wooden walls. The interiors are plaster and the exterior shake shingles. There are pitched shingle roofs and wood casement windows.

The facilities provide educational, nutritional, recreational, and personal services to persons over 55 years of age. There is a senior population of approximately 2,000 in the area, and 182 are actively participating in various programs, such as physical fitness, painting, and crafts. The Department of Aging will use this project to determine feasibility of renovating 30 old school buildings to provide social services to the aging within the county.



Design Approach

The design approach will explore passive solar applications to:

- A solar greenhouse
- Clerestories with solar curtains

- Use of rock storage
- Natural lighting
- Inductive cooling related to landscaping
- Radiant heat with thermal mass
- Trombe walls
- Wood or coal burning stove for supplement heat
- All hot water requirements.

Design Tools

Design tools will include analysis of incremental cost for improvement versus anticipated payback period indicated by fuel savings. Schedule analysis will involve prediction of diurnal temperature variations on a monthly basis.

PROJECT TITLE: **ENHANCEMENT OF BLAST COMPUTER PROGRAM**

Institution: *Department of the Army, Construction Engineering Research Laboratory Champaign, Illinois*

Principal Investigator: *George Walton*

Contract Number: *DE-AC02-79CS30239*

The BLAST computer program is a building energy analysis and system design program which can be expanded to handle passive solar systems. This is a comprehensive computer program for estimating hourly space heating and cooling requirements, hourly performance of fan systems, and hourly performance of conventional heating and cooling plants, total energy plants, and/or active solar energy systems. The computer program uses detailed and rigorous algorithms to compute building loads and system performance. The following paragraphs define the scope and sequences of work to incorporate passive capabilities into the BLAST program.

Task One: Define Models –

The Construction Engineering Research Laboratory (CERL) will work with the Lawrence Berkeley Laboratory (LBL) to define the necessary algorithms (mathematical models), input variables, and input language for modeling passive systems. This task will precede any development or modification of computer code. The specific models to be studied are:

- Zone control based on both mean radiant and air temperatures. The present BLAST model for controlling comfort conditions in the rooms (zones) considers only the air temperature
- Building exterior radiant interchange. Models will be used for sky and ground temperature to estimate the energy radiated between the building and the environment
- Movable insulation for nonmassive surfaces. A simple model for movable window insulation and insulation over lightweight surfaces will be installed. Language will be written to describe the many control options available
- Analytical distribution of solar gain. The existing shadow casting algorithms in BLAST will be enhanced to compute how much solar energy transmitted through windows falls on each of the interior surfaces
- Passive wall components. Models will be constructed for Trombe walls, waterwalls, and roof ponds
- Iterative solution of the heat balance equations. BLAST presently uses a special Gauss elimination procedure to solve the room surface and room air heat balance equations, but this has limitations. An iterative method tested briefly in April 1978 will be used
- Rock bed storage. A model will be incorporated into BLAST to provide thermal storage for nighttime ventilation cooling systems. An evaporative cooling model will be introduced with the rock bed storage.

Task Two: Implement Models in a Test Program –

The models described in Task One will be employed in a test version of the BLAST program, which will not include BLAST's language interpretation section.

Task Three: Modify Language Interpreter –

The results of Task One and Task Two will be analyzed to determine which models will be implemented in the user version of BLAST. Evaluation will be in terms of energy significance, additional user input requirements, and program execution costs. The language interpreter will be expanded to interpret all necessary new input. Program documentation will be accomplished simultaneously with Tasks One, Two and Three, and will use CERL's Automated Documentation System.

Task Four: Modify User's Manual –

The BLAST user's manual will be modified by a supplement describing the input language developed for passive solar systems.

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *Deadwood Creek Services, Inc.*
Deadwood, Oregon

Principal Investigator: *Bill Cirino*

Contract Number: *DE-FC02-80CS30336*

Deadwood Creek Services, Inc. located in Deadwood, Oregon, has proposed to build a structure that will contain 2500 square feet and will serve as a community center and volunteer fire station. The building will be rectangular with a long wall facing south. The structure will be a simple wood frame and will be built by community volunteer labor; thermal mass will be provided in the floor and in simply constructed mass walls.

Design Team

- Architect: Equinox Design, Inc., of Eugene, Oregon, is composed of two partners with extensive and diverse environmental backgrounds. G. L. Brown and John Reynolds are also faculty members of the University of Oregon Department of Architecture. They specialize in energy-environment projects involving energy and materials conservation, solar energy, and waste recycling.

- Contractor: All construction work to be done by community volunteers.

Design Approach

The Deadwood Creek Community Center will be casual and expandable in design. It will include the possibility of a wide variety of uses: storage for fire truck, meeting hall, food preparation, day care, adult education, and community recreation.

The building will contain a wide variety of passive heating techniques as practically appropriate. Wood stoves are intended to furnish back-up heat.

Design Tools

- Initially, the design team will use "rules of thumb" for floor area to be provided in south aperture for direct gain, thermal storage wall, and sunspace systems. Similar rules of thumb will determine initial thermal mass sizing.

- As the design becomes more refined, more sophisticated simulation tools will be used to evaluate the thermal performance of proposed design schemes.

Evaluation

Members of the Deadwood community will monitor the consumption of energy, both electricity and wood. Later, an automatic data acquisition system will be installed and tied in to the University of Oregon Solar Energy Center.

PROJECT TITLE: **CHARACTERIZATION OF POTENTIAL MARKETS FOR PASSIVE SOLAR TECHNOLOGIES**

Institution: *Early Insights*
Golden, Colorado

Principal Investigator: *Regina V. Roze-Benson, Early Insights; Mark McDade, SERI*

Contract Number: *AM-9-8307-1 (under contract to the Solar Energy Research Institute)*

The new construction market constitutes a substantial potential for increase in the use of passive solar techniques. These industries are engaged in resource development across the country, make major capital expenditures, and employ numerous contractors. Major decisions relating to land and housing development are made at their corporate level.

For DOE/SERI to promote increased passive solar technology in new construction, basic information regarding these industries is needed; i.e., who the pertinent decision makers are and the location and status of major construction projects. Early Insights will obtain this information for DOE/SERI.

The major resource developments to be identified in the United States are those with expected work forces of over two hundred temporary and one hundred permanent workers. Twenty projects of this type are to be documented. The research by Early Insights will produce:

- Identity of individual corporations involved in housing development for natural resource projects
- Geographic location and resource type of each project
- Number of housing and community facilities (by type) to be produced and their completion schedule
- List of individuals with authority to make housing/economic decisions in each construction project, including resource development company, related construction industry, and involved financial institutions
- Names of potential suppliers for each project.

This information will be validated through personal and telephone contacts for a minimum of one-half of the projects documented. Projects will be ranked in accordance with their readiness for using energy conserving passive solar techniques. The top six executives in this ranking will be interviewed personally. Discussions with these executives will stress advantages of solar applications in new construction and a report of the contacts will be prepared for SERI.

PROJECT TITLE:	**EXPERIMENTAL INVESTIGATION OF THERMAL PROPERTIES OF SOILS**
Institution:	*Earth Tech Research Corporation* *Odenton, Maryland*
Principal Investigator:	*Peter Jay Huck*
Contract Number:	*DE-AC03-80SF11509*

For development of Passive and Hybrid Cooling Systems, a knowledge of thermal properties in the upper area of soil is required. The objective of the program is to determine the thermal diffusivity and heat capacity of soils under a range of compaction and moisture conditions. The determination of these characteristics will aid in realistic modeling of underground heat flow for earth contact heating and cooling systems. The program will involve in-situ measurement of thermal properties complemented by their measurement in the laboratory under simulated conditions.

In-situ tests at about eight sites are planned. The sites will be selected on the basis of geographic delineation of climates, e.g., wet, seasonally wet-freeze, dry freeze-thaw, etc. A field and laboratory program for time invariant and time varying parameters is planned. Parameters to be measured include temperature, electrical resistivity, moisture content and heat flow required to maintain each segment of a central heater at desired temperatures. An array to read temperatures at sixty locations, forty within 40 cm (16 in.) of the heat source and twenty at four meters (13 ft) to establish background levels is suggested. Moisture content will be measured by capacitive transducers. Using a cylindrical heat source and axi-symmetric geometry, measurement of diffusivity, heat capacity and thermal conductivity is planned.

PROJECT TITLE:	**DEVELOPMENT OF A COMPACT DUAL-EFFECT REGENERATIVE EVAPORATIVE COOLER**
Institution:	*Energy Alternatives, Inc.,* *Boulder City, Nevada*
Principal Investigator:	*Jerry Bradley*
Contract Number:	*DE-FC03-80SF11507*

The purpose of this project is to develop a compact, unitary, dual-effect regenerative evaporative cooler (DEREC) to replace vapor compression air conditioning in many regions of the U. S. EAI will specify the design goals for the DEREC unit in terms of maximum operating outdoor dry bulb and wet bulb temperatures, the maximum allowable interior conditions of temperature, humidity, air flow and mean radiant temperature, the moisture transfer rates to the interior under operating conditions, the parasitic power requirements, water consumption, fraction of makeup or recirculated air, backup system requirements and the system cycle and climatic limits as displayed on psychrometric charts.

PROJECT TITLE:	**DEVELOPMENT OF A TEMPERATURE SWITCHABLE DESICCANT MATERIAL**
Institution:	*Energy Materials Research Company* *Berkeley, California*
Principal Investigator:	*John Brookes*
Contract Number:	*DE-FC03-80SF11506*

This project is to be funded at a modest level to explore the feasibility of a concept developed by the proposer for a desiccant material whose absorption properties change at a specific threshold temperature. A variety of materials and molecular structures will be evaluated for applicability to systems embodying such a principle. The advantage of a temperature switchable desiccant is that it could lower the temperature required for regeneration, thus enabling the use of low cost solar collectors.

PROJECT TITLE: **RADIATIVE COOLING MATERIAL DEVELOPMENT**

Institution: *Energy Materials Research Company*
Berkeley, California

Principal Investigator: *John Brookes*

Contract Number: *DE-FC03-80SF11504*

The goal of this project is the development of an infrared transparent glazing material capable of withstanding ultraviolet radiation and outdoor weather conditions, while transmitting little or no visible solar radiation. The approach consists of coextruding a thin ultraviolet absorbing layer with an infrared transparent plastic substrate sheet. The substrate will be provided with suitable microscopic pigment particles having a density sufficient to enable it to reflect visible light while remaining transparent to infrared radiation, especially in the 8 to 14 micrometer region of the spectrum.

PROJECT TITLE:	**PASSIVE COOLING EXPERIMENTAL FACILITY HOT/ARID CLIMATE**
Institution:	*Environmental Research Laboratory, The University of Arizona Tucson, Arizona*
Principal Investigator:	*John F. Peck*
Contract Number:	*DE-AC03-80SF10816*

Under this contract, ERL will design, construct, and monitor a passive cooling experimental facility to be built in the hot, arid climate of Tucson, Arizona. A number of passive and hybrid cooling options will be evaluated and compared regarding their potential to produce and enhance comfort, their ability to adapt readily into the building community, their total requirement of parasitic energy, and the probability of success in the hot, arid zone. Because of the variety of options to be tested, we expect that every arid location will find at least one that is adaptable to their own particular needs.

Four reconfigurable test structures will be built and monitored over a three-year period in order to test approximately twenty-six passive/hybrid cooling options and complementary comfort enhancement techniques. The end product will be several levels of data, from raw data to short summaries, and verified mathematical design analyses.

PROJECT TITLE:	**EXPERIMENTAL INVESTIGATION OF THERMALLY INDUCED VENTILATION IN ATRIA**
Institution:	*Eureka Laboratories* *Sacramento, California*
Principal Investigator:	*Steven Leung*
Contract Number:	*DE-AC03-80SF11511*

The major effort in this contract will be devoted to obtaining scientifically defensible experimental data on air-motion which is thermally induced in atriums for purposes of cooling the occupants and building structure and for maintaining air quality. At least eight of the ten or more atriums instrumented in the test phase will be examined from this point of view.

The secondary effort will be to collect experimental data on air flow rates and heat transfer rates between solar heated atriums and attached buildings for space heating. At least two of the ten or more atriums instrumented in the test phase will be examined for this purpose.

The project will place special emphasis on commercial buildings. Therefore, at least five of the ten or more atriums instrumented in the test phase will be commercial or large multi-family residential structures.

Data collected will be evaluated for the purpose of generating correlative algorithms which describe volumetric air flow rates and heat transfer rates as a function of the range of environmental conditions and gross parameters of the system (such as level of insolation, height and other dimensions of the atrium, and size of the air flow connections to the attached building). Additionally, it is expected that sufficient data will be available to establish design rules of thumb for various U. S. climates.

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PROJECT TITLE:	**INVESTIGATION OF PASSIVE COOLING TECHNIQUES FOR HOT HUMID CLIMATES**
Institution:	*Georgia Tech Research Institute Atlanta, Georgia*
Principal Investigator:	*James M. Akridge*
Contract Number:	*DE-AC02-79CS30238*

As work under this contract progressed, the decision was made to focus research studies in the areas of thermal properties of soils, heat and moisture transfer in soils and aquifers, and couplings to buildings. The statement of work reflecting the initial phase of this new direction is as follows:

Phase I

Task 1: Literature Search –

The contractor will perform a literature search to identify previous work done in the areas of earth tempering and ground coupling. This search will include topics on thermal properties of soils, heat and moisture transfer in soils and aquifers, and coupling to buildings.

Task 2: Adapt BNL Ground Simulation Program –

The contractor will acquire the ground simulation program written at Brookhaven National Laboratory and implement it on the Georgia Tech Computer for simulating a heat exchange coil buried at an arbitrary depth below a field. Additional relevant programs such as TRNSYS and MITAS are already operational.

Task 3: Simulate Earth/Coil Heat Transfer –

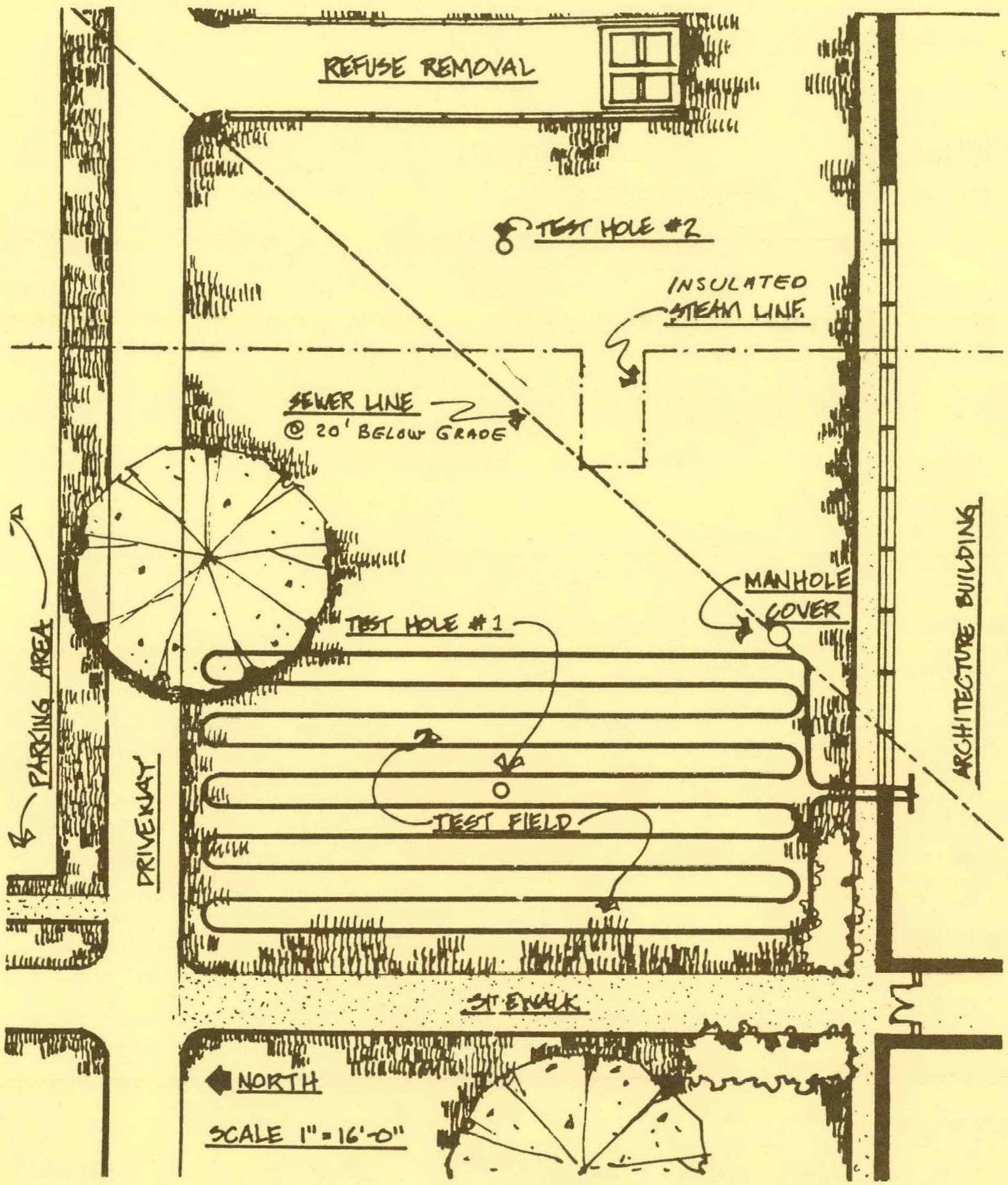
Using the computer programs of Task 2, the contractor will perform detailed modeling of the consequences of various fluid flow rates and temperatures on the temperature profile of the coil field under conditions typical of its application as a heat sink for passive cooling applications. The purpose of this task is to provide design specifications for the coil field including optimal coil material, wall thickness, pipe size, separation of coils, depth of burial, and flow rates for various assumed heat rejection loads.

Task 4: Install Ground Temperature Probes

The contractor will drill two holes at the coil field site for the purpose of installing temperature probes to monitor site behavior before and after installing the coils. One hole will be remote from the coils and free of other perturbing influences and will contain a number of temperature and moisture sensors to a depth of approximately 10 meters. The other hole will be similar in nature, but located approximately in the center of the coil field.

Task 5: Install Underground Water Coils –

Based on the design specifications of Task 3, the contractor will prepare the field site by trenching, bulldozing, and other suitable means and install the coils. A pump and electrically operated heat load will be connected to the field coil along with any other required temperature and/or moisture sensors.



Plan of Test Site

Task 6: Test Earth/Coil Heat Transfer –

Determine heat transfer rates from the electric heat load to the coil field using different flow rates and fluid temperatures. Experimental results will be compared to and reconciled with computer performance predictions. Heat removal rates from the coil field via conduction through the soil will be determined together with heat buildup in the field. The relative importance of the various thermal resistances in the system will be established. Parasitic power shall be measured.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Girl Scouts of Greater Philadelphia* *Philadelphia, Pennsylvania*
Principal Investigator:	*Judith A. Helder, Exec. Dir.*
Contract Number:	*DE-FC02-80CS30338*

The Girl Scouts of Greater Philadelphia plan to build a "Program Center Building," which will be the major component of an overall development that will include a caretaker's residence, maintenance building, renovation of an existing barn, a swimming pool, and a bathhouse.

Primary uses of the Program Center Building include:

- Year-round resource for personnel from Greater Philadelphia Girl Scout Council area
- Summer day camping site
- Training of adult Girl Scout leaders
- Cultural events and career education seminars
- Center for outdoor education.

The gross building area of 5,500 sq. ft. will be primarily wood frame. The building will have an unusually large amount of concrete or masonry to provide thermal mass.

Design Team

- Architects/Planners: Bohlin Powell Brown, Architects/Planners/Engineers of Pennsylvania
- Solar Consultants: Burt Hill Kosar Rittlemann and Associates of Pennsylvania
- Structural Consultants: A & R Engineering Co., Inc.
- Mechanical and Electrical Design: Paul H. Yeomans, Inc.

Design Approach

The interaction of energy-related considerations with the building's architecture is apparent in the design approach:

- Indirect solar gain results from a mass Trombe wall for those portions of the building having a requirement for natural light during the day
- A direct gain approach has been selected for that portion of the building that serves as a lobby and circulation space
- The exterior form of the building relates the northeast and northwest sides to other buildings on the site.

Design Tools

During the schematic design phase, three analytical tools will be used:

- *Bin Data Analysis*: This considers the physical characteristics of the building with changing external environment climate and variation in internal conditions, such as occupancy, lighting, temperature, and ventilation

- *Solar Analysis Program*: Designer-applied input values are used (plus climatic information) and are related to building energy requirements that are calculated for an average day in each month of the year

- *Solar Load Ratio Method*: This method will be based on experiments at Los Alamos Scientific Laboratory to determine the performance of solar test cells.

During the design development stage, additional analytical tools will employ a *Solar Shading Program*. This will be capable of analyzing either horizontal, vertical, or combination shading devices. This information provides input for the bin data analysis program.

PROJECT TITLE: **PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**

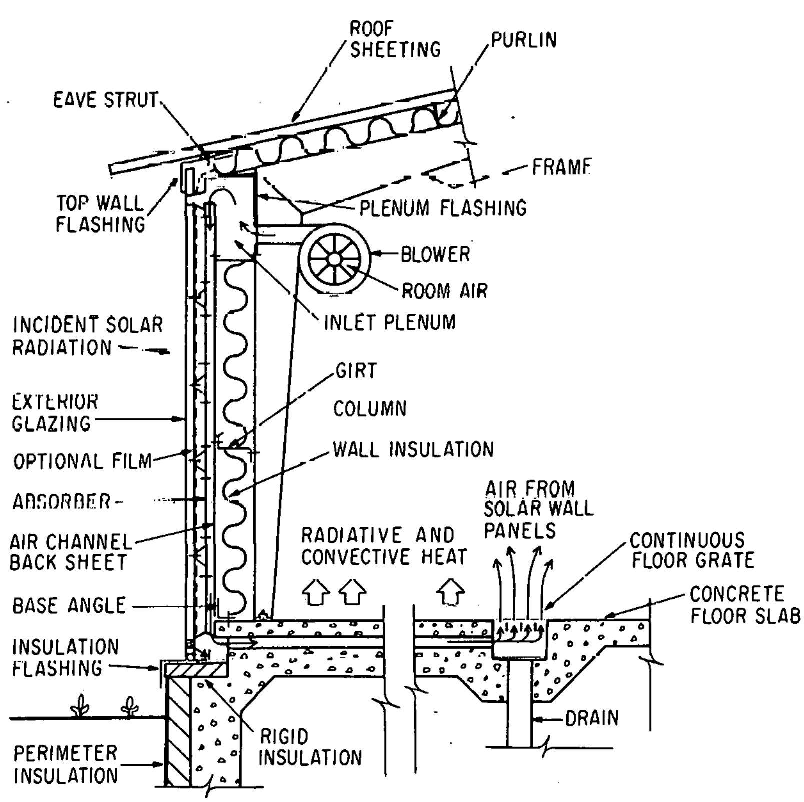
Institution: *Gulf States Manufacturers, Inc.*
Starkville, Mississippi

Principal Investigator: *Neil Watkins*

Contract Number: *DE-FC02-80CS30374*

The objective of the design phase of this project is to develop a system for the design, fabrication, and marketing of solar systems for space heating, nocturnal cooling, enhanced ventilation, and/or daylighting with an optional domestic hot water system for manufactured metal building systems primarily for commercial and industrial applications. Manufactured metal buildings are usually custom designed, fabricated, and field erected in a very short period – two to three months. Consequently, emphasis has been placed on the development of computerized analysis tools and component designs which are compatible with the mode of operation of the industry.

Gulf States Manufacturers, Inc. markets buildings through an extensive dealer network and provides the technical assistance as appropriate to those dealers. This will allow them to assist their clients in making appropriate decisions in the selection of any Solar System components to be integrated into the total building system. In order to meet this need, a simplified applications manual is planned to make the resultant analysis tools and designs meaningful to the dealers.



The basic concept of design in this project is for a cost-effective wall integrated passive/hybrid solar collection system with a building integrated thermal storage system with a 24-hour storage capacity. Because of the possible advantages for some daytime only operations, daylighting and direct gain solar systems are also considered.

Summary

Three optional system preliminary designs based on the concepts presented above were generated based on the generic types of direct gain, the Trombe wall – vented and unvented, and the convective wall. Simultaneously, a Bouchillon and Associates computer program for building thermal and lighting energy analysis based on a modified BIN-DATA method was modified to provide for direct gain and south vertical wall solar collection with no storage, storage of sufficient capacity for carrying the building through 8:00 p.m. after a clear day, and for sufficient storage capacity for a 24-hour period. Predications were based on ASHRAE solar data and a collector performance prediction equation. Transient analyses for floor slab thermal storage to provide an appropriate rapid response design system have been developed. Life cycle costing also has been programmed and executed for the various designs.

The preliminary designs were reviewed by DOE and SERI and the selection of the Convective Wall Panel Solar Collector with floor slab integrated storage was chosen after appropriate consideration was given to the movable night insulation systems which are necessary to make the direct gain and the Trombe wall effective in many areas. Both the added costs and the lack of reliability of automatic systems were negatives in the selection of the preferred design. The thermal storage in the floor slab also incorporates a considerable additional mass underneath the slab to provide for longer term effective storage than would be the case for an 8 in. concrete Trombe wall.

The final design, construction drawings and specifications for Solar System components will be completed for both the Convective Wall Panel Solar Collector system with the Floor Slab Storage as well as the triple glazing for the direct gain system when used for space heating and daylighting.

A preliminary proposal for a Phase II – Prototype Fabrication/Assembly and Engineering field test evaluation of the Passive and Hybrid Solar Manufactured Housing and Buildings Program of DOE has been submitted and reviewed by DOE and SERI.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Gunnison County* *Gunnison, Colorado*
Principal Investigator:	*Dorothy M. Johnson*
Contract Number:	*DE-FC02-80CS30339*

Gunnison, Colorado, is in the Central Rocky Mountains of Colorado. The proposed building is an airport terminal facility of 9,703 square feet. The configuration of the building is rectangular. The proposal submitted is for a building design that will employ a passive solar energy system. There is an inadequate supply of natural gas in Gunnison, and the only energy source available for heating the new terminal is electricity, therefore, a major emphasis on solar energy is essential.

Design Team

- Architect and Program Manager: Mr. Leon Waller, registered architect in Colorado and president of Associated Architects of Crested Butte
- Solar Engineering: Dr. Jan Kreider of Solar Architects and Engineers.

Design Approach

The design team has concluded that the passive solar design system for the Gunnison County Airport will consist of a masonry, thermal storage wall. Also, a moderate amount of direct gain is present resulting from runway viewing requirements. A south-facing clerestory of 140 square feet provides both light and heat (via the high heat return duct) to the building. The backup heating system for the passive solar system is an electric boiler/hot water system with auxiliary fan-coil heat for perimeter zones.

For the building design, there are several critical areas where the integration of passive solar systems are impacted. These include the following:

- Integration of the solar system with the desire of southern natural light, ventilation, and view
- Interface of the passive solar system with the backup, conventional mechanical system
- Construction of the passive solar system in relation to the construction of the building
- Aesthetics of the passive solar systems, especially on a highly visible facade
- Detailing of the integration of the solar thermal wall with the conventional wall
- Initial costs of the passive system in relation to the overall budget for construction.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Hispano-American Multi-Service Center, Inc. Indianapolis, Indiana*
Principal Investigator:	*Lynne Holloway*
Contract Number:	*DE-FC02-80CS30340*

This proposal involves the passive solar retrofit of a building now owned and operated by the Hispano-American Multi-Service Center. The building was originally built in 1874 as a grade school. In 1971, it was converted into a community center to serve the needs of the Hispanic community of greater Indianapolis.

The building is rectangular with the long dimensions facing east and west. The construction is solid masonry, with outer walls from 12 to 18 inches thick. The building is three stories tall, has 4,000 sq. ft. on each floor, for a total of 12,000 sq. ft.

Design Team

- Solar Consultant: Dennis Weston, president of Sun Design Group, will have responsibility for the majority of the passive design system

- Mechanical Engineer: Bruce Brush, president of Bruce Brush, P.E., Inc., will consult on matters concerning air flow patterns, air flow rates, duct and blower sizing, and the overall functional efficiency of the passive system.

- Architect: James Statzman, Architect, will be consulted concerning the architectural aspects of the passive system retrofit.

Design Approach

The design approach for the passive solar retrofit of the building is based on the following criteria:

- Existing building orientation
- Building form, configuration, and directional exposures
- Building envelope construction
- Opening construction and orientation
- Organization of interior spaces
- Occupant usage
- Current method of heating
- Thermal efficiency of building.

After these criteria have been analyzed, a preliminary determination of the feasibility of a passive solar retrofit will be made. Selection of the passive system will be determined by the adaptability of existing forms and materials that can be used as part of the passive system.

Design Tools

Design tools will include short methods to determine the feasibility of various retrofitting techniques. After the short method indicates which passive system is most appropriate, a detailed thermal and cost analysis will be made.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE DEMONSTRATION**
Institution:	*Irvine Unified School District* *Irvine, California*
Principal Investigator:	*David E. King*
Contract Number:	*DE-FC02-80CS30341*

The Irvine Unified School District proposes to build a single-story elementary school of approximately 28,000 square feet, to be used by 540 students and 40 adult staff members during regular school hours, along with various community functions during late afternoons and evenings. The designer will attempt to incorporate an optimal combination of passive features for building heating, cooling, lighting, and ventilation to reduce nonrenewable energy consumption to a minimum.

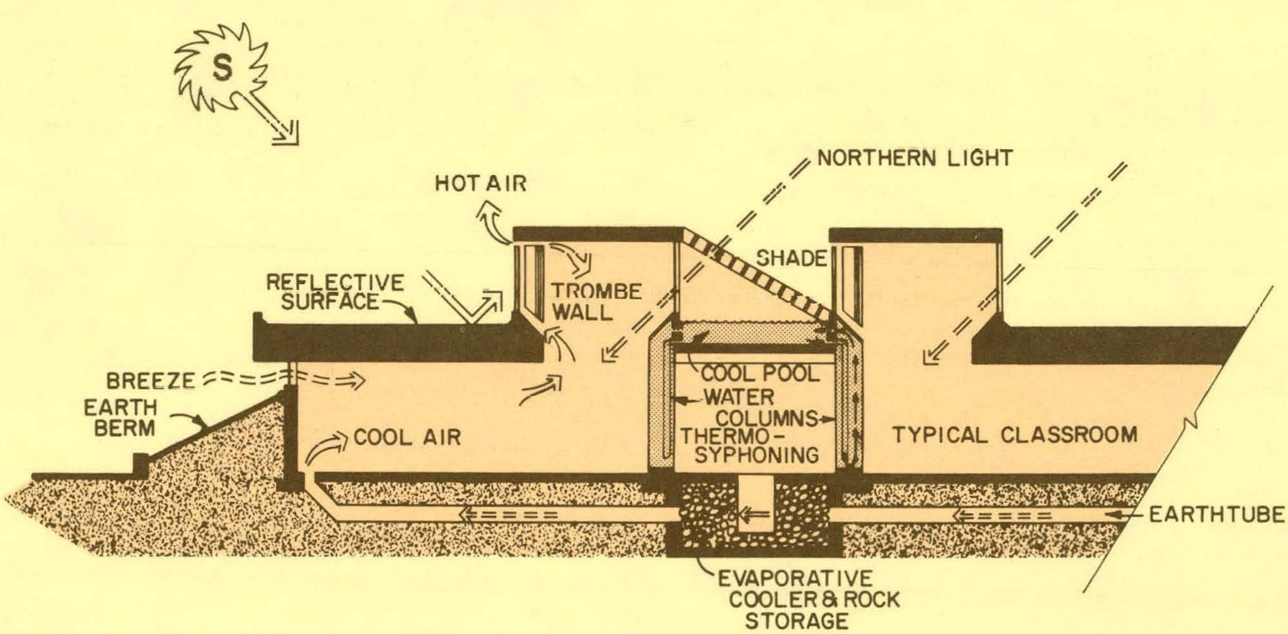
Design Team

- Architecture and Planning: Jan Hansen, AIA, a principal of Porter-Jensen-Hansen-Manzagol
- Solar Energy Engineering: Owen McCoughey, P.E., a principal of McCoughey & Smith Energy Associates, Inc.
- Mechanical Engineering: John Baum & Associates
- Electrical Engineering: Frederick Brown Associates.

Design Approach

The design approach will include:

- High mass/high thermal capacitance construction
- Earth berming as appropriate
- Extensive natural lighting



- Passive solar heating and passive structural cooling
- Maximum natural ventilation and convective cooling
- Environmentally planned landscaping as a passive design feature.

The passive solar components of this building will be designed, where possible, for ease of prefabrication or duplication for future projects.

Design Tools

- Initiating an up-to-date survey of the passive concepts and design tools currently available
- TEANET program, developed and marketed by Total Environmental Action, Inc., Harrisville, NH, provides a 7-node thermal analysis program which runs on MSEA's TI-59/PC100A calculator
- SOLAR-5, a passive building interactive computer model available at UCLA
- DEROB III is a 200-node thermal network program that can be used to simulate a large building.

PROJECT TITLE: **COMMERCIALIZATION PROGRAM SUPPORT**

Institution: *Institute of Public Administration*
Washington, D.C.

Principal Contact: *Dale A. Fousel, IPA; Pete Ketels, SERI*

Contract Number: *XM-9-8242-1 (under contract to the Solar Energy Research Institute)*

Numerous tasks have been identified to be undertaken in order to achieve the goal of accelerated commercialization of passive solar systems for heating and cooling. In order to provide timely implementation of these tasks, the necessary operating framework must be defined to include priority, schedule, resource allocation and other key elements.

A large part of the work involves coordination of the diverse groups involved in program planning and providing input data. These individual groups must identify accessible market areas and strategies for influencing the decision makers in those areas. Those strategies, once identified, must be integrated as specific deliverables, in the general task areas presently outlined in the Multiyear and National Passive Program Plans.

The Institute of Public Administration will be responsible for coordination of the market and public relations contracts issued by the Solar Energy Research Institute, to insure that they provide products of substantive interest to the Program.

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *Gordon D. Kieffer*
Middleton, Wisconsin

Principal Investigator: *Gordon Kieffer*

Contract Number: *DE-FC02-80CS30343*

This project involves the retrofit of an existing structure to function with passive solar energy concepts. The building, located in Wausau, Wisconsin, is 50 years old, with fire-resistive wood framing. It is a two-story structure with partial basement. The lower level will be designed for commercial, and the upper level will be a combination of residential/office space.

Design Team

- Developer: Gordon D. Kieffer
- Architect: Bruce Kieffer, registered architect in the State of Wisconsin and a senior partner in North Design Architecture/Engineering/Planning
- Construction Manager: Bruce Kieffer will be the manager/coordinator of construction activities.

Design Approach

The proposed project is a passive solar retrofit. It is speculative in the sense that no prospective tenant has been identified. Thus, the design must have the capability of meeting the needs of a number of potential retail shop users.

The design approach will include definition of user needs in terms of thermal comfort, lighting levels; occupancy and daily energy use patterns; and passive solar opportunities. Based on these design considerations, the highest ranking and cost-efficient alternatives will be incorporated into the final design. The design team anticipates the passive solar solution for this retrofit will probably be indirect gain or isolated gain.

Design Tools

- Library and bibliographies reference file of user needs data
- TI-59 Programmable Calculator Programs
- TEANET III Passive Solar Analysis Program.

PROJECT TITLE: PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION

Institution: *Ron Lau*
Santa Cruz, California

Principal Investigator: *Ron Lau*

Contract Number: *DE-FC02-80CS30344*

An existing shopping center, owned by Mr. Ron Lau, is located on the main commercial/retail street in Santa Cruz, California. The existing 14,000 sq. ft. cluster of buildings is constructed of 8-in. concrete blocks and encloses an open 2,000 sq. ft. courtyard. This courtyard is now used for circulation, a coffee shop seating area, a flower shop, and access to four retail stores.

The objective of this proposal is to enclose the courtyard with a passive solar cost-effective covering. The design and installation of an all-climate responsive covering will demonstrate a technique for reducing the energy consumed in air conditioning the mall. Additionally, by creating a tempered zone, the mall will reduce the thermal and lighting loads of the retail space itself.

Design Team

- Architects and Solar Designers: Van der Ryn, Calthorpe, and Partners
- Thermal and Energy Computer Modeling: Berkeley Solar Group
- Materials Consultant: Suntek.

Design Approach

Design approach involves relevant participants associated with each design stage:

- Site and climate analysis including urban influence, microclimate and weather tape development
- Program statement with a listing of objectives, constraints and research
- Conceptual design with problem identification and development of preliminary solutions
- Thermal analysis and computer modeling including parameter studies of significant variations
- Working drawings with specification and details of solar components of design
- Final thermal studies involving computer simulation of final building design and energy budget.

The solar and energy issues to be addressed in the design process are:

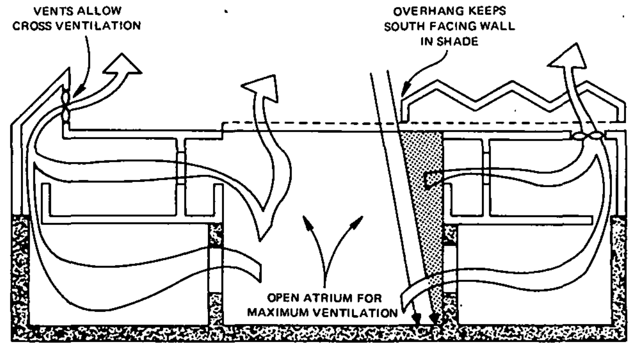
- The effects of creating a thermal buffer zone (enclosed court) on overall building energy consumption

- Winter passive heating of the space issues include:

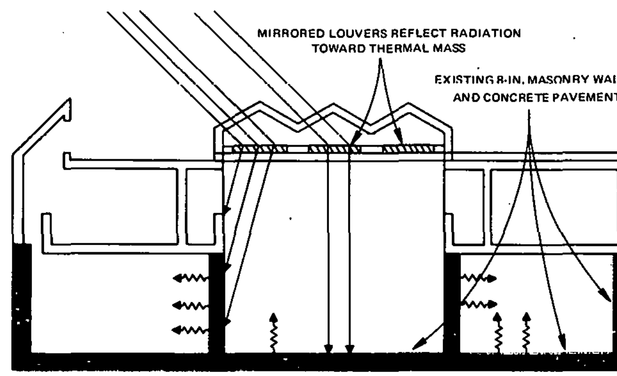
  - Existing and new thermal mass
  - Potential of night insulation
  - Temperature stratification in courtyard
  - Problems of glare and overheating
  - Differing load profiles of different stores.

- Summer time operational issues include:

  - Ventilation - stack effect or fan
  - Shading and daylight retention
  - West facade treatment
  - Night vent and thermal mass.



SUMMER MODE



WINTER MODE

- Interaction of energy-related components with standard building criteria:

  - Maintenance, cleaning and operations of solar components
  - Aesthetics of the environment impacted by solar features
  - Security and comfort criteria.

Design Tools

The design tools for basic thermal analysis will be NBSGLD, the Berkeley Solar Group's proprietary building thermal load computer program. The program uses an explicit dynamic thermal balance model that runs on SOLMET or TMY type data. The building will be monitored for thermal performance, energy consumption, and system operation.

PROJECT TITLE: **HEAT TRANSFER ANALYSIS**

Institution: *Lawrence Berkeley Laboratory (LBL)*
Berkeley, California

Principal Investigator: *Ron Kammerud*

Contract Number: *In-house*

A part of the LBL involvement in passive solar analysis stems from a perceived need to provide the building community with technical information and relevant thermal analysis tools. The initial thrust has been toward the construction of computer models describing heat transfer characteristics of specific passive solar systems appropriate for large-scale buildings. These models are being incorporated into the building energy analysis computer programs of BLAST (Building Loads Analysis and System Thermodynamics) and DOE-2. Both computer programs have extensive capabilities for analyzing commercial building systems of conventional design.

LBL will compile and make available to the design professions in FY 1980 a documented version of BLAST with passive capabilities for:

- Direct gain systems with movable insulation
- Thermocirculation systems with massive and nonmassive absorbers
- Direct ventilation cooling of occupied space
- Direct conductive coupling between thermal zones.

Continued research efforts by LBL will result in additional enhancements to existing capabilities of BLAST and DOE-2 computer programs, such as:

- A validated and documented model describing the response of the occupied space to environmental excitement due to solar radiation and outside temperature
- A roof pond model in BLAST
- An "empirical" relation describing interzone convective heat transfer in terms of individual zone parameters, the algorithm being compatible with BLAST and DOE-2 analysis techniques
- A documented computer code appropriate for analysis of stack effects in multistory spaces, thermocirculation system inlet and outlet configuration effects; and inter- and intrazone convective heat exchange processes
- Evaluation of parametric sensitivities with configuration influences in stack effect systems; the effect of inlet and outlet conditions on thermocirculation systems performance; and, the effect of multizone convective coupling on heat exchange within a single zone.

PROJECT TITLE:	**INFRARED SKY RADIATION/RADIATION ASSEMBLY TEST FACILITY**
Institution:	*Lawrence Berkeley Laboratory (LBL)* *Berkeley, California*
Principal Investigator:	*Dr. Marlo R. Martin*
Contract Number:	*In-house*

In 1976, members of a Solar Energy Group at LBL became interested in the feasibility of developing passive radiative cooling systems. A radiative cooling system is one which extracts heat (thereby cooling) primarily through conduction and stores this heat in a given area for subsequent release via radiation to another medium (usually the outside environment) at a given time when that medium is cooler than the heat storage container.

Sky radiation involves the direct transport of energy through space by means of electromagnetic waves. Of all of the sun's radiation, approximately 49 percent is in the infrared band which can be experienced as heat.

One of the major objectives of the radiative cooling program was to measure spectral infrared sky radiance in four to seven U. S. cities and correlate the results with pyranometer and conventional weather parameter measurements, as a means of assessing the potential of using radiation phenomena as a cooling resource.

As a result, a sky radiance measurement program was initiated under ERDA and, subsequently, DOE sponsorship. Four spectral infrared sky radiometers were designed, fabricated, and deployed to record the detailed measurements. An existing computer program was adapted to calculate the spectral sky radiance as a function of the zenith angle, and comparisons were made with experimental results.

The four sky radiometers have been recording detailed infrared sky radiance for two summers in Tucson, Arizona; San Antonio, Texas; St. Louis, Missouri; and Gaithersburg, Maryland.

Results from measurements in the infrared sky radiation at the Radiator Assembly Test Facility will provide an accurate estimate of the potential for radiative cooling and provide the basis for possible future work for a more total understanding of radiation mechanisms as a method for passive cooling.

Subsequent to the sky radiation studies, a Radiator Assembly Test Facility will be used for comparing the cooling performance of various radiation mechanisms.

This assembly will allow promising concepts to be field simulated economically.

Examples of unresolved performance characteristics include convection suppressing windscreens, infrared transparent glazings that reflect visible sunlight, and the use of reflector elements to collimate the field of view of the sky as seen by a radiator surface. Another facet of this study will be to analyze the performance of alternative surface materials. Optical properties of material often differ between the visible and thermal infrared spectral regions, and it is possible that selective infrared emission properties can significantly improve the performance of thermal radiators.

PROJECT TITLE: **MODEL COOLING SYSTEMS**

Institution: *Lawrence Berkeley Laboratory (LBL)*
Berkeley, California

Principal Investigator: *Dr. Marlo R. Martin*

Contract Number: *In-house*

The purpose of this project is to devise or enhance computer models to simulate passive cooling concepts, develop sensitivity analysis techniques and validate the models and algorithms using data from instrumented test structures.

A modified building loads computer program (BLAST) will be used to model selected passive cooling systems. Parametric studies will be conducted to determine the sensitivity of various systems to changes in their design parameters. This work will be closely coordinated with the experimental work underway at two passive cooling experimental facilities and at New Mexico State University on full scale small residential structures.

PROJECT TITLE: **PASSIVE SOLAR DESIGN**

Institution: *Lawrence Berkeley Laboratory*
Berkeley, California

Principal Investigator: *Ron Kammerud*

Contract Number: *In-house*

As part of an overall program for studying passive solar technology, LBL is seeking a thorough understanding of how this technology applies to large buildings. This project, in conjunction with the Heat Transfer Studies and Analysis project (being performed as a parallel task), is the basis for developing simplified methodologies in the form of design tools, so that these concepts can be easily applied by the design professions.

The research areas being pursued by LBL are those in which the building community to date has not been well equipped to participate. Yet, they are essential if an accelerated emergence of Passive Solar Technology is to be realized.

Project activities include the following:

- Analysis of design concepts for commercial building-scale thermocirculation systems, undertaking economic evaluation and engineering tests if technical feasibility warrants
- Completion of a case study design for a moderate size office building using passive solar concepts; the building will serve as an organization headquarters and a community college classroom
- Conduct two commercial building case studies of an office building and retail sales establishments
- Evaluate design concepts for a commercial building-scale shaded roof aperture heating and daylighting system, documenting the results in a manual; economic analysis will be performed in conjunction with LASL
- Analysis of thermal mass and direct gain residential systems.

Whereas the initial work at LBL emphasized application of solar technology to large structures, much of the current work has revealed applicability to residential or small buildings. Accordingly, a certain portion of the project has addressed the residential sector.

PROJECT TITLE:	**PERFORMANCE STUDIES**
Institution:	*Lawrence Berkeley Laboratory (LBL)* *Berkeley, California*
Principal Investigator:	*Ron Kammerud*
Contract Number:	*In-house*

The performance studies project will provide detailed data for validating thermal simulations of well established passive systems and will serve as a tool for exploring behavior of new passive concepts.

The following activities describe the studies currently underway and the systems currently being explored:

- Three ongoing residential parametric studies will be completed on the effect of thermal mass in residential buildings, the user effects on the performance of direct gain systems, and the effect of thermal mass on the comfort of direct gain spaces. In each of these studies the results will be condensed into design tools usable by the building community.
- Parametric examination of the effects of various energy management schemes for commercial buildings will provide a baseline for evaluation of conceptual designs for passive solar systems.
- Convective exchange of thermal energy between zones in buildings will be studied to develop natural ventilation design guidelines.
- A positive freeze-protected thermosiphon domestic hot water heating system will be fabricated and tested for efficiency and regional applicability.
- Infiltration measurements will be performed in several passive solar structures which are instrumented to measure thermal performance. These data will be used to validate the passive models being incorporated into BLAST (a modified building loads computer program).
- Parametric sensitivity studies will be undertaken to investigate the effectiveness of daylighting design strategies, solar-control glazings, and shading on their thermal performance of direct gain systems in commercial buildings.

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *Madison Industries, Inc. of Georgia*
Conyers, Georgia

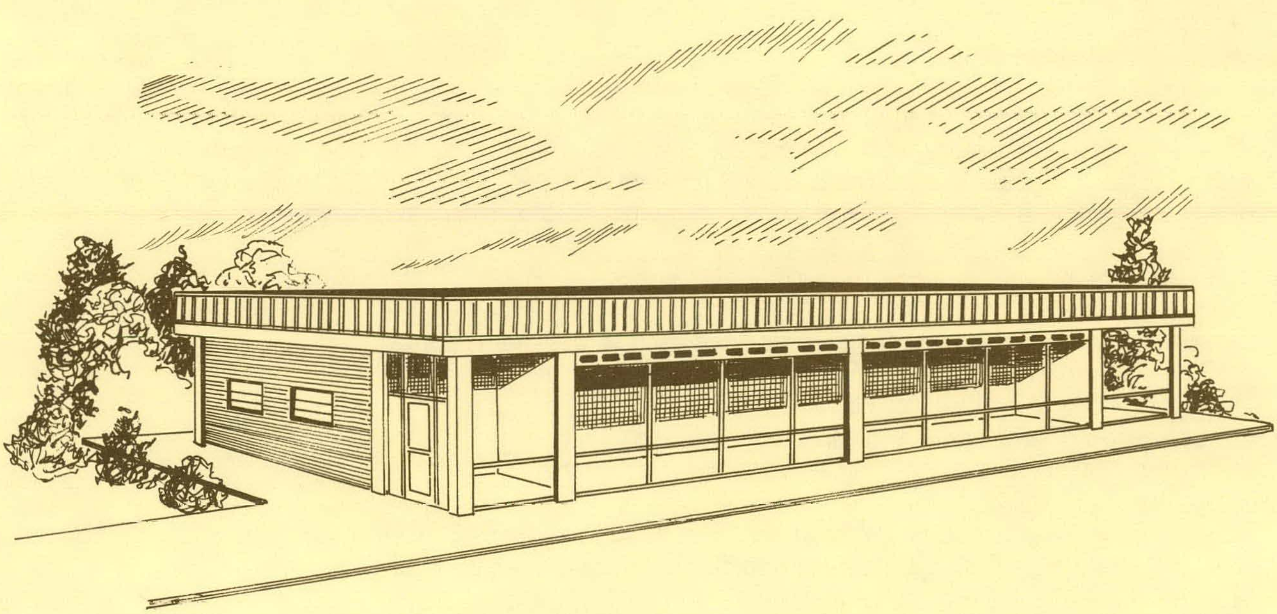
Principal Investigator: *Ralph Stanaland*

Contract Number: *DE-FC02-80CS30375*

Madison Industries, Inc. of Georgia, a wholly owned subsidiary of John S. Frey Enterprises, is engaged in the production and installation of pre-engineered structures, modular buildings, combination modular and pre-engineered buildings and building components. The current market is primarily directed toward light commercial applications such as fast-food retailers and automobile service stations. Other market areas include mini-warehouses and preliminary ventures in the residential sector.

The basic approach to the design of this manufactured building will be to utilize a cooperative effort involving Madison Industries' staff which is skilled and experienced in building design, customer needs and expectations, and component fabrication and the Georgia Tech staff which is capable in the areas of passive system design, solar energy utilization engineering, building thermal and energy analysis, weather and solar radiation modeling, and system simulation. The basic design philosophy will be to avoid preconceived approaches in favor of considering integrated design concepts aimed at achieving the desired goal of passive utilization of natural energy sources for space heating, water heating, natural daylighting, dehumidification, and cooling by a synergistic approach which considers the ultimate use of the building, the available manufacturing techniques and materials, and the expected environment in which the building will function. These will be based on quantitative evaluation of building performance and construction economics to achieve a cost-effective design using technically and commercially feasible approaches.

The design process will be characterized by interaction between the design teams assembled by Madison Industries and Georgia Tech, and the advisory panel at Georgia Tech to provide maximum input in the creative design, evaluation, and execution stages.



PROJECT TITLE:	**SOLPAS DEVELOPMENT**
Institution:	*Martin Marietta Aerospace* *Denver, Colorado*
Principal Investigator:	*Roger T. Giellis*
Contract Number:	*DE-AC01-78-CS35243*

The development and demonstration of active solar systems has received widespread attention and financial stimulation from both government and private agencies in the past few years. These efforts have generated a keen awareness of the capabilities and limitations of active solar systems. Specifically, it is becoming increasingly clear that active systems cannot be installed for under $30/sq. ft. if the manufacturer and solar contractors are to maintain a reasonable margin of profit. The net result has been a heightened interest in passive building features as a cost effective solar alternative.

The primary objective of this project is to develop, validate, document, and disseminate a passive solar simulation program to assist researchers, building designers, and consulting engineers in the analysis of passive solar systems.

The proposed software program, SOLPAS, will study the configurations of passive solar buildings, the behavior of a modeled building in various climates under varying heating and cooling loads, the validity of performing simulations using condensed weather sequences, and how to modify the TRNSYS Program for terrestrial applications of solar energy.

Present work involves the finalization of the development of several subroutines pertaining to:

- Glazing transmission
- Convection coefficients
- Solar radiation processor
- Phase change walls
- Reflectors
- Cost
- Rock bed storage.

Review of the capabilities of the subroutines referenced above indicated that three additional subroutines were necessary to make SOLPAS a viable tool in performing thermal simulations on passive systems. These new subroutines will provide SOLPAS the ability to read weather data tapes, print out descriptive energy balances and generate artificial ambient temperatures.

The documentation phase of the work will itemize:

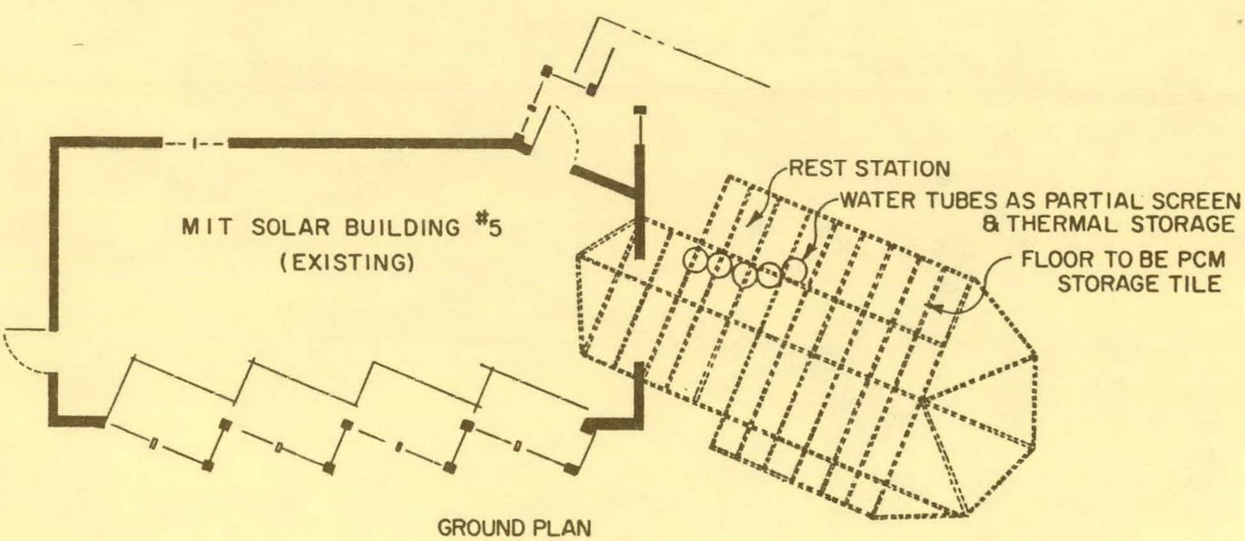
- governing equations and the assumptions used in their derivation
- application limitations
- instructions on how to communicate with the program through the computer including definition of all "command" instructions
- listing of Fortran source programs for the subroutines.

The final product will be reflected in the developed computer program and a User's Manual which will include sample problems in addition to instructions on how to use the program.

PROJECT TITLE:	**CRYSTAL PAVILION – TOTAL PASSIVE HEATING USING NEW GLASS SELECTIVE TRANSMITTERS**
Institution:	*Massachusetts Institute of Technology Cambridge, Massachusetts*
Principal Investigator:	*Timothy E. Johnson*
Contract Number:	*DE-AS02-77CS34513*

During 1979 the first low-cost, large area, glass substrate heat mirror was installed in the MIT Solar Building No. 5. The prototype indium-tin-oxide (ITO) coated glass system was fabricated by AIRCO of Murray HIll, New Jersey and has proven to be mechanically durable and noncorroding. Payback periods for a single heat mirror layer vary from 1.5 to 3 years depending on the glass orientation (assuming oil heat at 75 cents per gallon). The MIT installation is a double glazed system where each lite is coated on one side with ITO. The solar transmission of this system is 65% when absorption heating in the heat mirror is accounted for. The U value of the system is 0.26 Btu/hrft^2°F. This means the double layer system insulates twice as well as ordinary double glazing while transmitting 85% as well as two layers of glass. Second generation heat mirror systems being developed by AIRCO will exhibit effective solar transmissions of 70% with U values of 0.25 Btu/hrft^2°F. With this kind of large solar gain to thermal loss ratio, it becomes feasible to build an all heat mirror-on-glass structure that will heat itself during average winter cloudy days in lower New England. Any opaque wall, no matter how well it is insulated, shows a positive heat loss on cold, cloudy days. On an overcast day at the freezing mark, the heat mirror wall would operate with a net heat loss over a 24-hour period equivalent to a daily average heat loss coefficient of 0.08 Btu/hrft^2°F. This is 20% better than a wall with 6 in. of fiberglass insulation and a minimum amount of ordinary double glazing. Additional building heat losses due to infiltration can be met with only a moderate amount of additional solar energy. Thus, it now is possible to economically achieve 100% solar heating in moderately cold climates using high performance heat mirror without resorting to seasonal storage. Also, nonsouth exposures can be used profitably for solar heating for the first time which increases architectural flexibility immensely.

This project intends to demonstrate those concepts with a prototype all glass extension to the MIT Solar Building No. 5. The purpose of the demonstration is to show an all glass structure can be built that does not suffer from the thermal problems associated with glass products while maintaining the architectural excitement that glass offers. Completion of construction is scheduled for December 31, 1980 followed by a monitoring period of one full year.



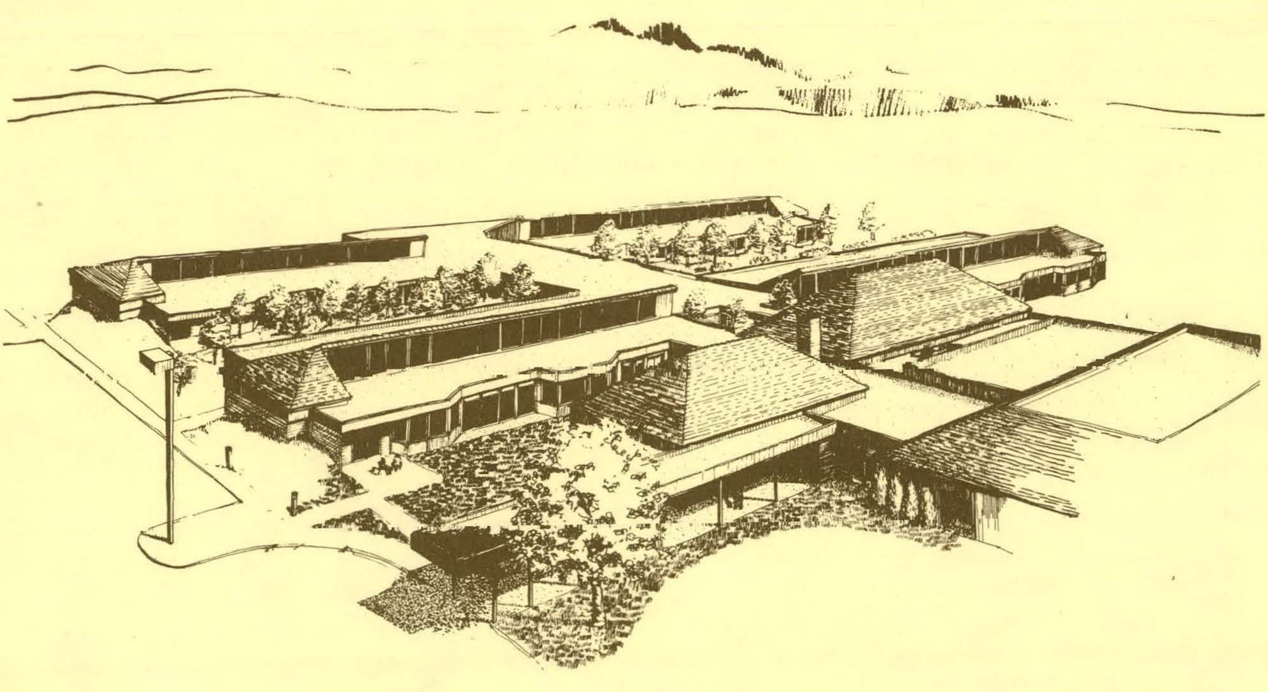
GROUND PLAN

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Mennonite Home* *Albany, Oregon*
Principal Investigator:	*Wilbur Kennel*
Contract Number:	*DE-FC02-80CS30345*

The Mennonite Home is an 80 bed intermediate care facility for the elderly. The patients are sensitive to temperature fluctuations, and a stabilized temperature was a major design consideration.

The Mennonite Home is located in Albany, Oregon. Approximate latitude is 45° north. The winters are overcast and rainy with an average temperature of 42°F. Colder temperatures generally occur in combination with clear skies, mild temperatures with overcast skies. The summer is dry and mild with an average temperature of 63°F. This is a favorable climate for mass walls which act to minimize day-night temperature swings.

The building is one story, masonry load bearing construction, with a wood truss roof. The patient wings are elongated in the east-west direction to maximize exposure to natural light and ventilation. Interior courtyards provide daylight and views from the corridors and the patients rooms. Three feet of earth is bermed against the north walls to minimize wall exposure to winter winds. The roof is insulated with 9-inch fiberglass batts for an R=30. The exterior masonry walls, excluding the Trombe walls, have their cells filled with foam insulation of an R=11. The floor slab is insulated with rigid boards to R=4.5. Additional energy conserving features include double glazed windows, and vapor barriers used throughout the building, and heat exchangers that recycle heat from waste water produced by showers and dishwashing to preheat domestic hot water. Night set back thermostats are provided on each fan coil unit.



The passive solar features include a combination of full and half height mass Trombe walls which are exposed to the patients rooms. The walls of the interior corridor are masonry with the cells grouted full. These walls provide a stabilizing influence which minimize temperature fluctuation. A south facing clerestory providing direct heat gain extends the length of the corridor. These windows also provide natural daylighting which will save an estimated 16,000 kWh per year.

The projections for the Trombe walls and other indirect gain features indicate they will supply 45 percent of the yearly heating requirements of 250 million Btu's. The building also includes active solar collectors which will provide 52 percent of the domestic hot water. Ninety-five percent of the corridor requirements will be supplied by the clerestory.

The Mennonite Home Trombe walls, mass walls, and the heat exchangers will be monitored for two years beginning in November 1980, to determine their actual performance and supply information to fine tune this hybrid system.

PROJECT TITLE:	**PATOKA NATURE CENTER**
Institution:	*Miami University* *Oxford, Ohio*
Principal Investigator:	*Fuller Moore*
Contract Number:	*EG-77-04-4090*

The scope of this project includes 1) purchase and installation of instrumentation to monitor the thermal performance of the 3200 sq. ft. Nature Center, 2) to monitor performance for one year, 3) to analyze the data, and 4) to report the findings.

The passive solar system is a direct gain type with the collector being 1536 sq. ft. of glazing on the 60° south slope of an "A" frame roof. An aluminum foil ceiling is used to reflect insolation onto the storage mass. Thermal storage is in a massive floor (quarry tile on slab on grade, with perimeter insulation), two rows of 18" X 8' vertical fiberglass water tubes, and sand-filled wood joist ceiling construction over certain areas. "Beadwall" (movable styrofoam bead insulated glazing), interior shutters, and extensive berming reduce heat loss/gain. Mild weather cooling is by natural convection and nocturnal radiation. A reversible air-to-air heat pump provides auxiliary heating and cooling.

Current work involves performance monitoring and data analysis.

PROJECT TITLE: **MARKETING ACTIVITIES**

Institution: *Mid-American Solar Energy Complex*
Minneapolis, Minnesota

Principal Contact: *David Pogany*

Contract Number: *In-house*

The major thrust of this program is the performance of several efforts relating to the marketing of passive solar energy. The strategy calls for promotion of solar energy concepts, systems, and products through organizations with high-multiplier capabilities. The approach calls for utilizing established networks, professional associations, organizations and projects which link educational programs to actual construction projects. The objective is to develop a passive solar technical infrastructure within the region while simultaneously building passive solar structures.

One of the major elements of these marketing activities is an extension of the SOLAR 80 program which involved the design of 20 passive solar residential buildings. A distribution of over 10,000 brochures describing the results of this program will occur during 1980. Working drawings and specifications will be available at a nominal cost through MASEC.

MASEC will also let a competitive contract for the development of a comprehensive passive solar marketing program that will cover specific target audiences including homebuyers, builders, contractors, HVAC distributors, lumberyards, lenders, realtors, architects, and others.

Some of the scheduled FY80 accomplishments are:

- Distribution of over 10,000 SOLAR 80 concept books
- Establishment of blueprint distribution system
- Selection of 8–10 sites for passive monitoring systems
- Publication of numerous public service announcements and national magazine articles
- Distribution of 10,000 retrofit concept books.

PROJECT TITLE: **SOLAR UTILITIES DEVELOPMENT**

Institution: *Mid-American Solar Energy Complex*
Minneapolis, Minnesota

Principal Contact: *David Pogany*

Contract Number: *In-house*

MASEC plans to develop a two-day workshop for executives of rural electric co-ops and municipal gas and electric utilities. This workshop will present information on state-of-the-art solar technologies specifically applicable to utilities. Case histories of utilities which have initiated solar and energy conservation loans will be discussed. The workshop will directly involve the DOE Residential Conservation Service. After the workshop, MASEC will announce the solicitation of bids (for FY81) to install solar utilities within the Region. A Source Evaluation Board will recommend one or two utilities which will receive subgrants to begin initial planning for the organizational structure required to finance extensive solar energy and conservation measures in the Region. This is a pilot project designed to reveal potential problems unforeseen at present.

The Residential Conservation Service portion of this project will be through the State Solar Offices. This involves a coordination of state efforts and sharing of methods developed by the utilities companies.

PROJECT TITLE: **PASSIVE SOLAR TEST PROCEDURES, CODES, AND STANDARDS**

Institution: *National Bureau of Standards*
Gaithersburg, Maryland

Principal Investigator: *Robert A. Dikkers*

Contract Number: *EA-77-A-01-6010*

The National Bureau of Standards is the government institution charged with establishing and maintaining procedures and standards.

Relative to the passive solar program, they are working to develop standard methods for:

- modeling and evaluating the thermal performance of passive components, systems and buildings
- assessing the degree of comfort maintained in passive buildings
- determining the health, safety, durability and reliability of passive materials, components and systems.

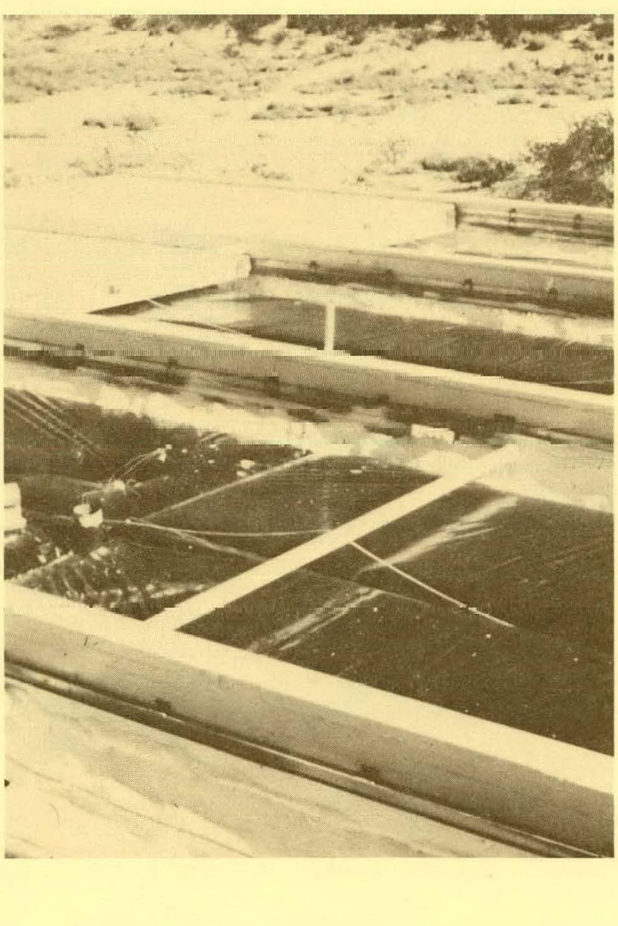
NBS is undertaking several initiatives which will contribute to developing appropriate standards and performance criteria in order to ensure the successful commercialization of passive solar energy. The status of these efforts is presented in the following paragraphs:

- A method of instrumenting, gathering data, analyzing the data, and reporting the performance of passively heated and cooled buildings was proposed in 1979. Detailed experiments on a building incorporating the major types of passive heating concepts will get underway in 1980. These experiments will test the validity of the proposed methods.
- The major types of passive components have been classified into eight major categories. Standard testing procedures for the purpose of rating them on thermal performance will continue to be developed over the next three years. It is expected that proposed procedures for sun and heat control devices with no heat storage as well as thermal storage walls will be available in 1980.
- During 1979, work began on the development of procedures to evaluate solar applications in urban commercial environments. Summaries of the NBS work were published in proceedings of the 4th National Passive Solar Conference. In 1980, work will be focused on the development of a solar availability model and energy load analysis techniques.
- Additional work will begin in 1980 to further the development of standards and performance criteria for passive buildings. This will include assessing the degree of human comfort in existing passive buildings; analysis of existing building code requirements inhibiting the use of passive technology and identification of unusual health and safety problems associated with its use; and development of standard techniques for determining the long-term performance and durability of phase-change storage materials.

PROJECT TITLE:	**PERFORMANCE EVALUATION OF EXPERIMENTAL PASSIVE SKYTHERM HOUSE**
Institution:	*New Mexico State University Las Cruces, New Mexico*
Principal Investigator:	*Thomas R. Mancini*
Contract Number:	*EY-76-S-04-4157*

This project by the New Mexico State University is a follow-on proposal to one initiated in September 1976 with funds from the State of New Mexico. After 1 year of extensive modeling and design, the State of New Mexico granted funds for the construction of a "SKYTHERM" house on the campus of the New Mexico State University in Las Cruces. The term SKYTHERM is a trademark of Skytherm Processes and Engineering of Los Angeles, California. In 1977, funds were received from ERDA to install instruments and evaluate the performance of the house. House construction was completed in June 1978. Data have been collected since January 1979 on an hourly basis using a data logger. This follow-on program of the New Mexico State University is a 2-year evaluation of the SKYTHERM Solar House.

The hot climate of southern New Mexico affords a unique opportunity to fully evaluate the cooling capabilities of the SKYTHERM environmental control. The SKYTHERM concept was first tested by its inventor, Mr. Harold Hay, in 1967. In this system, the thermal mass is concentrated on the flat roof of the house in the form of 6- to 8-inch pool of water. The water is contained in a clear plastic bag, the bottom of which is colored black to absorb the incident radiation. The collector-storage roof may be covered by an insulated panel during either the day or night depending on whether the house is in the heating or cooling mode. When the house is operating in the cooling mode, the removable panel is in place during the daylight hours. This does not permit the sun's energy to warm the water. However, during this time, the water is absorbing heat from the interior of the house, and thereby, cooling it. This heat is then rejected by convection and radiation to the clear night sky when the insulating panel is removed.



When the solar system is operating in the heating mode, the cycle is reversed. That is, the insulated panel is removed during the daytime and in place at night. The roof pond absorbs the sun's energy during the day and releases it into the interior of the house for the evening hours. The cost of the roof pond is nominal since it replaces a portion of the original roof.

In this project, several variables have been cited for their importance:

- Variation of water depth in the roof pond
- Separate evaluations of radiative and evaporative heat losses from the roof pond
- Sensitivity of system to infiltration, both in the building; and above the water bags
- Contribution to cooling by floor slab
- Sensitivity of system to insulating plan control strategy.

The principal investigator, Thomas R. Mancini, has been requested by DOE/LBL to publish results of this experiment with an analysis to indicate how the findings can be generalized for different climate conditions and less massive buildings.

PROJECT TITLE:	**MARKET RESEARCH**
Institution:	*Northeast Solar Energy Center* *Cambridge, Massachusetts*
Principal Contact:	*Didier Thomas*
Contract Number:	*In-house*

The purpose of this project is to identify the near-term commercialization opportunities for application of passive solar systems and products in the Northeast Region. NESEC's goal of having 0.25 quad of energy provided by passive solar by 2000 can only be achieved with a significant commercialization effort promoting passive solar designs, systems, and products.

Introductory to this effort is the identification of the most promising commercialization opportunities that can lead to rapid solar installations. Work will focus on residential and commercial buildings (both new and existing construction) to assess the nature of the market and help identify the most appropriate marketing activities, such as workshops, home shows, and promotional campaigns.

These activities will provide the basis for establishing a data base from which the following statistics can be obtained:

- Existing single family and multifamily housing stock, new housing starts and trends, existing commercial building stock and new construction project size, market values, costs, heating and cooling systems, and energy consumption patterns
- Consumer attitudes, demands, expenditures, gross income, disposable income and demographics
- Commercial business needs, attitudes, demands, and planned construction expenditures
- National and regional economic data, employment statistics and trends, available capital, tax incentives, institutional barriers, and fuel costs
- Relative costs of passive solar versus conventional structures, financing mechanisms, and influencing factors and groups.

Analyses of these data will yield the following deliverables:

- Comprehensive and up-to-date passive solar market data base that can be used for market penetration studies and trend analysis of the residential and commercial building sectors
- Marketing reports on a quarterly basis, specifying the commercialization opportunities for passive solar designs and products in the residential and commercial building sectors
- Marketing workshops for the passive solar industry
- Marketing materials and brochures on passive solar designs and products for 18 home shows, real estate agencies, lending institutions, professional organizations, and the media.

PROJECT TITLE: **OUTREACH ACTIVITIES**

Institution: *Northeast Solar Energy Center*
Cambridge, Massachusetts

Principal Contact: *Didier Thomas*

Contract Number: *In-house*

NESEC has embarked on a program to accelerate the adoption and application of passive solar systems and products. Initial tasks include the following:

- Installation and testing of low-cost monitoring equipment on selected passive systems as well as collecting fuel-use data on noninstrumented sites
- Establishing liaison with the passive solar community to communicate and keep informed on developments and opportunities
- Developing training aids and sponsoring programs to educate designers, builders, developers, and building inspectors on the fundamentals of passive solar technology
- Offering technical support to the passive solar community via a network of specialized consultants
- Administration of incentive programs to stimulate the usage of passive solar concepts.

PROJECT TITLE:	**SYSTEM DESIGN**
Institution:	*Northeast Solar Energy Center* *Cambridge, Massachusetts*
Principal Contact:	*Didier Thomas*
Contract Number:	*In-house*

This effort will study existing passive systems in the Northeast Region. Data collected on the performance of these systems will be compared with predicted performance generated by computer programs. Upon verification of system performance and predictive methods, various types of information will be disseminated to the appropriate professions. Some specific deliverables include the following:

- *Design notes* for architects and engineers focusing on graphics and well supported rules of thumb for Northeast subregions
- *Application notes* for contractors that describe construction and installation methodologies of different types of passive systems that have been successfully demonstrated by Northeast contractors
- *Design tools* describing various validated manual and computerized analytical techniques
- *System notes* defining the feasibility of integrating various types of techniques.

The passive solar design process requires that the intended building be viewed as a functional operating system that has considered environmental variables not commonly applied to the building design process. The design should present the best balance of aesthetic appeal, thermal performance and cost efficiency. Unfortunately, there is insufficient information in usable form at the present time to permit designers to easily incorporate passive solar concepts. The purpose of this task is to generate easily usable design tools that will allow designers more simplified methods of incorporating passive solar concepts into their designs.

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *Office of Physical Planning*
Princeton, New Jersey

Principal Investigator: *Jon Hlafter, Director*

Contract Number: *DE-FC02-80CS30346*

This project involves the redesign and remodeling of the School of Architecture and Urban Planning at Princeton University using passive solar concepts. The existing building is a three-story reinforced concrete frame enclosed with brick and concrete block cavity wall panels and single-glazed (gray glass) window panels. The Design Studios occupy a two-story volume, approximately 165 feet long by 56 feet wide by 19 feet high, at the second floor of the main wing of the building. The studios are poorly insulated and the large areas of single-layer glass are a source of tremendous heat loss and discomfort to the occupants.

Design Team

- Architect/Solar Designer: Harrison Fraker
- Solar Consultants: Princeton Energy Group
- Project Manager: Jon Hlafter, Director, Office of Physical Planning, Princeton University.

Design Approach

In developing the new design of the building, various relationships between design, climate, passive solar systems and cost will be studied. Included are:

- Impact of climate factors on building form
- Energy consumption use patterns
- Various passive heating, cooling and lighting systems and required back-up mechanical systems.

Preliminary passive solar design considerations include:

- South-facing brick/concrete block cavity wall bays to be painted with highly absorbent black paint and then double glazed with ASG "Low Iron" sealed edge insulating glass, thus creating modified "Trombe" wall collectors
- Double glazed south-facing windows between brick bays with the same ASG "Low Iron" insulating glass
- Solar insolation transmitted through two acrylic glazing surfaces, one vertical and one horizontal, and focused by reflectors onto a storage pipe that runs the length of the building under a roof aperture.

PROJECT TITLE: **REFLECTIVE INSULATING BLIND/PASSIVE HEATING AND COOLING TECHNIQUES**

Institution: *Oak Ridge National Laboratory*
Oak Ridge, Tennessee

Principal Investigator: *Hanna Shapira*

Contract Number: *In-house*

Work in the Passive Solar Technology Program at Oak Ridge National Laboratory has focused in two areas:

- Development of Reflective Insulating Blinds

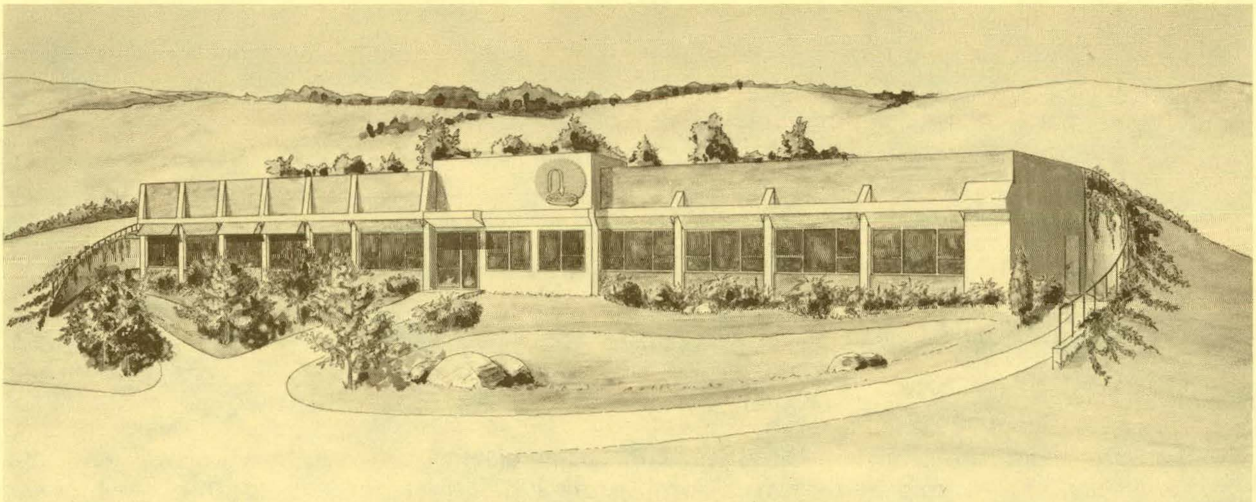
- Demonstration and Testing of Passive Solar Heating and Cooling Techniques.

The Reflective Insulating Blind operates on the basis of a "Venetian Blind Mechanism." The composition of the slats of the blind is manufactured so that the window is insulated from normal heat loss when the window is closed. When in an open position, the surface of the slats are designed to permit a maximum amount of light to be reflected inward. The design of the blind has been completed and manufacturing processes are now being investigated. Preliminary studies indicate the most promising market to be large buildings with many windows of similar size.

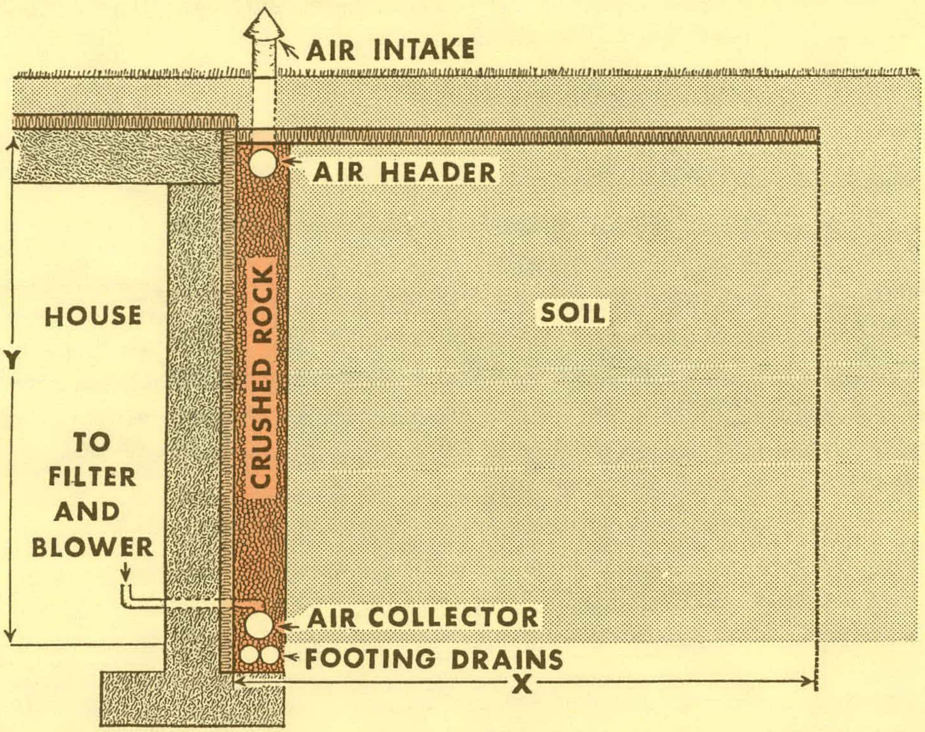
The Demonstration and Testing of Passive Solar Heating and Cooling Techniques project pertains to passive solar systems designed in the Joint Institute for Heavy Ion Research. Examples of the natural and passive cooling techniques under study are:

- Extendable overhangs
- Vegetational shading/cooling
- Cooling via an earth/rock bed heat exchanger.

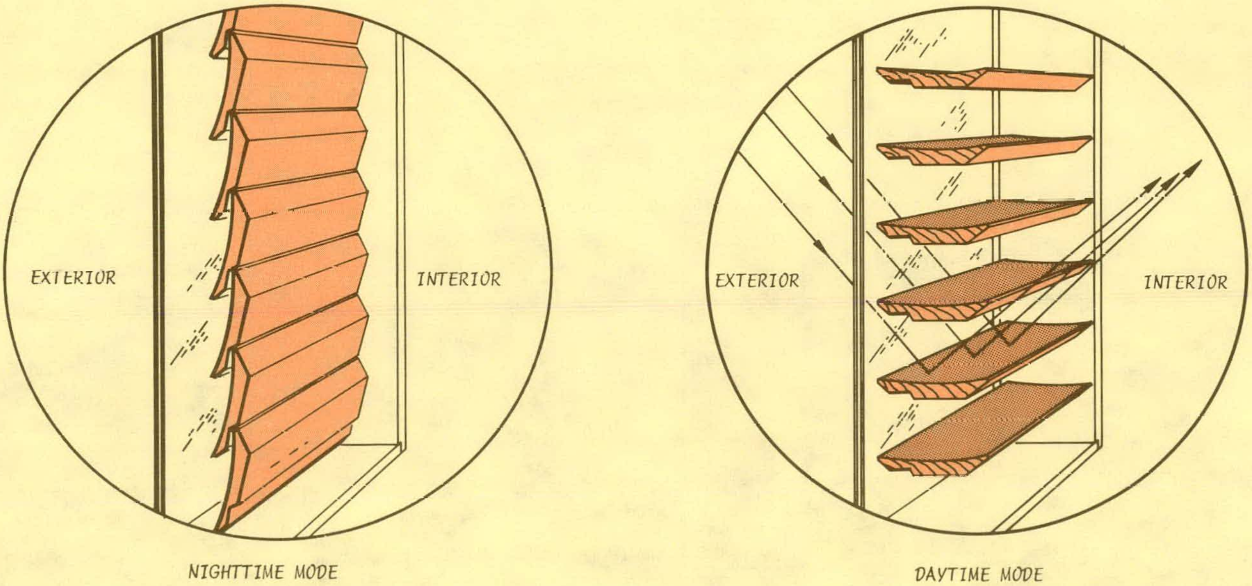
Data from these systems will be recorded and used to test performance of the DOE-2 simulation. Construction of the building is scheduled to be completed during 1980.



JOINT INSTITUTE FOR HEAVY ION RESEARCH



Earth-Rock Bed Heat Exchanger Concept



Reflecting-Insulating Blinds
(Patent Pending)

PROJECT TITLE: **PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**

Institution: *W. H. Porter, Inc., Poligon®*
Holland, Michigan

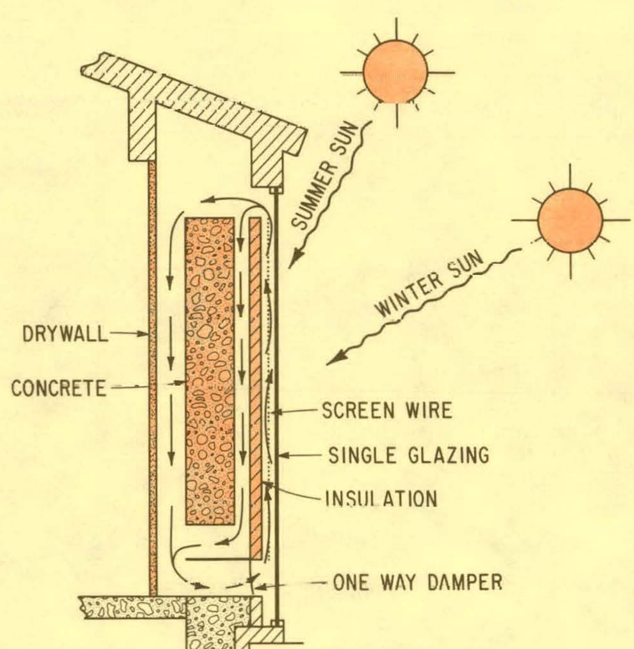
Principal Investigator: *William H. Porter*

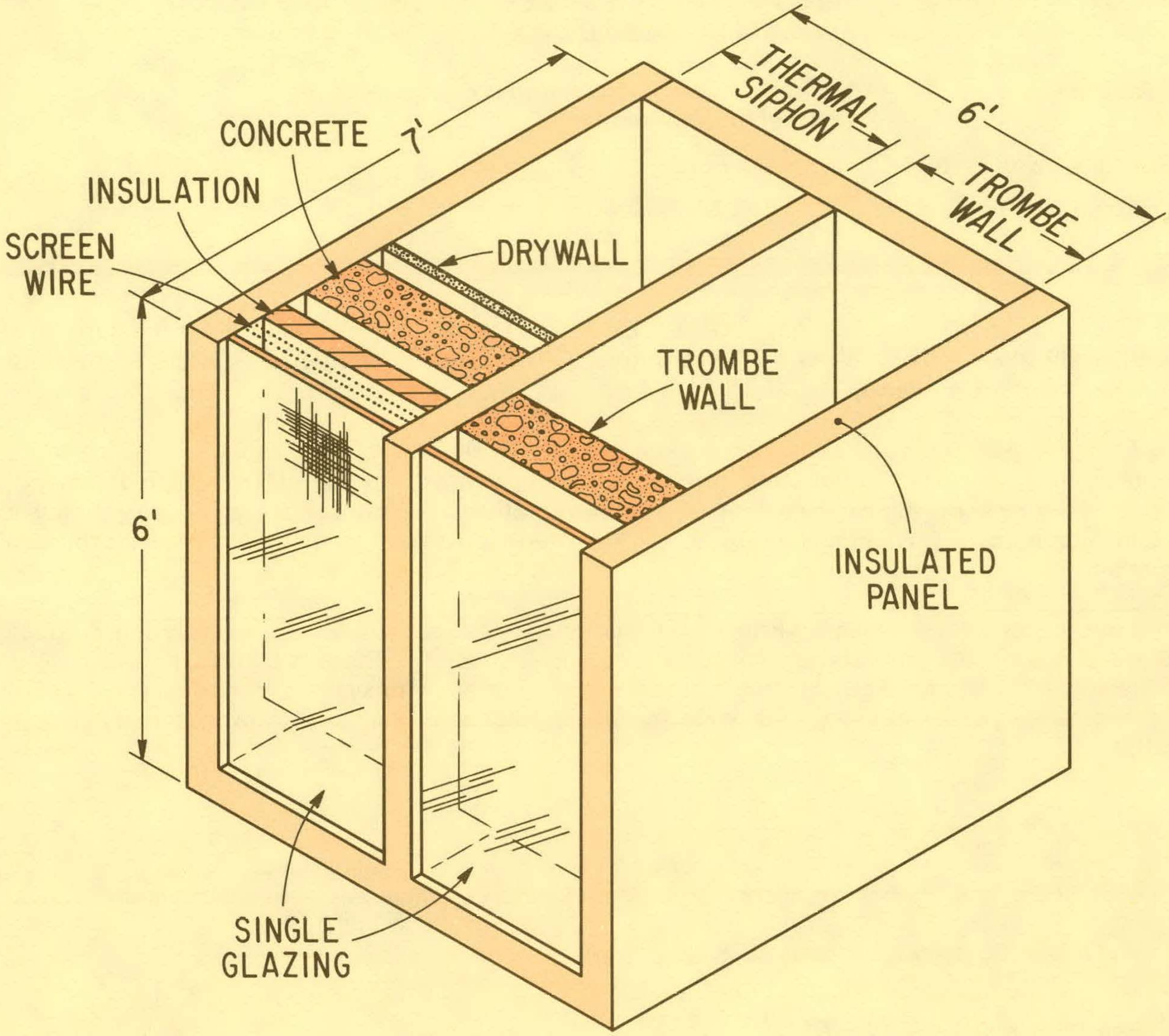
Contract Number: *DE-FC02-80CS30388*

W. H. Porter, Inc., of Holland, Michigan, manufactures under the trade name of Poligon® hexagonal recreational, commercial, and park structures. These structures have been used for libraries, cafeterias, nature study centers, restrooms, concession stands, and recreational facilities throughout the United States. The product line of W. H. Porter, Inc., will be revised to include more passive solar techniques.

The design approach by W. H. Porter, Inc., will be to consider all factors involving energy conservation and passive solar and then relate these to the structure. The experience of W. H. Porter, Inc., in manufacturing cold storage facilities where insulation and vapor barriers are critical has been beneficial in providing passive solar-insulated buildings.

Design modifications necessary to make Poligon® passive solar are primarily water or Trombe walls. The existing skylight already provides much light to the building, and the addition of a larger skylight with a large reflective surface could offer 100 percent daylighting. Because the panels form an interior finished surface, have super insulation, and have a roof deck in one step, considerable labor is saved. Almost any type of roofing can be applied over the structural-insulated panels. By using the foam core structurally as well as for insulation and by saving construction labor, this building system makes an attractive structure adaptable to passive solar at a competitive cost.





TEST BOX FOR COMPARATIVE THERMAL ANALYSIS

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *Princeton Communications Park Associates*
Princeton, New Jersey

Principal Investigator: *Jeremiah Ford*

Contract Number: *DE-FC02-80CS30348*

The Princeton Communications Park Associates was formed as a joint venture for the purpose of real estate development on a 27.92-acre tract. This tract is located in Princeton Township, Mercer County, New Jersey.

The proposed building comprises a total area of 64,000 sq. ft. of professional office space. Primary occupancy will be doctors, lawyers, and design firms. The use pattern of predominantly daytime occupancy allows nighttime temperature setbacks. With lower yearly operating and maintenance costs, premium office space will be offered on a cost-competitive basis with the local market.

The proposed development of Princeton Communications Park will occupy a gently south-sloping wooded site on a main thoroughfare of Princeton, New Jersey. Through its use as a professional office building, the project will have a broad exposure to all members of the community. This will be a generic type of building with wide regional applications from small towns to medium-sized cities.

Design Team

- Solar Designer: Princeton Energy Group with Lawrence Lindsey as team coordinator
- Architects: Harrison Fraker, Short, and Ford.

Design Approach

The design approach in Phase I (Schematic Design) will follow normal American Institute of Architects' basic services. These basic services during Phase I will be modified and expanded to include:

- Analysis will be made of potential impact of climatological factors on the form of the building
- Load analysis will be conducted to establish relative importance of heat loss, heat gain, internal loads, and use patterns and energy consumption of the building
- Alternative energy conscious design strategies will be proposed for the building envelope (form, shape, orientation, walls, windows/skylights, and mass); the objective will be to minimize climatological liabilities, as well as taking advantage of climatological assets to provide appropriate lighting and comfort levels by natural energy flows
- Monthly and annual simplified computer energy performance analyses will be conducted; these will establish the annual solar heating fraction, annual daylighting factor, annual reduction in cooling loads, and total annual auxiliary energy required

- Benefit/cost analyses will be made on the alternative energy conservation design features

- Alternative mechanical systems will be considered before providing auxiliary back-up equipment for natural heating, cooling, and daylighting designed as a part of the building envelope.

Design Tools

Design tools used during the schematic design phase will include:

- Hand-held calculator program that features a 24-hour simulation of a direct gain or attached sunspace. This is used to size exhaust fans, rock beds, thermal storage, and windows

- Solar-load ratios from a microcomputer program. This program includes connections for varying thermal mass, single to triple glazing, any night insulation, and variations in internal mass

- Analyses of daylighting provisions. Calculations are made of monthly electric lighting loads

- Thermal network analyses by a microcomputer program establishes hour-by-hour simulation of any linear, thermal configuration; this will yield hourly temperatures, and accumulated heat flows and will indicate venting and heating thermostat set points.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Rensselaer Polytechnic Institute Troy, New York*
Principal Investigator:	*Richard E. Scammall*
Contract Number:	*DE-FC02-80CS30350*

Rensselaer Polytechnic Institute (RPI), located in Troy, New York plans to design and construct a Visitor Center on its campus. In addition to the functional requirements for the facility, the building will emphasize the use of passive solar systems for heating, cooling, lighting, and domestic hot water. The proposed Visitor Center has a projected gross area of approximately 4,000 square feet.

Design Team

The design team consists entirely of faculty and staff employed by RPI.

- Solar Design Consultant: Walter M. Kroner, Associate Professor of Architecture, will have major responsibility for the passive solar system design
- Architectural Design: Peter Parsons, Assistant Professor of Architecture, has primary responsibility for architectural design
- Engineer: John A. Tichy, Assistant Professor of Mechanical Engineering, has primary responsibility for the detailed engineering aspects of the passive solar system
- Back-up Systems Design: Richard H. Bodette, Adjunct Assistant Professor of Architecture, has primary responsibility for design of back-up heating and cooling systems, lighting, electrical, and domestic hot water system
- Computer Simulation: Robin J. Smith, Research Associate, will have primary responsibility for the predesign and schematic design computer simulation activities.

Design Approach

The design approach is based on the conventional design phases of architectural practice and includes schematic design, design development, and construction documents.

- The schematic design will explore various design alternatives, such as:
  - Utilization of earth berming
  - Structural and envelope materials with heat storage capacity
  - Entry locks to reduce infiltration
  - Reduction of envelope areas exposed to climate
  - Spatial organization based on thermal and lighting hierarchy
  - Combination of passive solar systems
  - Utilization of energy-flow controls (conduction, convection, and radiation controls)
  - Solar domestic hot water systems
  - Natural convective cooling.

- Design development – which includes structural engineering, mechanical systems, material compositions, and envelope subsystems.

- Final design – includes preparation of working drawings, specifications, detailed cost, and thermal and energy analysis.

Design Tools

- Predesign computer simulation

- Interactive computer graphic simulation.

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

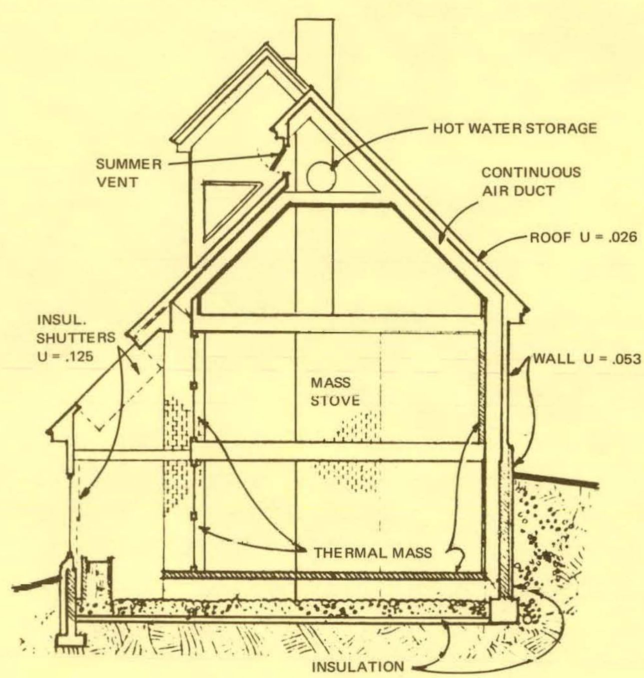
Institution: *Rocks and Trees Cooperative Land Preserve*
Middletown Springs, Vermont

Principal Investigator: *Barbara Miles*

Contract Number: *DE-FC02-80CS30351*

The Rocks and Trees Cooperative Land Preserve plans to construct a multistory facility which will be used as a cooperative day care center and for group meetings and for offices. The site is 20 miles southwest of Rutland, Vermont, on a small 0.8-acre lot. The ground rises abruptly, making extensive earthsheltering a relatively easy process. There are water sources uphill that will provide uninterrupted gravity-fed water to the site. The building will be a rectangular structure, 24 ft X 36 ft, with an attached 24 ft X 8 ft greenhouse. The lowest floor will have space for utilities, the greenhouse, and a pottery workshop. The construction will be similar to a standard-poured concrete basement on three sides with a glazed wall on the long south-facing side. Styrofoam insulation will be applied to the exterior of the concrete. The main floor will have a large room for day care and community meetings, plus restrooms. Two or three offices will be built on the top level.

The building will be built from locally available timber, using a traditional post and beam-framing method. A major design, structural and thermal element, will be a massive masonry chimney and wood-fired furnace (the back-up heating system). The chimney will be a major target of incoming sunlight. The chimney mass will incorporate a long maze of flue passages to allow the masonry to store and radiate wood heat. The wood-fired furnace is used whenever the solar heat intercepted and stored by the chimney is dispersed after several cloudy winter days. Passive solar energy (with wood back-up) will be an economical means of heating this building.



"A" CROSS SECTION

Design Team

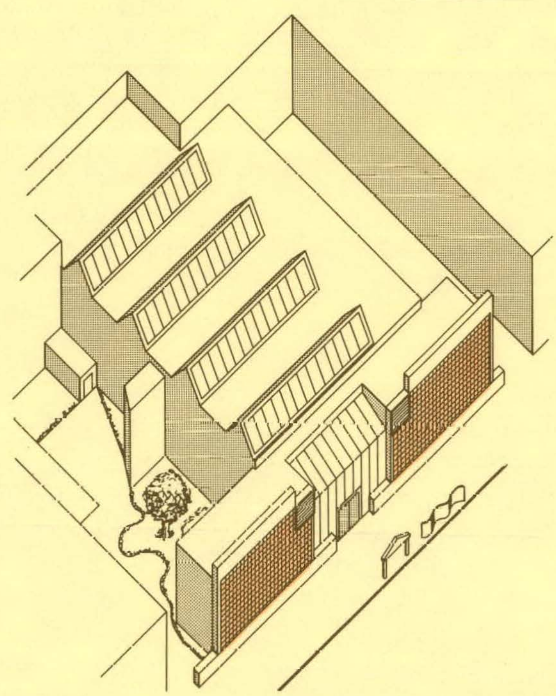
- Architect: Sunroots Design, Rutland, Vermont
- General Contractor: David P. Wright, independent contractor.

Design Approach

In the design approach, a simultaneous investigation is made to determine solar availability, exposure, slopes, microclimate, and shading. From this information, schematic designs are constructed. Activities and space needs are matched to thermal, structural, and light characteristics of various passive techniques. Using various rules of thumb, thermal design is checked, and the proper floor-to-glass ratio, mass placement within the structure, and mass-to-glass ratios are incorporated into the design. Detailed thermal calculations are made on a hand-held programmable calculator. This work includes standard heat-loss calculations, solar heat gain information, storage mass sizing, and solar fraction data. Careful consideration will be given to all passive and energy conserving possibilities, including building orientation and shape, wind sheltering, infiltration control, effective placement of insulation, earth sheltering, movable insulation at windows, earth/air heat exchangers, thermal chimneys for summer ventilation, landscaping for microclimatic effects, summer shading, reflectors for increased winter solar gain, clerestories, greenhouses, skylights, mass placements of various kinds of walls and floors (and underfloors), convective air flow paths, auxiliary heating system tie-in, early morning direct solar gain, spatial layout to make best use of thermal zones, radiant slabs, and walls cross ventilation. These will all be tempered by aesthetic qualities, economic considerations, and local availability.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*St. Mary's Parish Alexandria, Virginia*
Principal Investigator:	*Rev. Msgr. Joseph L. Wingler, Pastor*
Contract Number:	*DE-FC02-80CS30362*

The proposed passive solar project involves construction of a gymnasium-auditorium addition to the existing St. Mary's School structure located in Virginia. Funding for this project will be for the design of a passive solar heating system, integral to the new building structure, for the purpose of supplementing the space and hot water heating as well as the lighting requirements of the addition, and to identify and implement related energy conservation measures applicable to the existing building structure and its system.

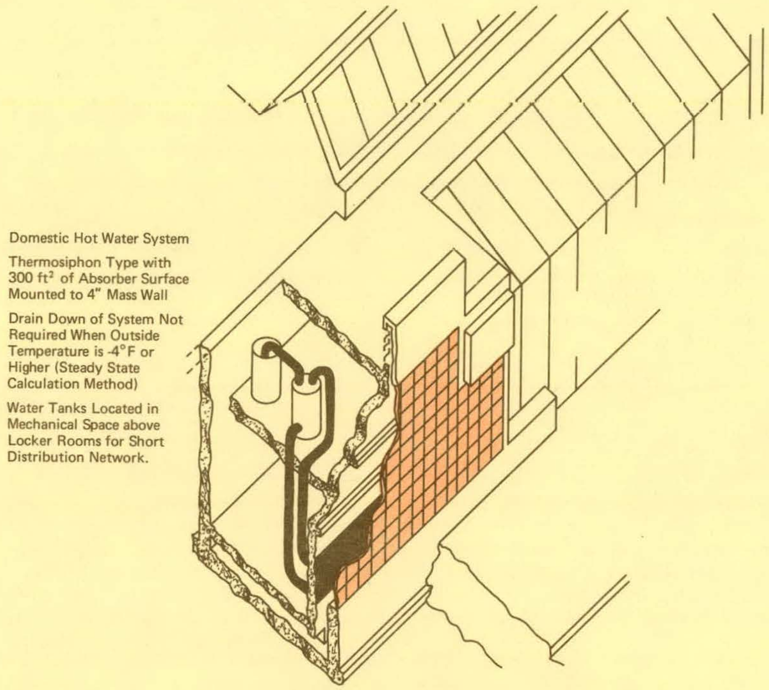


Design Team

- Architect/Project Manager: Architects Group Practice, Architects and Engineers – will serve as the prime contractor and provide project management and architecture-civil engineering services
- Solar Consultant: Archetype – will serve as a consultant for passive energy system design services
- Structural Engineers: Guld and Fernandez – will serve as consultant for structural engineering services
- Mechanical/Electrical Engineering: Office of Lee Hendrick.

Design Approach

During design a strong emphasis will be placed on analysis of climatic characteristics, including shading, temperature, humidity, and wind movement. Careful analysis of user needs, activities, and patterns will be prepared in conjunction with these studies and will determine the most appropriate passive solar systems for the building. The design process will also consider the special problems of integrating new construction with an existing facility requiring a careful matching of their thermal properties. The design team anticipates that the installation of the bulk of the passive system will be integral with the actual construction of the building.



Design Tools

- Degree Day Method – estimation of general heating requirements
- Efficiency of Utilization – estimation of general energy consumption
- Effective U-Value Computation – determination of climatic response of building components (New Mexico Energy Institute)
- PEGFLOAT and PEGFIX – hand calculator program for estimation of hourly system performance (William Glennie, Princeton Energy Group)
- BIN Method Procedure – detailed estimation of energy consumption
- Modified Liu and Jordan Method – determine insolation on a tilted plane, developed by Klein, Duffie, and Beckman.

Following completion of the work, a representative of St. Mary's will log temperatures at critical points in the passive system and exterior weather conditions. These records will be kept on a daily basis during the first few weeks of the system's operation. Thereafter, recordings will be made on a weekly basis for the first year of operation. Monthly records of fuel consumption will also be made and all results reported to the architects/solar designers for evaluation.

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *Security State Bank of Wells*
Wells, Minnesota

Principal Investigators: *Frank Clarke and Bob Hart*

Contract Number: *DE-FC02-80CS30353*

The Security State Bank of Wells, Minnesota, is planning to replace their existing facility with a new two-level building. The new building will be of masonry construction with a total of 10,000 square feet. Wells is a town of 3,000, located in a prosperous farming community in south central Minnesota. Location of a passive solar building in Wells is believed to reflect positively on the U. S. Government's efforts toward energy conservation and should encourage rural community members to consider energy-conserving efforts. Security State Bank is an excellent subject for passive solar demonstration because of its leadership position in the local community.

Design Team

- Architect – Gene Hickey and Associates, Inc. of Edina, Minnesota
- Mechanical Engineer and Electrical Engineer – Emanuelson-Podas, Inc. of Minneapolis, Minnesota
- Solar Designer – John Weidt Associates of Chaska, Minnesota

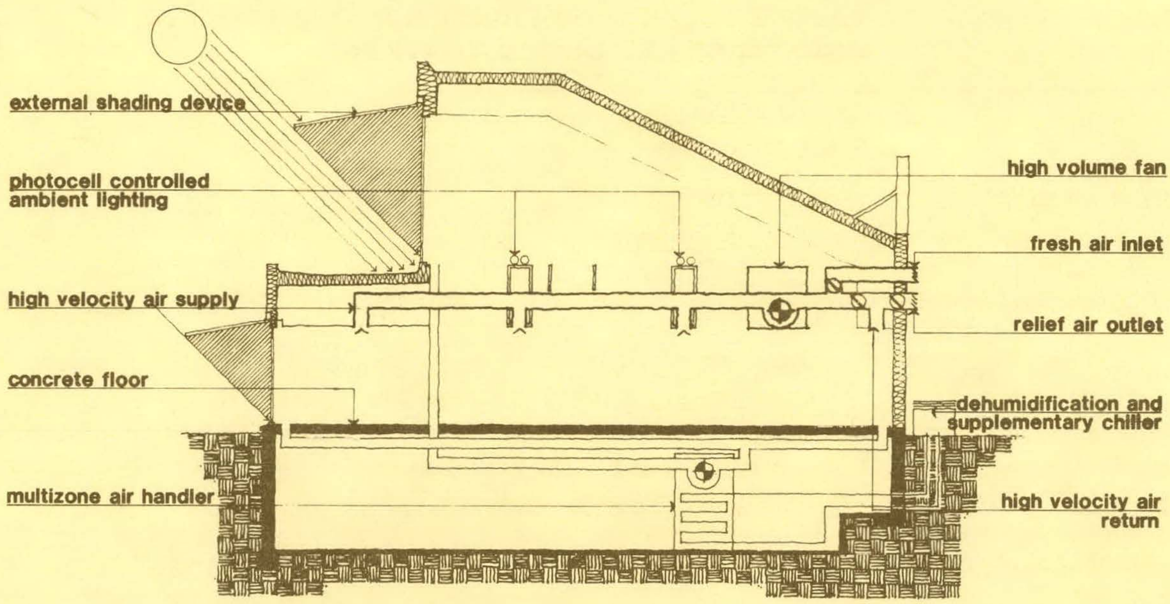
Design Approach

In the design approach, all energy using aspects of the building will be considered. Priority will be given to the following consuming areas:

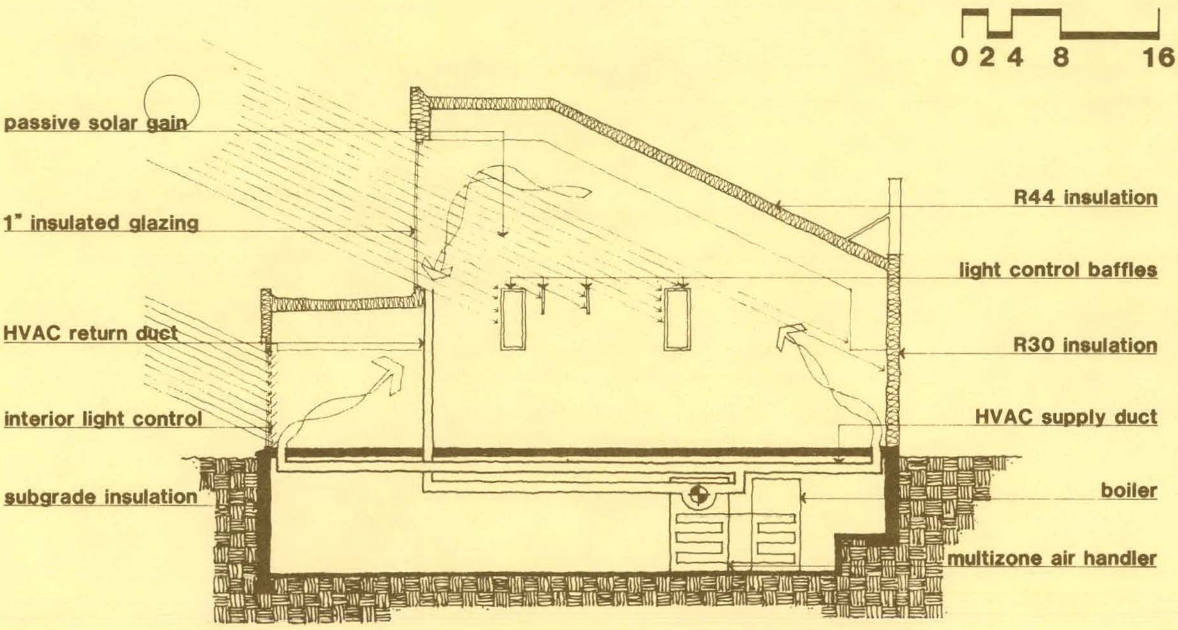
- Lighting – Day lighting, task lighting, variable dimming
- Heating – Passive heating, storage to provide for nonoccupied periods, heat recovery
- Air Conditioning – Minimal refrigeration, nonmechanical evaporative cooling, diurnal cycle ventilation, increased ventilation velocity
- Ventilation – Provision for natural and stack ventilation, maximum summer/minimum winter rate variability
- Ancillary – High-efficiency equipment, minimal use of nonessential mechanical systems

Design Tools

- Building Load Studies – Determining energy usage via a simplified method of estimating building load, the hourly temperature data bins, equivalent temperature differentials, monthly extremes, sky cover, occupant, light and motor loads



COOLING



HEATING

- Passive Systems – A numerical thermal network algorithm for simulating the performance of passive systems. Performance simulation can be for direct gain, Trombe, water walls, roof ponds, and heavy mass buildings. Temperatures are calculated at each of seven network nodes on an hourly basis.

- Lighting – Models will be constructed and measured to analyze daylighting.

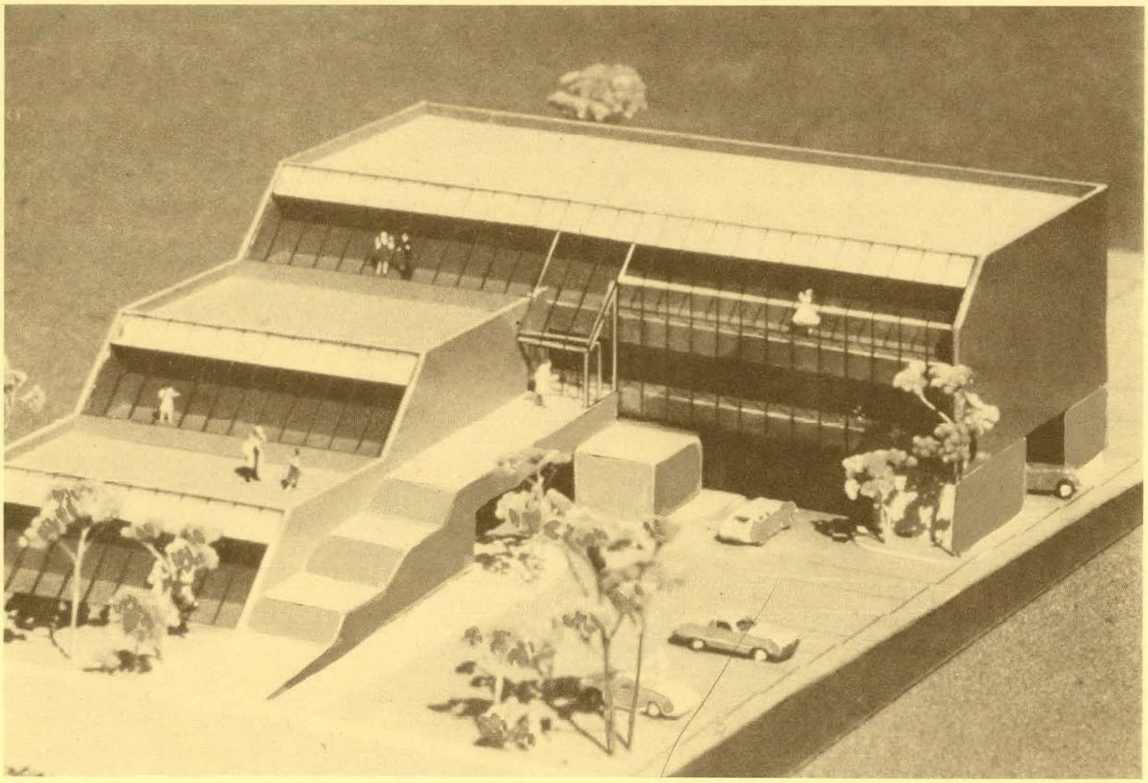
PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *Robert W. Smedley*
Littleton, Colorado

Principal Investigator: *Robert W. Smedley*

Contract Number: *DE-FC02-80CS30354*

A passive solar-heated and solar-cooled office building is planned for Littleton, Colorado, by owner/developer Robert W. Smedley. The initial building form is planned as two masses with a connecting core or atrium to allow the possibility of phasing the construction, and the masses will be raised to permit more required parking and landscaping at grade level. Leasable office space would be two or three floors above the parking.



Design Team

- Architect — H. Jay Harkins & Associates
  Principal — H. Jay Harkins
  Solar Designer — Dean Randle

- Mechanical Engineer — Beckett, Harmon, Carrier and Day, Inc. with Energy Management Consultants, Inc.
  Design Engineer — Reg Smith

- Electrical and Lighting Engineer — Garland D. Cox Associates

- Structural Engineer – KKBNA, Inc.
  Principal – Dave Austin

- Construction Manager – CMC, Inc.
  Principal – Dick Benes

Design Approach

The objectives of the design approach are to obtain the greatest cost-effective benefit possible through:

- Passive space heating
- Passive space cooling
- Passive domestic hot water heating
- Natural ventilation
- Natural day lighting.

Generic passive or passive hybrid systems will be identified for each of the five objectives. Variables that affect each system will be identified. The variables that affect different systems for each objective will be placed in a model by the most appropriate computer program. Alternative models would be evaluated in terms of:

- Passive contribution to the demand/backup requirement necessary
- Associated cost increment/cost effectiveness
- User comfort/user reponse.

PROJECT TITLE:	**DESIGN METHODOLOGIES FOR PASSIVE COMMERCIAL BUILDINGS**
Institution:	*Solar Energy Research Institute* *Golden, Colorado*
Principal Investigator:	*Steven E. Ternoey, AIA*
Task Number:	*In-house*

The objective of this project is to reduce the use of nonrenewable energy in commercial buildings for heating, cooling, lighting and ventilation through the use of new architectural design concepts and design process methodologies that integrate energy conservation, solar techniques and innovative mechanical/electrical systems.

In cooperation with DOE national labs and A/E firms (under DOE contract) the following activities are being undertaken:

- DOE Program Opportunity Notice (PON): Passive Solar Commercial Buildings Design Assistance and Demonstration
- Passive Commercial Building Data Base
- A Handbook: "The Design of Passive Commercial Buildings"
- Design Integration/Design Methodologies Research.

As lead technical experts for the DOE/PON, an innovative approach to a demonstration program was devised. This approach provided technical experts to review contractors' designs to ensure superior solutions, provide for complete documentation of the design process, and to initiate a data base on the topic. This data base is being used for a variety of National Program activities, including the writing of the advanced handbook "The Design of Passive Commercial Buildings" by SERI to be revised yearly. The data base is also showing the limitations of our knowledge on the topic and represents a very good indication of research that still remains to be done. SERI research in this area is concerned with the integration of daylighting and cooling components, and new architectural designs that simultaneously integrate the elements of architectural form, energy systems and building materials.

PROJECT TITLE: **INTERNATIONAL PROGRAMS**

Institution: *Solar Energy Research Institute*
Golden, Colorado

Principal Investigator: *Michael Holtz*

Task Number: *In-house*

The objective of this project is to further the state-of-the-art of passive design through participation in multilateral and bilateral International passive activities. The project presently consists of four activities: 1) U. S. – Italy Cooperative Agreement technical management; 2) NATO/CCMS Passive Applications Group Participation; 3) International Passive Cooling Working Group Participation; and 4) Survey of International Passive Research, Development and Demonstration Activities. The major FY 1980 accomplishments of each of these activities are listed below.

U. S. – Italy Cooperative Agreement in Passive Solar Applications

- Development of passive designs for two multifamily housing projects and one commercial office building
- Preparation of common methods of performance evaluation of these projects when constructed.

NATO/CCMS Passive Applications Group

- Construction of Standard Test Room for analysis of innovative passive heating systems
- Comparative analysis of four passive simulation computer programs
- Development of standard format for reporting performance data.

International Passive Cooling Working Group

- Co-chaired first meeting of working group that included preparation of regional monographs and position papers on state-of-the-art of passive coding.

International Survey of Passive R&D

- Prepared and mailed survey to passive researchers in over 100 countries (over 200 mailed)
- Developed computerized data base based upon over 250 responses
- Prepared preliminary report on results. Final report to be completed in January 1981.

PROJECT TITLE: **NATIONAL PROGRAM SUPPORT**

Institution: *Solar Energy Research Institute*
Golden, Colorado

Principal Investigator: *Michael Holtz*

Task Number: *In-house*

SERI has been designated by DOE as the lead technical support laboratory to the National Passive Program. In this role, SERI provides technical, planning and management assistance to many elements of the Passive Program. Major activities of this project are program planning, program coordination, and technical contract monitoring. The major FY 1980 accomplishments in each of these areas are listed below.

Program Planning

- Preparation of National Laboratory Multi-Year Plan. A coordinated set of plans from each of the National Laboratories involved in the Passive Program. (LASL, LBL, NBS, SERI, ORNL, Ames).
- Preparation of multi-year plans for selected elements of the National Passive Program including Performance Evaluation, Communications, Solar Cities, Products, and Manufactured Buildings.
- Participation in National Passive Program Steering Committee to guide project selection and implementation.
- Technical assistance to DOE branch chief and resource manager responsible for passive and hybrid building systems in legislation (proposed tax credits), regulation development (BEPS, RCS, etc.), and program implementation (RSEC coordination, RFP and PON preparation etc.).

Program Coordination

- Provision of national program coordination in manufactured buildings, performance evaluation, communications, market research, solar cities and commercial buildings. This involves technical assistance to DOE or SERI contracts, coordination with RSEC's and budget and planning support to DOE operations offices.
- Prepared technical chapters on passive systems as part of Solar Federal Buildings Program.

PROJECT TITLE:	**PARAMETRIC STUDIES**
Institution:	*Solar Energy Research Institute* *Golden, Colorado*
Principal Investigator:	*Craig Christensen*
Task Number:	*In-house*

The objective of the project is to study the appropriateness of various design guidelines and design tool assumptions. Parametric studies were performed using hour-by-hour simulation codes (i.e., DOE 2.1 and BLAST) to analyze prototypical building designs.

Heating and cooling loads as a function of residential window sizing and location for various levels of building mass, have been studied for several locations. Analysis has included consideration of internal gains, night setback, operable shading, ventilation, etc.

The sensitivity of heating loads to hourly profiles for internal gains has been studied for residential and commercal buildings. This addresses the definition of "skin-dominated" and "load dominated" buildings and the appropriateness of design tool assumptions.

PROJECT TITLE: **PASSIVE COMMUNICATION ACTIVITIES**

Institution: *Solar Energy Research Institute*
Golden, Colorado

Principal Investigator: *Dr. Floyd Shoemaker*

Task Number: *In-house*

The objective of this project is to design and conduct effective communication activities for the design professions, for the builders/developers, and for the potential residential and commercial users of passive solar energy systems.

The activities involved in this project have included the following:

- Preparation and publication of *Passive Design: It's a Natural* brochure for homeowners and potential homeowners
- Promotion and distribution of "Sunbuilders" film to national commercial TV stations and cable networks, to Regional Solar Energy Centers, to the DOE film library, and to various organizations
- Preparation and publication of a pilot issue of the Passive/Hybrid Research Journal in cooperation with the American Section of ISES
- Production of 275 release prints of "Sunbuilders" film for national distribution
- Preparation and publication of *A Sunbuilder's Primer* to accompany the film "Sunbuilders"
- Preparation of public service announcements on passive systems for distribution to 1000 radio stations
- Preparation of 90 second TV news spot on passive systems for distribution to 50 TV stations in major markets of the United States
- Preparation of selected articles on passive systems for publication in national magazines
- Preparation of a Passive Communication Plan.

PROJECT TITLE: **PASSIVE MARKET RESEARCH**

Institution: *Solar Energy Research Institute*
Golden, Colorado

Principal Investigator: *Peter Ketels*

Task Number: *In-house*

The general objective of this task is to provide market research direction to passive solar research that is either currently ongoing or planned. This effort is being coordinated with the regional solar energy centers to address regionally specific needs for market research information. The market research efforts are directed at both the consumer (demand side) and the residential building sector (supply side) of the economy.

The work is currently designed to measure awareness/acceptance levels of both of the market sectors. The market research effort is being conducted by Market Facts, Inc., under subcontract to SERI with guidance received from SERI and the regional solar energy centers.

To date research is directed to new home construction (consumer and builder) and to retrofit on existing housing stock.

PROJECT TITLE: **SIMULATION VALIDATION PROJECT**

Institution: *Solar Energy Research Institute*
Golden, Colorado

Principal Investigators: *Ron Judkoff, David Wortman*

Task Number: *In-house*

The objective of this task is to develop and execute procedures to validate building energy analysis simulation codes.

The work involved in the task in FY 1980 centered around two studies:

- Comparative study: In this study, building models are developed which can be both solved as the solution to mathematical equations, and also modeled using the simulation codes
- Analytical verification technique study: In this study, the same building model and weather data are used as input to each code. The output values of hourly zone temperatures and heating and cooling loads are compared and the differences are analyzed.

These studies and procedures discovered errors in several of the major building energy analysis codes. Included in these studies were SUNCAT, DOE 2.1, DEROB and BLAST.

These procedures are being applied to a wider range of codes, and further procedures, including empirical validation, are being developed.

PROJECT TITLE: **INFORMATION TRANSFER**

Institution: *Southern Solar Energy Center*
Atlanta, Georgia

Principal Contact: *Kal Turkia*

Contract Number: *In-house*

SSEC is promoting the commercialization of passive design techniques through two broad approaches: (1) creation of an awareness of solar alternatives and (2) provision of reliable information (case studies and workbooks) to help builders and designers select and build the most appropriate passive alternatives. A special information program is being groomed for the manufactured and mobile home industry.

This information project is being presented to several target groups through a variety of media, including pamphlets, notebooks, display booths, lectures, workshops, and newspapers. SSEC is interviewing target groups to determine their needs with respect to context and mode of delivery. SSEC is examining specific information requirements to locate areas requiring improvement and elaboration, specifically regarding climatic requirements of the south.

Southern Solar Energy Center display at National Association of Home Builders Annual Meeting, Las Vegas, January 1980. Modular components have been utilized at several Home and Garden Shows throughout the southeast.

This project's objectives include the following:

- Increase consumer awareness and demand for passive solar concepts
- Assist professionals with the design tools and knowledge required to handle passive systems
- Present the construction industry with working information on passive systems
- Support financial, governmental, and real estate personnel with the knowledge and tools to evaluate passive systems
- Establish SSEC as a reliable, supportive, and authoritative source of useful information for the Southern Region.

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*Spancrete Industries, Inc.* *Milwaukee, Wisconsin*
Principal Investigator:	*Robert Nagy*
Contract Number:	*DE-FC02-80CS30382*

Spancrete Industries of Milwaukee, Wisconsin, has been manufacturing and marketing concrete products since 1946. They have developed a variety of building systems to meet specific architectural needs.

The building model proposed by Spancrete Industries for passive solar design is the low-rise precast concrete "wall panel" system. This has widespread use throughout the country for warehouses, manufacturing buildings, office park complexes, and low to medium-rise apartments. Wall panel systems vary greatly in size, configuration, and appearance but are generally characterized by a repeating pattern of precast components, both for visual effect and economy.

Spancrete Industries believes there is a promising market for passive solar precast concrete building systems. The cost of these buildings is more closely related to the cost of fabrication and erection than the cost of materials (such as concrete and reinforcing steel). Therefore, the cost of increasing the thermal mass in some portions of a building should be a negligible additional expense. The other costs associated with passive solar systems can then be justified on the basis of energy conserved over the first several seasons of operation.

Design Approach

Considerations in the design approach of manufactured buildings include the market implications of size and configuration limitations, manufacturing feasibility, shipping and erection, and economies of mass production. Spancrete Industries adds to these design processes energy conservation and passive solar techniques. Energy concerns will be introduced early in schematic design conceptualization. There will be continual testing of design choices.

Design methodologies planned by Spancrete Industries include:

- Collecting hourly data from weather tapes, with simultaneity of wind, temperature, and humidity
- Identifying major passive design strategies from climatic analyses
- Using hand calculator procedures to analyze building energy requirements of schematic alternatives by dynamic simulation
- Analyzing three-dimensional model forms of various subcomponents (e.g., for natural lighting or ventilation effects).

PROJECT TITLE: **PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**

Institution: *Structures Unlimited, Inc.*
Manchester, New Hampshire

Principal Investigator: *Bruce Keller*

Contract Number: *DE-FC02-80CS30383*

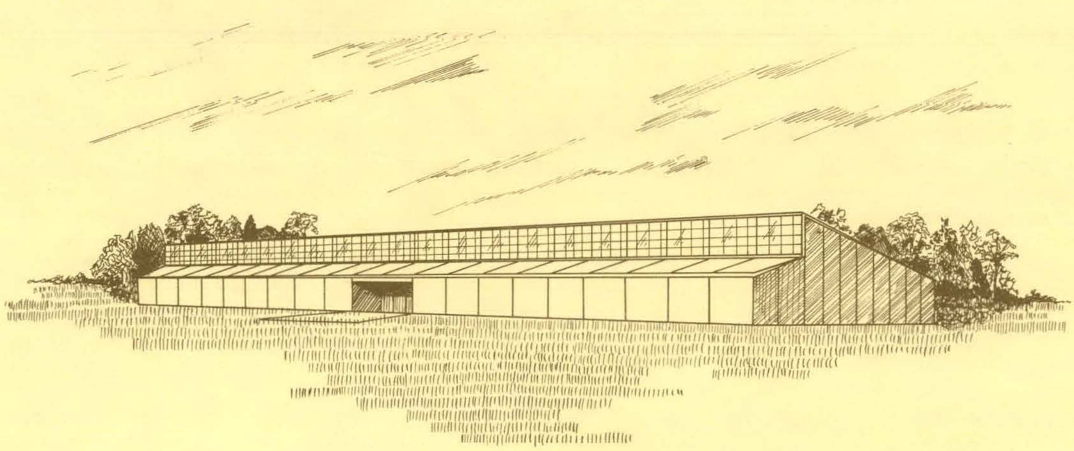
Structures Unlimited, Inc. is a component of the Keller Group of Companies. The Keller Group of Manchester, New Hampshire, consists of 10 companies which have 16 different diversified divisions. They are manufacturers and distributors of specialty building material products, including the solar heating industry.

Structures Unlimited, Inc. is proposing two basic conceptual changes to their standard building: modification of the building configuration and the addition of thermal mass. The building will be designed to meet all climate and site conditions with minimum changes. The company's overall goal will be to design a building with the widest applicability while benefiting from the economics of large-scale production of repeatable units.

Design Approach

The design process will involve a cost/performance analysis of alternative passive solar features considering building form, function, and fail-safe criterion. The building must function as a highly energy-conserving structure for the anticipated markets. With fuel shortages and electrical failures being current realities, the design will also address provisions for natural daylighting and thermal storage. The building envelope will be insulated to meet the latest national energy conservation standards. Heat loss due to infiltration will be minimized by use of entry way air locks. Attention will be paid to adequate weatherstripping of doors, windows, and loading dock entrances. Vision and vent windows will be double glazed with thermally broken sashes. Foundation and floor slab design drawings will indicate adequate perimeter insulation. Potential fall and spring overheating will be prevented by roof and clerestory overhanging shading, operable wall or roof vents, and possible moving roof sections. Glazing heat losses will be minimized by using multiple-layered glazing panels. Summer cooling requirements will be handled by natural ventilation.

These buildings have been used as recreational facilities, municipal natatoriums and hotel/motel activity centers, garden atriums, clean and waste water treatment plants requiring passive light and heat energy, and commercial/industrial facilities.



PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Sunbelt Communications, Ltd.* *Albuquerque, New Mexico*
Principal Investigator:	*Larry H. Kirby, Gen. Mgr.*
Contract Number:	*DE-FC02-80CS30355*

Sunbelt Communications is a radio broadcasting company incorporated under the laws of the State of New Mexico. They propose to design and construct a new building of 6,500 square feet which will contain two radio stations. The radio stations require offices, production and control rooms; and ancillary spaces such as lounge, conference, and restrooms for 35 to 40 people. Sound isolation will be required throughout, combined with visual connections in some areas. The proposed design is to be compact, with individual offices surrounding communal areas and production and control rooms on a mezzanine level for visibility.

Design Team

- Project Manager – Channell Graham Architect, AIA, PE
- Solar Consultant – Bickle/CM
- Mechanical Consultant – Walker Brown Engineering, Inc.
- Electronic Systems Consultant – E/E' 2000 Engineering, Inc.
- Structural Engineer/Cost Estimator – W. R. Underwood, Jr.

Design Approach

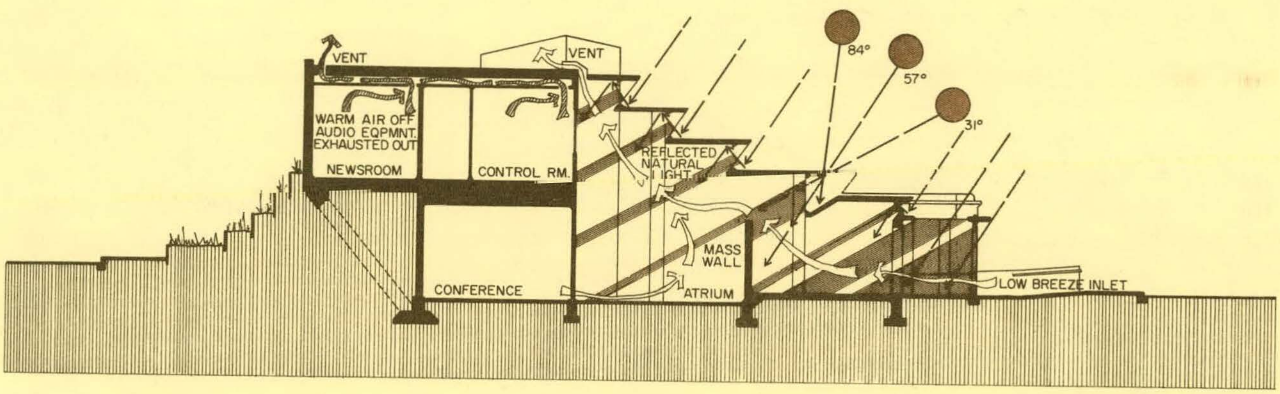
The design approach will pursue an integration of four fundamental goals to:

- Provide an interesting and comfortable working environment for employees of the radio stations in terms of sensual stimulation, social atmosphere, and user-building interactions
- Produce an efficient and economic structure in terms of activity arrangements and building morphology
- Make passive solar technology a primary design element, so that building forms and details are related to the natural materials, climate, and sunlight of the site and region
- Produce a radio station package that expresses modern mass communications technology and Northern New Mexico regionalism, through a balance of functional planning and sensitive response to site and climate

The design will consider utilization of various passive solar thermal control systems such as:

- Solar greenhouse (isolated gain)
- Roof-radiating heat sink (indirect gain)
- Heat sink floors and walls
- Natural convection air circulation

- Induced ventilation via solar chimney
- Water pools and vegetation to add humidity
- Night sky radiation
- Summer shade devices.



Evaluation

Evaluation of this facility will be based on visual inspection of the components to determine their long-term survivability/maintenance behavior. In addition, separate electric meters will be installed on the major components such as lighting system and heating system to measure energy consumption by major end use.

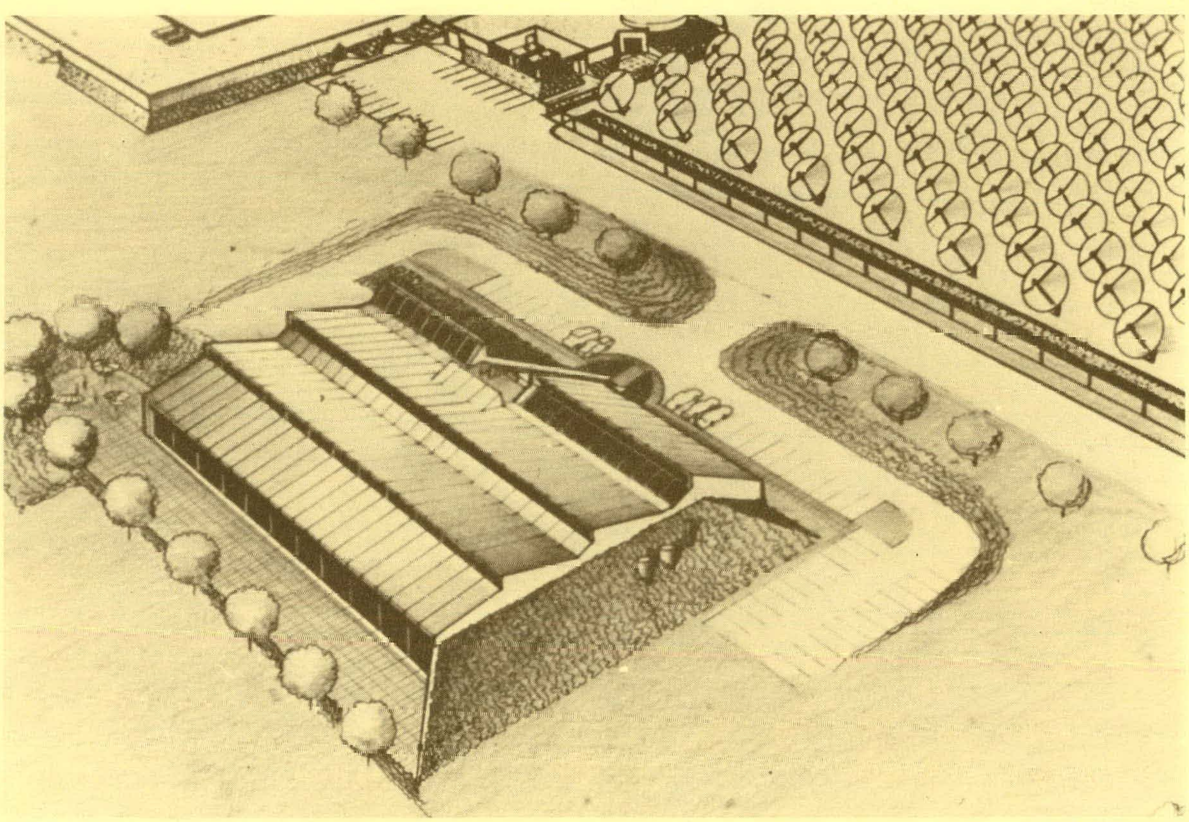
PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *Sunflower Solar, Inc.*
College Park, Georgia

Principal Investigator: *Wayne Robertson*

Contract Number: *DE-FC02-80CS30356*

Sunflower Solar, Inc., plans an application of solar heating and cooling for an essentially underground industrial plant, except for the north entrance truck accesss and a south wall devoted totally to providing solar heating and natural light. A concrete roof and high-beamed east and west wall provide a desirable thermal mass. The 40,000 sq. ft. energy conservation building will require very low Btu/ft.^{2} annually. It is anticipated that 100 percent of the heating and cooling energy can be supplied by the passive south wall design and by waste energy from an adjacent DOE Solar Total Energy Project (STEP). Complementary flat plate solar collectors will provide heating energy during periods when STEP is not in operation. Natural gas standby will be available for extensive adverse climatic conditions.



The building will be located in Shenandoah, Georgia, south of Atlanta. The building will be of masonry and steel construction. The east and west walls will be beamed to the roof height, estimated at 14 feet. The beam will have a 30° angle of repose and may contain cooling tubes for passive cooling capability.

The unique aspect of the Sunflower Solar, Inc., proposal is the integration of its building with the world's largest solar total energy plan, both architecturally and in an energy-conservation manner.

The DOE Solar Total Energy Project (STEP) is on an adjacent 5 acres. STEP is an experimental project that produces 400 KWs, 1,340 pounds per hour process steam and 173 tons of air conditioning for a 25,000 sq. ft. facility that manufactures high-fashion knitwear. STEP excess energy will be piped as hot water from the DOE facility to the Sunflower Solar plant and stored in one or more tanks. From these tanks, energy could be used to provide backup heat to the passive solar heated manufacturing area. The tank would also provide the thermal source for heating and absorption air conditioning for the 2000 sq. ft. administration area.

Design Team

- Architect – Sizemore/Floyd of Atlanta, Georgia

- Solar Design and Engineering – Edward Ney, Site Project Integrator for the Georgia Power Company/DOE Solar Total Energy – Large Scale Experiment at Shenandoah; Bradley Cruickshank, Senior Vice-President of Community Relations, Shenandoah Development, Inc.

Design Approach

The goal of the schematic design is the development of a baseline with an integral solar approach. Trade-off studies between performance and cost will be performed on critical design parameters. Upon completion of the trade-off studies, a total building/system simulation will be run.

Design Tools

A full range of design tools will be used throughout the design process. The methodology will rely heavily upon computer simulation, especially in the critical trade-off studies of design development. The passive solar performance program will be tied to the Georgia Power Company computer.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Syracuse Research Corporation, Onondaga Community College Energy Research Center, Syracuse, New York*
Principal Investigator:	*Clyde H. Beigh*
Contract Number:	*DE-FC02-80CS30357*

The initial phase of this project will result in the design plans of a passively solar-heated energy conservation education center. The facility will be located on the Onondaga Community Campus in New York and will be used by students, as well as by members of the public at large. This facility will be designed to house classrooms, laboratories, demonstration areas, and conference rooms. It will be the subject of ongoing experimental work, testing, and analysis.

Design Team

- Project Manager – Syracuse Research Corporation will manage the project and be responsible for the design and documentation.
- Architect – Curtin, Gere, and Ashley
- Solar Consultants – Berkeley Solar Group and Total Environmental Action of Harrisville, New Hampshire.

Design Approach

The proposed building design will combine many existing energy conservation strategies and some new concepts to create a prototype design which will almost totally eliminate the use of fuel or electricity for heating and substantially reduce the need for electric lighting inside during the day. The basic design will use south-facing windows and solar-light roof monitors as a primary heat source. The design will also eliminate the need for artificial light during the day time. In addition, a greenhouse-type south wall is proposed that would be allowed to cool at night with excess heat removed to a storage bed.

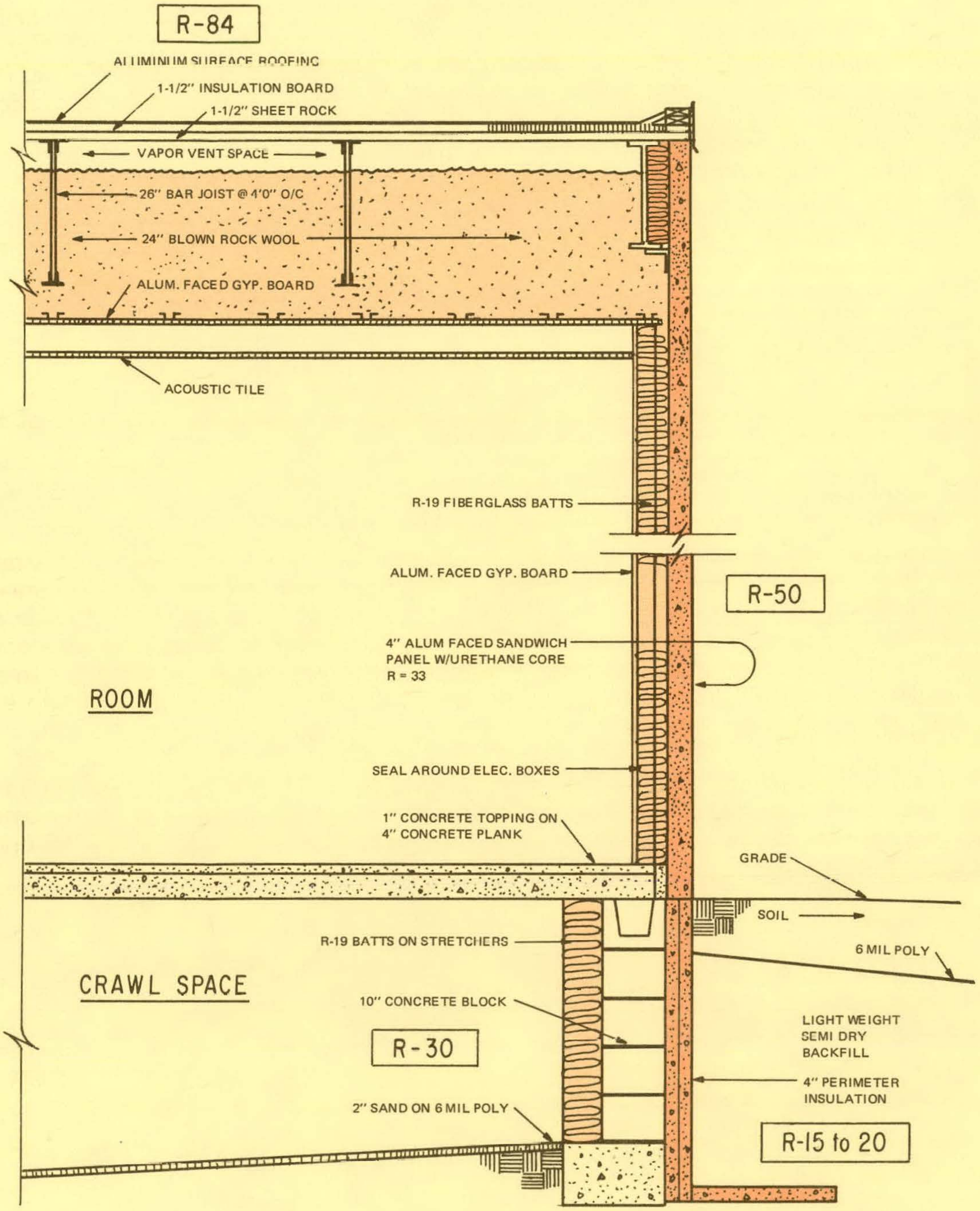
The building will be compact with two stories on the south side and a berm of earth on the north side. Special attention will be devoted to insulation values to allow close to a balance between heat loss and heat gain for the worst winter months' average temperature in Central New York, which is about 20°F in January.

Design Tools

- Syracuse Research Corporation believes that the most efficient design tool is "sound engineering practice and architectural design insights borne of experience"
- The Berkeley Solar Group will employ the NBSGLD program modified to analyze details of the proposed design and perform cost-benefit analyses.

Evaluation

It is anticipated that this structure will use only a small fraction of the energy required by similar traditional structures. A rather comprehensive system of monitoring the building will be instituted. This will make possible the operation of a common system for collecting microclimate and building performance data so that comparative analyses can be validated in detail. Also, the monitoring system will be used as a research tool for educational purposes. A sensor system will provide necessary information to control the building's systems to maximize energy performance while maintaining creative comfort.



TYPICAL WALL SECTION

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIALIZATION**
Institution:	*State of California* *Sacramento, California*
Principal Investigator:	*Jerry Yudelson*
Contract Numbers:	*DE-AC02-79CS30245 and DE-AC02-79CS30246*

A solar commercialization handbook will be developed which summarizes efforts in California to promote increased solar utilization. This handbook will analyze the most effective programs of state and local government agencies, solar industry, lenders, builders, and legislative bodies. California has pioneered a number of approaches to solar commercialization, many of which are not widely publicized, and have never been presented in one publication for other state, regional, or local solar energy agencies or groups. The handbook will analyze proven and effective techniques in 10 areas of solar commercialization. Current legislative program initiatives will be summarized in each of those areas, with suggestions for a variety of state-level approaches to increase solar utilization.

The Contractor will also develop an awards program for homebuilders who use solar energy systems in tract developments, a homebuilder's assistance program, and prepare a program to promote the use of passive solar water heaters.

The deliverables from this project will involve two items:

- A handbook which provides suggestions for a variety of state-level approaches to promote solar utilization
- A final report of a model program on the state level for passive solar commercialization programs.

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGNS ASSISTANCE AND DEMONSTRATION**

Institution: *Plato Touliatos*
Memphis, Tennessee

Principal Investigator: *Plato Touliatos*

Contract Number: *DE-FC02-80CS30359*

Plato Touliatos is a forestry graduate from Louisiana State University. He has worked for the United States Forest Service and is presently a nurseryman and businessman in Memphis, Tennessee. He is currently president of the Tennessee Nurseryman Association.

The proposed building type will be a passive solar greenhouse with decaying organic matter heating backup. This system, known as "Solganic Greenhouse," was designed and built by Plato Touliatos in 1977, 1978, and 1979. Heat from organic matter is released through aerobic bacterial action. The biomass used is wood chips and shavings. The objective of a new Solganic Greenhouse type is to improve the design and make it practical for off-the-shelf purchases by greenhouse owners.

Design Team

- Owner – Plato Touliatos
- Architect and solar designer – Gary Copeland
- Builder and solar specialist – Chip Crager.

Design Approach

The design team will concentrate on materials that lean toward monolithic construction while creating thermal mass, exterior insulation, favorable economics, and a desirable growing and retailing space.

The design team will investigate the following solar considerations:

- Plenum space between organic bin and greenhouse space
- Need for increased summer light levels without need for extra summer heat
- Need for drains in organic bins
- Need for an efficient low cost night closing system
- More air and water to organic bin
- Thermal mass should be exposed to sun.

Evaluation

The major method to evaluate the performance of a greenhouse is by the condition of the plants and by the diurnal temperature fluctuations during the hottest and coldest part of the year. Temperatures, relative humidity, and carbon dioxide levels will be measured daily; temperature of the organic matter, pH of the organic matter, nitrogen-level moisture content of organic matter, and oxygen levels in the organic matter will be measured weekly. Other information needed to properly analyze the performance of the greenhouse is the daily temperature of the thermal mass, the quantity of wood burned each day, and its moisture content.

PROJECT TITLE: **DEVELOPMENT OF A HIGH EFFICIENCY VAPOR COMPRESSION DEHUMIDIFIER**

Institution: *Trinity University*
San Antonio, Texas

Principal Investigator: *Earl Doderer*

Contract Number: *DE-FC03-80SF11505*

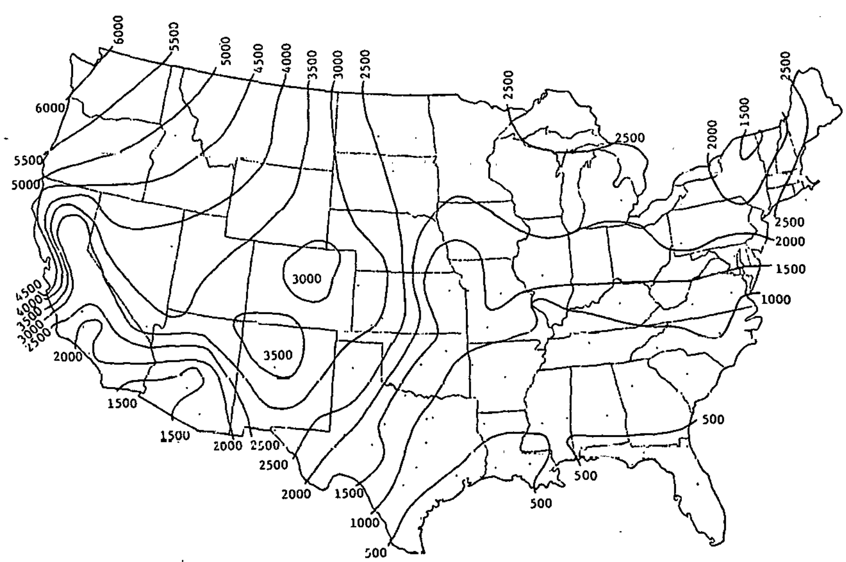
Simulations of several passive cooling techniques indicate significant potential for providing human comfort in hot arid regions and for providing reduction of sensible cooling loads in hot humid regions. There is a need, however, to provide low-energy consumption dehumidification in the humid regions in order to provide human comfort.

Trinity University will attempt to develop and commercialize such a low-energy, high efficiency vapor compression dehumidifier. The objective is to maximize condensation while minimizing air cooling, through combination with an integrated air to air heat exchanger. Thus the passive system could handle the sensible cooling load, allowing for use of a drastically down-sized, load-optimized vapor compression unit for low-cost dehumidification.

PROJECT TITLE:	**EVAPORATIVE, RADIATIVE AND CONVECTIVE COOLING PROCESSES AND SYSTEMS**
Institution:	*Trinity University San Antonio, Texas*
Principal Investigators:	*E. E. Clark and C. H. Treat*
Contract Number:	*DE-AC03-77CS31600*

An alternative to active solar air conditioning is the use of nocturnal air and sky directly as heat sinks instead of interposing a heat-driven cooling device. This passive air conditioning depends on some combination of three natural cooling processes: evaporation, nocturnal air convection, and infrared radiation into the night sky. Natural cooling processes were widely applied before the relatively recent advent of mechanical air conditioners. Passive cooling processes are of special interest to architects because the relatively small temperature differences and cooling rates available require large heat-transfer areas. When cooling is only available at night, then thermal storage is required. In new buildings, a cost-effective solution is to use elements of the building (roof, ceiling, floor slab, and walls) as thermal storage and heat-transfer components in the passive cooling system. From this viewpoint, the building becomes a heat dissipation and storage system which allows controlled thermal coupling to the environment. When the environment is thermally helpful, the interior should be closely coupled to the exterior.

In this project, Trinity University assessed the regional potential for cooling by various combinations of convection, nocturnal radiation, and evaporation. Environmental parameters critical to those passive cooling processes and residential cooling loads were used to define climate regions. Regional charts of the average monthly cooling rates for various surface designs and for a narrow range of temperatures centered near the average wet bulb temperature were compiled from the predicted passive cooling data. The most promising processes were later adapted to two residences in the San Antonio, Texas, area for monitoring.



TYPICAL JULY NOCTURNAL NET COOLING RATE FOR EXPOSED HORIZONTAL WET SURFACE AT 76°F (BTU FT^{-2} DAY^{-1})
(77 CITY HOURLY DATA BASE. SURFACE IS PERFECTLY INSULATED WHENEVER IT CANNOT DISSIPATE HEAT.)

PROJECT TITLE: **PASSIVE TEST FACILITY**

Institution: *Trinity University*

Principal Investigator: *Earl Doderer*

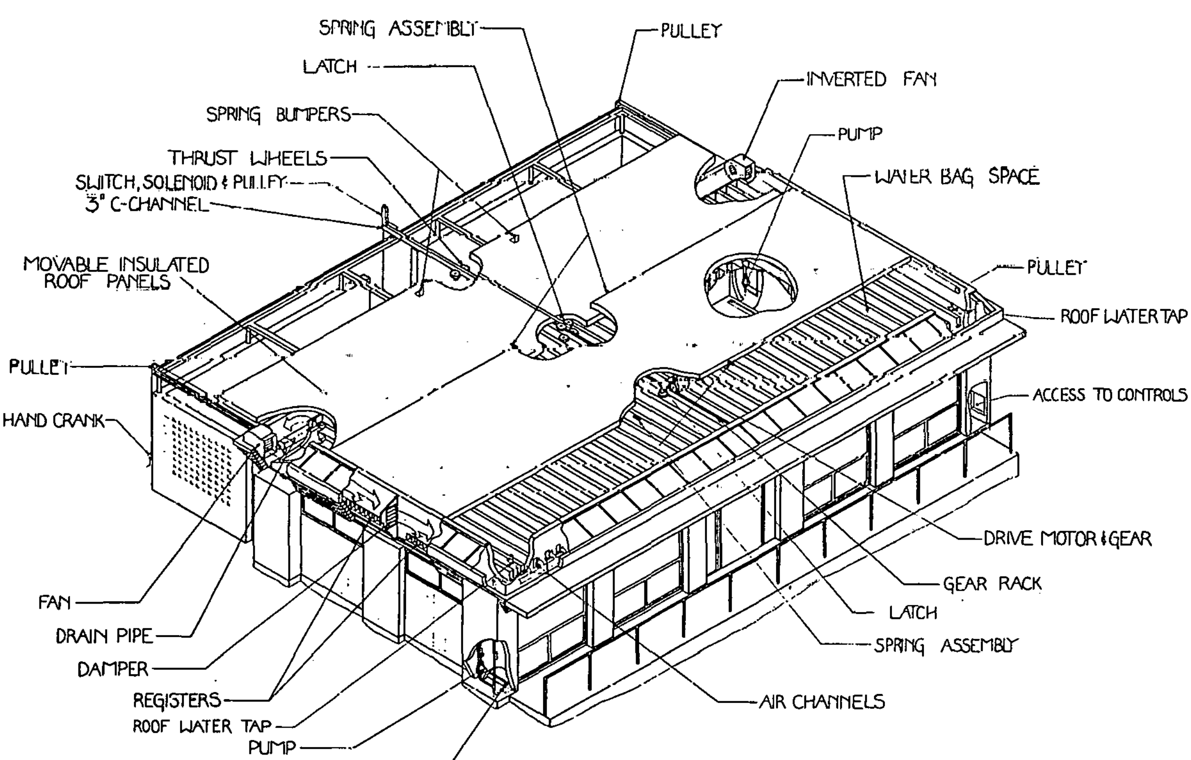
Contract Number: *DE-AC03-79CS30201*

The negligible operating costs and intrinsic simplicity of passive systems suggest a potential for low-cost displacement of fossil fuels, not only for residences but commercial buildings. However, there are barriers that must be overcome before these advantages of passive systems can be realized commercially. The fundamental heat-transfer rates inside passively heated and cooled structures and between the heating and cooling surfaces and the environment cannot be predicted with precision. To a large extent, these uncertainties are due to the effects of scale factors on heat-transfer coefficients. Only accurate measurements made on full-scale structures can resolve these issues.

Trinity University is undertaking a research, design, development, and performance monitoring project that will remove many of the thermal performance uncertainties and will study the cost, durability, and maintenance issues. The principal objectives of this project will be to establish accurate values of empirical heat-transfer relations for passively heated and cooled structures and to validate computer programs that simulate the performance of these structures in any climate and estimate supplemental heating and cooling requirements.

The four contract objectives of this project includes the following:

- Assess the regional typical year cooling rates from a horizontal surface due to convection, radiation, and evaporation; that is:



- Develop a new empirical model for nocturnal radiative cooling based on observations of atmospheric radiation, cloud cover, ambient dry bulb, and dewpoint temperatures

- Define critical environmental parameters for the prediction of passive cooling processes

- Construct an hourly, typical cooling season (April/September) data base for regions and subregions

- Predict regional cooling rates for each range of cooling surface temperatures

● Simulate regional monthly cooling loads for two standard residences using hourly data; that is:

  - Define two standard residences, a high thermal mass roof pond residence and a well-insulated typical tract house

  - Simulate the hourly cooling loads

● Assess the regional potential for convective and radiative cooling from tilted, glass and plastic, glazed and unglazed, and flat plate collectors

● Assess the regional feasibility of passive cooling of these standard residences using the process described

One major task will be to identify the most cost-effective passive heating/cooling system for residences in central Texas. This system will be installed in two residences to be constructed as adjacent halves of a duplex with 1,600 sq. ft. of living space. The two residences will be instrumented in sufficient detail to permit independent evaluation of the various heat-transfer processes operating on the elements of the residences.

Meteorological conditions will be monitored at the envelope of the two residences and at a neighboring DOE solar-meteorological research site. One minute averages of more than 30 solar-meteorological parameters will be recorded. DOE/LBL also operates a spectral infrared radiometer at this same site. These facilities offer a unique opportunity to establish the relationship between passive heating/cooling performances and meteorological conditions. Personnel assigned to this project have extensive experience with sensor and data acquisition system calibration and data quality-control procedures which are required to assure the accuracy essential to successful completion of project objectives.

Paralleling the design phase of the two residences, Trinity University plans a series of thermal experiments using a pair of instrumented water ponds. These ponds will serve as a preliminary source of validation for the simulated performance of a variety of passive cooling system designs.

Successful passive cooling of residences in the subtropical marine climate of San Antonio, Texas, will serve as a demonstration of passive cooling feasibility in those regions which are responsible for the majority of America's residential cooling energy use. By artificially increasing the internal load in one of the residences, Trinity University hopes to validate previous simulations which indicate the previous cooling will be practical in commercial applications.

PROJECT TITLE:	**THERMAL MODELING OF EARTH CONTACT STRUCTURES**
Institution:	*Underground Space Center, University of Minnesota Minneapolis, Minnesota*
Principal Investigator:	*Thomas Bligh and George Meixel, Jr.*
Contract Number:	*DE-AC03-80SF11508*

The primary goal of this project is to develop a detailed three dimensional heat flow computer program for conductive transfer through the ground in the vicinity of buildings. The model will be validated by experimentally measuring the temperature field near earth contact structures under a variety of surface boundary conditions. This effort will lead to the development of a subroutine capable of being implemented with a public domain building thermal analysis program such as DOE-2 or BLAST. Sensitivity studies will be performed for several building types in a variety of climates, and design guidelines will be developed along with a number of specific earth-integrated building designs.

PROJECT TITLE: **PASSIVE COOLING BY NATURAL VENTILATION**

Institution: *University of Central Florida Cape Canaveral, Florida*

Principal Investigator: *Subrato Chandra, Phillip Fairey*

Contract Number: *DE-AC03-80SF11510*

This contract provides for the monitoring of six buildings in order to determine ventilation rates by the SF_6 tracer gas decay technique as a function of external wind speed/direction. This in turn will allow the quantitative assessment of naturally ventilated residential and small commercial buildings, and the determination of aerodynamic flowfields ventilation rates, room heat transfer coefficients, comfort levels, and building energy use for a variety of aperture geometries and design strategies.

Further, FSEC will design five prototype building models, with reconfigurable apertures of traditional and innovative designs, and prepare a test plan to test models in the Colorado State University meteorological wind tunnel.

In Phase II, FSEC will test the models to determine flowfields, boundary conditions, and room convective heat transfer coefficients. Finally, test results will be correlated into a BLAST compatible subroutine and a design handbook will be published.

PROJECT TITLE:	**DEVELOPMENT OF PASSIVE DESIGN CURRICULA FOR PROFESSIONAL SCHOOLS OF ARCHITECTURE**
Institution:	*University of Pennsylvania* *Philadelphia, Pennsylvania*
Principal Investigator:	*Dr. Donald Prowler*
Contract Number:	*DE-AC02-79CS30241*

The overall objective of this project is to establish a passive solar design curriculum package that is adaptable to the varying needs of Schools of Architecture throughout the country. The approach to developing, implementing, and evaluating this project is segmented into three tasks: Task One identifies existing curriculum packages, based on the areas of study needing clarification and development and the nature of ongoing work.

Task Two identifies and subcontracts with other educational institutions to develop specific curriculum elements based upon their specialized knowledge. These subcontracts will be negotiated to produce educational materials and methods for numerous passive solar subjects such as:

- Basic heat transfer for architects
- Thermal programming and load analysis
- Site and climate
- Historic reinterpretation
- Passive standards
- Calculation procedures
- Labs/test cells
- Daylighting
- Postoccupancy evaluation and actual energy use
- Allied curriculum.

Parallel to the subcontract effort, the contractor will conduct an investigation of passive design considerations into the traditional studio structure. Examples which could be followed are:

- A semester studio with 6 weeks devoted to a thermally light building and 6 weeks to a thermally more complex structure (a common approach in schools which offer "energy studios")
- A series of six one-week sketch problems of different building types where a preliminary passive evaluation can be made to acquaint the student with a wide variety of issues, followed by an in-depth six-week problem
- A studio which is integrated with a course where two weeks of intense classroom work is followed by two weeks of design and iterated for three building types over the semester
- The traditional nonenergy studio into which curriculum packages are woven to encourage a heightened energy awareness.

The studios developed would be tested in an actual setting where student reaction and feedback shall be sought. Studio problems will be documented with architectural program, outlines, procedures, and techniques that can be used as education aids.

Task Three involves an outreach program aimed at a number of educational institutions which will adopt and assess the effectiveness of the curriculum. Based on positive results, the course and studio materials will be distributed to accredited schools of architecture in the U. S. on a free or minimum cost basis.

PROJECT TITLE: **ELEMENTARY SCHOOL SOLAR CURRICULUM**

Institution: *University of Southern California*
Los Angeles, California

Principal Investigator: *Seymour Lampert*

Contract Number: *EY-76-S-03-0113*

The University of Southern California in conjunction with the Jet Propulsion Laboratory has developed a solar curriculum to teach students in grades K through 6 about the potential power of the sun. Funded by DOE, the curriculum is being field tested across the country in the 1980–81 school year. The curriculum contains teacher lesson plans, student worksheets and suggested projects, such as constructing solar hot dog cookers and planning and building a solar city. The curriculum is designed to accommodate those students who read poorly or use English as a second language.

The curriculum was initiated in 1977 when 21 elementary school teachers from Southern California met together to develop a solar curriculum. The group divided the program into six areas: energy and its effect on life; the sun and light; measuring energy; energy and society; the social, political, and environmental aspects of solar energy; and the scientific method. In addition to disseminating the curriculum through the field test, in-service training workshops are being conducted to show teachers how to use the curriculum.

PROJECT TITLE: **DEROB DEVELOPMENT**

Institution: *The University of Texas*
Austin, Texas

Principal Investigator: *Francisco Arumi-Noe*

Contract Number: *DE-AC02-80CS30254*

The objective of this project is to put a computer program capable of simulating the thermal performance of architectural structures in the public domain. The program should: be capable of describing the complexity of real architectural configurations, answer trade-off questions that need to be answered during the design process, be physically validated and be user tested.

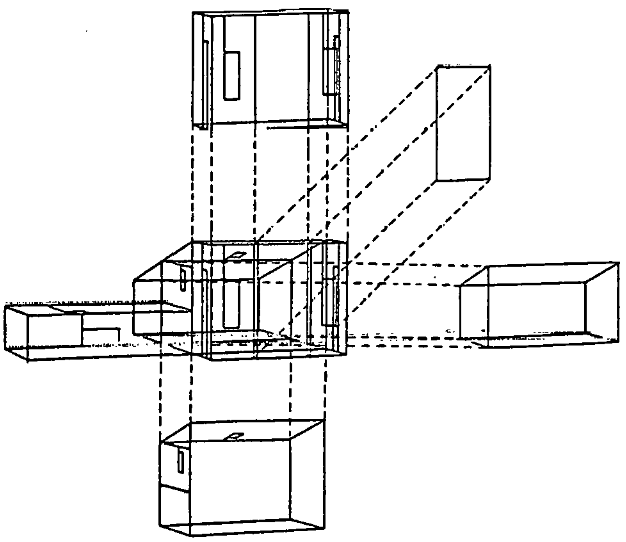
Background

DEROB (Dynamic Energy Response of Buildings) was originally conceived and developed in 1971–1972 as an educational aid for students in Architecture. From 1972 through 1977 a number of auxiliary programs evolved to handle the kinds of questions architecture faculty and students asked. These included solar rights analysis, daylighting, specular reflection and shadowing analysis, solar control design, and the ancillary graphics capability. During these years, however, there was no physical validation of the accuracy of the program, for at the time there was no good data available. In 1978 the Department of Energy (DOE) provided a grant to test and develop DEROB further. By this time the empirical projects at the Los Alamos Scientific Laboratory (LASL) had started to accumulate highly detailed data collected in occupied residences and controlled test rooms. Thus the physical validity of the programs could be tested and development, in response to the tests carried out, could be continued.

During the period of the DOE grants, the accomplishments have included the successful simulation of ten separate passive solar structures; the casting of the thermal solution of the program in an R-C representation; and the alteration of the R-C representation to reduce computational memory and time requirements. A number of discrepancies with the program have been identified. Most have been minor and readily corrected while others have required more extensive reprogramming.

Work is underway to develop more appropriate efficient algorithms to more accurately simulate thermal performance. These activities include:

- validation of empirical data
- development of better mathematical formulae
- improving and expanding computer "through-put" efficiency.



DEROB Model of the Hunn House

Longer range objectives encompass the integration of comfort index calculations, phase change materials and solar rights analysis by 1982 and the integration of thermal diodes and a data management program by 1983.

PROJECT TITLE:	**PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**
Institution:	*Walker Field, Colorado, Public Airport Authority Grand Junction, Colorado*
Principal Investigator:	*Paul D. Bowers, Asst. Mgr.*
Contract Number:	*DE-FC02-80CS30360*

Walker Field Airport in Grand Junction, Colorado, plans a new terminal building. The size will be approximately 45,000 sq. ft. The terminal will be divided into two major areas: public areas that are not revenue-generating and commercial, or revenue-generating space. The public areas will be 20,000 sq. ft., while the commercial space will be 25,000 sq. ft. Grand Junction is the largest city between Denver and Salt Lake City and is the major center in the Colorado Rockies for winter sports and summer vacationing.

Winter temperatures at Grand Junction rarely fall below zero. Weather extremes are both infrequent and of short duration. Grand Junction is surrounded by mountains which rise to 12,000 feet elevation. Summer temperatures often range from low 70s to the mid 90s.

The solar radiation data base for Grand Junction is the most extensive for any site in Colorado. The National Weather Service has recorded solar data for 30 years at Walker Field.

Design Team

- Architectural – Chambliss/Jenkins Associates is an architectural planning firm located in Grand Junction, Colorado
- Solar Architects – Jan F. Kreider & Associates of Boulder, Colorado.

Design Approach

The design approach for the Walker Field terminal will follow standard architectural practices set forth by the American Institute of Architects. In addition to basic engineering services, solar and landscape architecture will be needed. At the schematic design level, several passive solar systems will be identified. An economic assessment of each system will be made for the purpose of selecting the most desirable. As more detailed models are needed to assess relative economic viability, computer codes will be prepared. These will use the solar load ratio method developed at Los Alamos Scientific Laboratory to predict monthly performance of passive solar systems of the direct gain and indirect gain.

A request will be made to have a National Solar Data Network (NSDN) monitor installed at the site. This network established by IBM for DOE consists of sensors that monitor key solar performance parameters automatically. Monthly performance reports are filed with DOE and are (upon request) available to the public. With the broad cross-section of people exposed to the Walker Field Airport, many queries about performance are anticipated. The high-quality data of the NSDN will lend credibility to the entire project.

PROJECT TITLE:	**ALTERNATIVE STRATEGIES FOR WORKING CAPITAL**
Institution:	*Western Solar Utilization Network* *Portland, Oregon*
Principal Contact:	*William Davis*
Contract Number:	*In-house*

The objective of this project is to investigate, evaluate, and propose unique sources of equity working capital in response to the numerous requests received by the center from undercapitalized solar businesses, and to provide business development assistance to solar firms.

The project workscope includes investigating a variety of unique sources of equity and working capital for solar businesses. Research involves interviews with such sources as SBICs, venture capital firms, BIDCOs, SBA offices, SBDCs, banks, savings and loans, and insurance companies. A prescreening program will be designed to match solar businesses requesting help with venture capital sources.

For outlying areas, Western SUN will make specialists available to businesses requesting assistance for business plan review, financial analysis, production and market entry. Emphasis will be placed on using these consultants in the preparation of business plans for solar firms. The target audiences for this work are solar firms, contractors, financial and lending institutions, venture capitalists, and consulting and professional organizations.

The deliverable items resulting from the project will be a referral service for solar firms, venture capitalists, and lenders; a solar business prescreening process; and professional business consultations and planning documents.

PROJECT TITLE:	**INFORMATION/OUTREACH PROGRAM**
Institution:	*Western Solar Utilization Network* *Portland, Oregon*
Principal Contact:	*William Davis*
Contract Number:	*In-house*

Western SUN is developing capabilities to provide information to the general public and to specific target audiences interested in all aspects of solar energy. As a major part of their mission, Western SUN views the efficient and effective response to public inquiries as a clear priority to be met by the establishment of internal resources and highly visible public programs. Western SUN is acquiring extensive library resource materials, both print and nonprint media, available as reference materials and in some cases for loan. A complete audiovisual collection is being assembled for both staff and public use. Copies of books and supportive brochures, films and publications are available to the 14 State Solar Offices (SSO) in the SEIDB terminals for further access current information for a variety of audiences.

Western SUN plans to make widespread use of public media to convey general facts about solar energy and its specific applications in operation today to prime market areas. Professional campaigns will focus initially on solar water heating for domestic and commercial uses, residential passive solar designs, and the availability of state and federal tax incentives for solar installations. The campaigns will simultaneously use television, radio, and printed materials. No endorsement will be made of individual designs, manufacturers, retailers, distributors, or brand names. Future campaigns will be structured according to commercially viable technologies and tailored to specific subregions of the West. This work will involve the following tasks:

- Support national, regional and local solar conferences and workshops that meet Western SUN goals and priorities for outreach programs
- Provide technical assistance and information referrals through use of the SEIDB
- Build solar resource capabilities within existing local libraries
- Prepare a comprehensive publication describing and illustrating low-cost, portable solar retrofit options for renters
- Meet local outreach needs as expressed through SSO and through direct requests for support by disseminating basic solar information to the general public.

PROJECT TITLE: **STATE SPECIAL PROJECTS**

Institution: *Western Solar Utilization Network Portland, Oregon*

Principal Contact: *William Davis*

Contract Number: *In-house*

There are 14 State Solar Offices (SSO) in the 13-state region of Western SUN, California having two. These SSO's serve Western SUN as centers for collecting and disseminating solar information. Each state also has a Solar Advisory Group (SAG) composed of representatives from diverse backgrounds and dedicated to assuring the widest possible use of renewable energy sources. The SAGs are routinely used by the SSO to set project priorities and areas of emphasis for Western SUN. SAG's recommended activities for which special funds could most appropriately be spent are training, education, and support to local solar energy associations.

The ability of each state to respond to local needs insures that Western SUN's projects will reflect the current solar commercialization requirements of the states, as well as serve to expand the national commercialization effort.

Projects to be funded under this program include the following:

- $500 in Washington State to sponsor a 2-day solar information workshop for 30 King County librarians in Seattle
- $400 in Idaho for the developing and printing a series of 10 fact sheets about solar applications for farms and dairies
- $2,500 in Alaska to support the first renewable energy conference ever held in the state
- $800 in Colorado to design and construct an information display highlighting Western SUN renewable energy programs in that state; with additional funds, this display will be shown at county state fairs and will be staffed by members of local solar energy associations.

PROJECT TITLE: **SYSTEMS DEVELOPMENT**

Institution: *Western Solar Utilization Network*
Portland, Oregon

Principal Contact: *William Davis*

Contract Number: *In-house*

Western SUN's systems development project consists of two primary activities:

- *Performance Monitoring* – Instrumentation package will be designed and installed to monitor low-cost passive systems. Design of the monitoring equipment will emphasize ease of installation, removal, and reusability.

- *Stimulation of Market* – A design competition will be sponsored focusing on those states that currently have an insufficient number of passive installations. The competition will select for award outstanding designs that display pragmatic and cost-efficient passive heating and cooling techniques.

In cooperation with DOE and SERI, Western SUN will actively participate in the planning and operation of the Solar Cities Program in the Western Region. This program will extend carefully directed support to expedite the use of solar technologies, energy conservation, and management techniques in urban areas. Support will be available to both the public and private sectors.

A primary component of the Solar Cities strategy is to provide assistance to effectively incorporate solar and conservation concepts into the local planning process. Solar planning will also emphasize nontechnical variables such as quality of life and environmental factors. Special attention will be given to maximize local, social, and economic benefits.

Assistance will be provided also for activities related to solar operations. Activities eligible for support are solar design, information dissemination, and coordination activities.

Direct assistance for implementation of solar applications that are technically feasible and economically promising will be available. Solar applications taking advantage of economies of scale beyond single-building application will receive priority.

The data and results generated by the efforts will provide the basis for deciding which markets, systems, and products display the greatest potential for inclusion in future systems development programs.

PROJECT TITLE: **PASSIVE SOLAR COMMERCIAL BUILDINGS DESIGN ASSISTANCE AND DEMONSTRATION**

Institution: *Willow Park II Community Improvement Association Missouri City, Texas*

Principal Investigator: *Alvin T. Grant*

Contract Number: *DE-FC02-80CS30361*

The Willow Park II Community Improvement Association in Houston, Texas, has proposed construction of a 2,500 to 3,000 sq. ft. community center building, which will include a large meeting room, bathing facilities for men and women, and a small kitchen. An adjacent 33,000-gallon swimming pool is anticipated.

Design Team

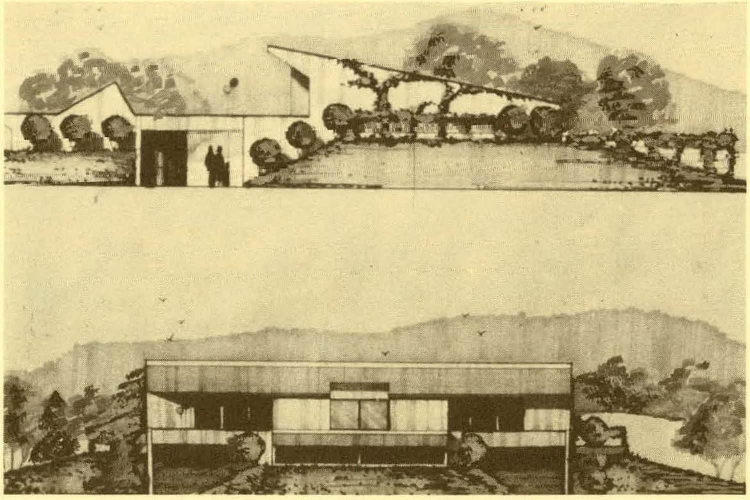
- Owner and Proposer – Willow Park II Community Improvement Association
- Architect, Solar and Structural Engineer – Interactive Resources, Inc.
- Mechanical Engineer – James Madget, Engineer.

Design Approach

- The schematic design phase includes extensive evaluation of site and climate and in-depth analysis of alternative designs
- The design development phase includes presentation drawings, schematics and diagrams of solar features, detailed cost estimates of solar system, and an extensive thermal and economic analysis of the design
- The construction documents phase includes detailing and specifying of solar features.

Design Tools

- An Apple II, 32K, minicomputer for basic analysis
- CAL/ERDA program on the Control Data Cybernet System for detailed energy-use estimating.



PROJECT TITLE: **NOCTURNAL AIR COOLING FOR NONRESIDENTIAL BUILDINGS**

Institution: *Ying Manufacturing Co.*
Gardena, California

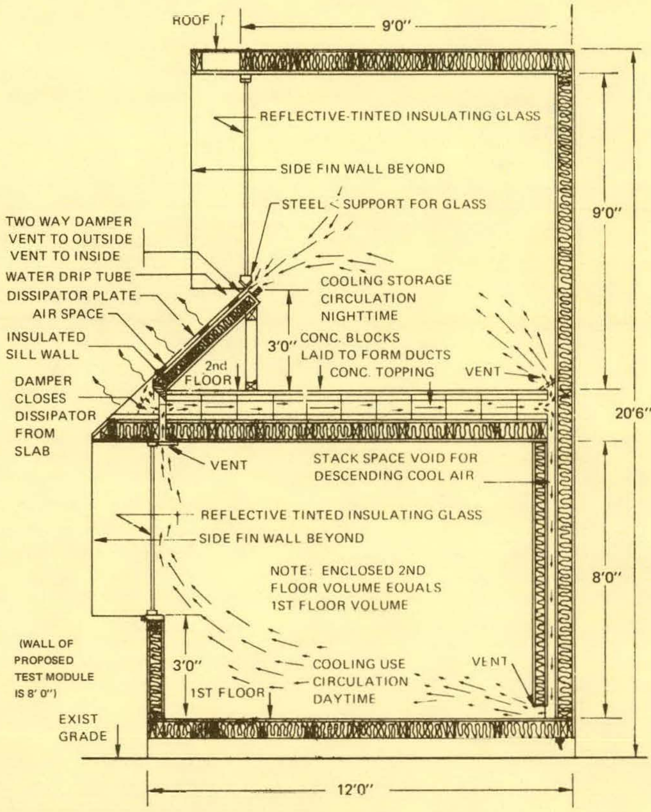
Principal Investigator: *Ying-Nien Yu*

Contract Number: *EG-77-G-04-4140*

The Ying Manufacturing Company has started research to design, construct, and monitor the passive cooling performance of a two-story office module typical of commercial construction. The system would have cooling advantages in climatic regions similar to Los Angeles, Phoenix, and Washington, D.C.

Cooling is a substantial energy consumer in certain types of buildings such as multistory buildings with high daytime use and high lighting levels. Examples are office and commercial buildings. Schools and apartments also are in this category. These buildings can be designed to be passively cooled by nocturnal cooling using the building structure as a thermal sink and other standard building features as thermal processors. Briefly, an integrated building cooling system can be attained by using the building envelope and other portions with a somewhat modified design.

This project involves construction of a small test module that will simulate conditions of a small perimeter office space in a multistory building. The test module size will be 12 ft. deep X 10 ft. wide and 20 ft.-6 in. high. There are two floors to test the dynamics of the cooling-storage, cooling-use cycles. The module will be instrumented with temperature sensors connected to a data logger.



In a multistory building at night, warm room air circulates through dissipator plates built into the sill wall at the exterior of the building. The air is cooled by nocturnal radiation, convection and evaporation. A built-in water tube drips water over the dissipator surface causing evaporative cooling. As the air becomes colder (denser and heavier), it sinks within the air space behind the dissipator and circulates through the ducted concrete floor slab, thus cooling the slab. The mass of concrete is favorable for thermal storage. At the deep end of the room away from the window, the air from the ducted slab is vented back into the room. A continual air circulating and cooling process then takes place in a passive mode with the circulation effectuated by motive pressures. In a hybrid mode, circulation and cooling are greatly increased by the addition of a relatively small fan.

This cooling system by Ying Manufacturing Company should work for single or multistory buildings. For actual multistory buildings, the *top* floor would vent outside air into and through the dissipator and ducted slab system.

CHAPTER VI: SOLAR PRODUCTS

Essential to the proper design of passive solar structures are products which can enhance the performance characteristics of solar designs. The projects in this chapter are representative of the types of products in various stages of development that can add to the solar efficiency of buildings.

In contrast to the other chapters, participants in this section of the program are primarily manufacturers who are not directly involved with the structural shell of the building but instead involved in the design and fabrication of component parts (i.e., windows, insulation, shades, etc.) of the building. Common to the other chapters is that the type of work activity ranges from the preliminary design stage through design development, prototype assembly, testing, marketing, and distribution.

PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*ABRI, Inc.* *Cambridge, Massachusetts*
Principal Investigator:	*Susan Gill*
Contract Number:	*DE-AC02-80CS30518*

The overall scope of this project is to evaluate the technical and economic potential of the proposed product and address the preliminary aspects of production, distribution and marketing. More specifically, the product involved is defined as a "Variable Insulation System" which utilizes lightweight translucent material to control thermal lighting and cooling loads.

Initial phases of work will concentrate on the design and fabrication of a prototype model(s), evaluating the compatibility of proposed designs with existing building systems and conducting preliminary commercialization studies.

PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*Capitol Products Corporation* *Harrisburg, Pennsylvania*
Principal Investigator:	*Graig W. Young*
Contract Number:	*DE-AC02-80CS30519*

A passive solar heating system providing for direct gain for daytime heating requirements and for thermal energy storage for nighttime heating is available in a "solar window" being developed by Capitol Products Corporation (CPC). Glauber's salt is the phase change material employed as the thermal storage medium. This material has the characteristics of low cost and high energy density which provide the following benefits to the solar window:

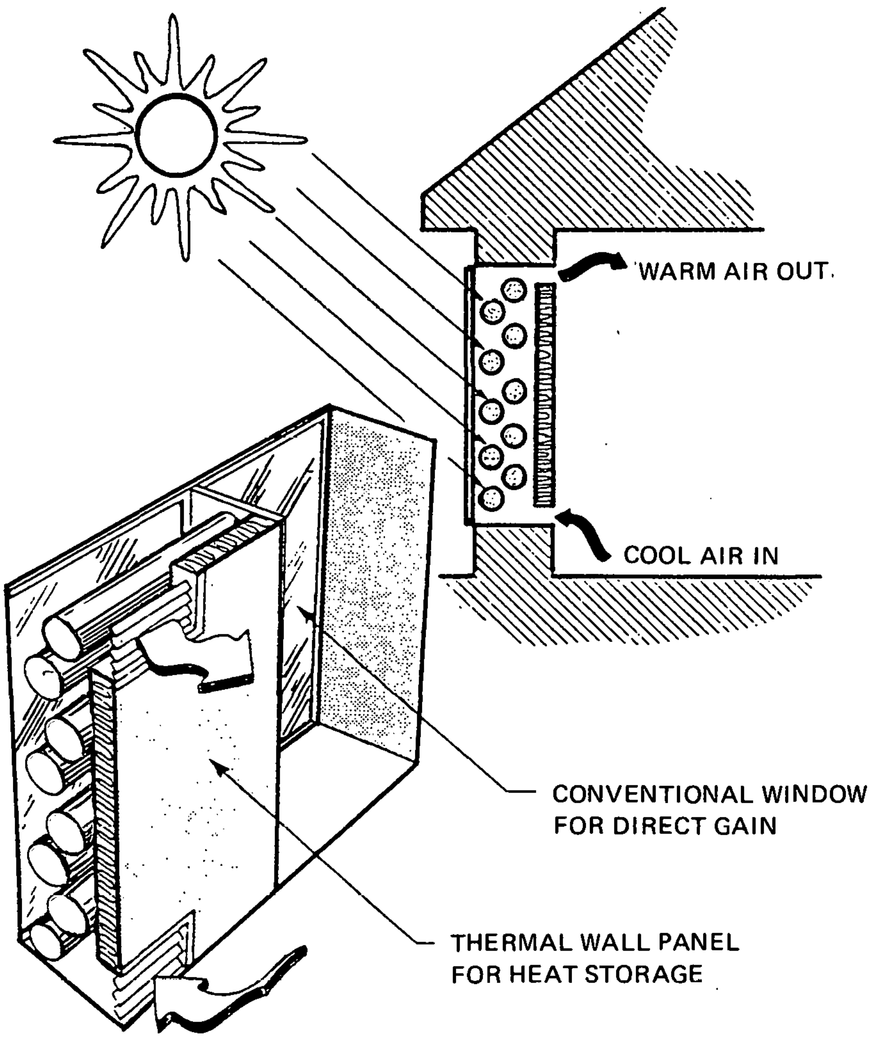
- Increased performance over alternate systems using specific heat materials
- Size and weight specifications which conform to accepted building techniques for installing conventional windows
- Modular construction of a marketable product for both new and retrofit construction.

Architects and builders will be able to use this new solar window in combination with southerly facing conventional windows to obtain the correct balance in each of their house designs in respect to the following needs:

- Providing sufficient storage mass for thermal energy absorption and storage without concern for use of masonry or stone construction for storage mass
- Direct gain in the daytime without experiencing overheating
- Correct sizing of auxiliary heating needs without concern for being too oversized because of the demands of large uninsulated glazed areas at night or on cloudy days.
- Daylighting to offset electrical lighting needs
- Reduced glass in living area without sacrificing solar gain opportunity
- Minimization of area subjected to fading of colors in material and wall coverings without sacrificing solar gain opportunity.

The Solar Window will be designed so several units can be joined with conventional windows to create a total solar wall for full house heating. Also, a design will be developed that can be applied as a single room unit. By so doing, a retrofit of existing south facing rooms would be no more difficult than present replacement or installations of new windows.

SOLAR WINDOW



PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*Communico/Crimsco* *Santa Fe, New Mexico*
Principal Investigator:	*Susan Nichols*
Contract Number:	*DE-AC02-80CS30520*

Communico, Inc. of Santa Fe, New Mexico is joint venturing with Crimsco, Inc. of Kansas City, Missouri to complete "Final Design Development" for Heat Wall, a manufactured water wall, for passive solar applications.

Communico, Inc. has been involved in passive solar design, construction, engineering and development since 1974. Crimsco, Inc. is a 30-year old small business that manufactures food equipment for hospitals and airlines. Crimsco manufactured the Suncraft Ⓣ active air solar system starting in 1973 and has been involved with developing the Heat Wall concept since 1977.

To manufacture the product, it was necessary to acquire a "License to Patent Rights" from Mr. Harold Hay, the Los Angeles Solar Pioneer. This license provides the right to employ flexible linears in upright factory built modular water wall sections. Following successful negotiations with Mr. Hay, Communico prepared schematic drawings. They are now entering the final design development phase. The term "Heat Wall" refers generically to vertical, stagnated water loaded Trombe walls, consisting of metal framing with optional exterior selective coatings, optional interior sealed lined channels (into which the water is poured), and optional sheet rock interior finishing so as to resemble a conventional wall.

The two most important applications for Heat Wall, in addition to new construction, are: simple retrofit on an existing south frame or masonry wall and use as mass backing for a retrofit greenhouse on an existing frame structure. The Heat Wall will replace frame construction and act as a thermal storage and buffer between the new greenhouse and the existing interior living space. This modified form of interior water wall and the straight retrofit application are contemplated as an immediate Heat Wall application.

PROJECT TITLE: **MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**

Institution: *Dow Corning Corporation*
Midland, Michigan

Principal Investigator: *Bernard Van Wert*

Contract Number: *DE-AC02-80CS30521*

Broad global experience has repeatedly shown southwall glazing to be one of the most cost-effective methods for passive solar space heating. Southwall glazing is particularly beneficial in more northern latitudes of the United States where heating requirements are the greatest and the inclination of the sun above the horizon is the lowest during the winter heating months. This form of passive solar heating converts both direct and diffuse insolation to heat energy in the southern wall of the structure; this heat is then radiated, conducted, and/or convected into the building interior.

Southwall glazing may be used to retrofit existing buildings as well as being applied to new construction. The space in commercial and industrial buildings that may be heated using southwall glazing may be up to five times the area of the southwall glazing.

Dow Corning proposes to develop a single-glazed southwall glazing system, primarily for masonry commercial, institutional, and industrial buildings. The silicone southwall glazing system will be suitable for both new construction and retrofit and may be site or locally fabricated.

The southwall glazing system would consist of:

- Silicone coated glass cloth glazing in roll form
- Hardware for attaching and sealing the glazing to the south wall
- Provisions for continually tensioning the fabric.

The other two elements of southwall passive heating systems are:

- Solar absorber surface
- Means for naturally distributing the energy collected on the absorber surface to the interior space.

The proposed southwall glazing system would be developed to be universally applicable to both selective and nonselective absorbers and to vented or nonvented heat distribution systems.

PROJECT TITLE: **MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**

Institution: *Four Seasons Solar Products Corporation*
Farmingdale, New York

Principal Investigator: *Joseph Esposito*

Contract Number: *DE-AC02-80CS30522*

Four Seasons Solar Products Corporation has proposed the development of an advanced passive solar greenhouse system which will:

- Allow for single, double or additional multiple glazing as local climatic factors may require
- Incorporate integral "night insulation"
- Provide integral summertime shading and ventilation and explore the possibility of recapture of vented heat for domestic hot water or air conditioning
- Incorporate thermal break and other thermal efficiencies in the details, connections and structural framework of the system
- Incorporate flexibility in the system in terms of size, span, configuration, solar orientation and modular expansion
- Maximize efficiency of materials by reevaluation of load requirements and in depth structural analysis including composite sections
- Maximize prefabrication and mass production efficiencies, simplify on site labor, reduce total installed cost of product.
- Minimize maintenance or replacement costs, maximize life of product, maximize life/cost effectiveness
- Consider interface with existing (retrofit) and new construction as well as new and existing related passive solar products (i.e., thermal storage systems, distribution systems, controls, heat transfer systems) and conventional heating systems and controls with which it will be used.

PROJECT TITLE: **MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**

Institution: *Hitek, Inc.*
Sweet Home, Oregon

Principal Investigator: *Charles Bliege*

Contract Number: *DE-FC02-80CS30523*

The objective of this project is to design, fabricate and test prototypes of a Passive Thermal Battery Module which use phase change materials already existing on the market. The thermal battery module will answer many of the shortcomings of the well known Trombe wall.

This thermal battery module is based on the development of a product by the Dow Chemical Company, although its use is not limited to this product. This product is now being marketed by several licensees under trade names such as Thermalrod-27 and Thermol-81.

Presently performance data on the storage rod used in passive applications do not exist. It is intended that these data be developed through this project along with the development of the module.

One of the most important aspects is the modular design. Module size will be optimized for installation, shipping and handling. The modular design allows installation as a retrofit behind south facing glass, in a greenhouse or other locations which might not allow the installation of a conventional Trombe wall due to weight. The module is expected to weigh 1/5 to 1/10 the weight of a Trombe wall with an equivalent storage capacity.

It is anticipated that a small fan system may be needed to facilitate better delivery of the stored energy from the thermal battery modules. This will be verified by calculations and tests.

A life cycle cost analysis was performed using a calculator program developed by Solar Environmental Engineering Co., Inc., Fort Collins, Colorado. With a 20-year analysis period the economic maximum first cost is $7205.00 for a module system of 180 sq. ft. projected to supply 26% of an annual load of 50M Btu. Estimated large production scale, installed costs for a module system of this size is $2500.00 This results in a savings of $6175.00 over the 20-year period with a 14-year payback.

Passive systems designers should find the product readily adaptable to their designs. They would need only to design the support structure and the external glazing system. They would select the modules and appropriate number of storage rods according to tables to be developed for each geographical and climatic area.

PROJECT TITLE: **MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATION**

Institution: *Intrel Service Company*
Nashua, New Hampshire

Principal Investigator: *James A. Kuzdsall*

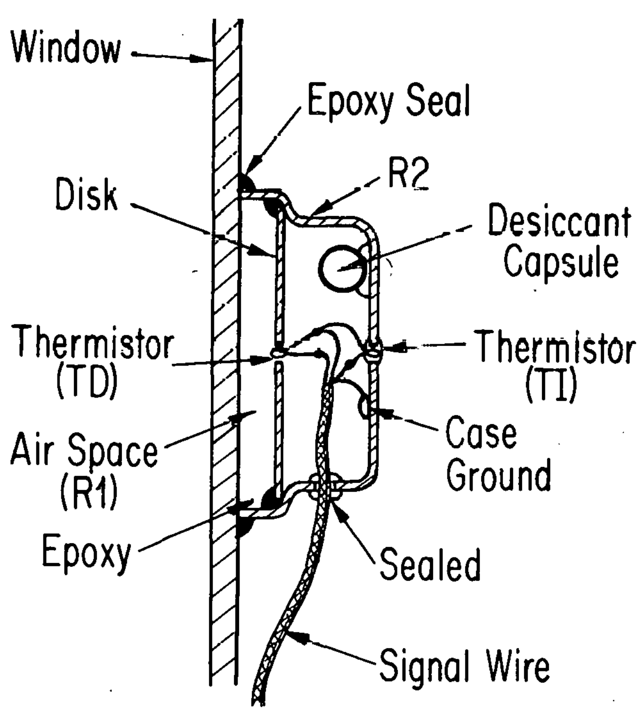
Contract Number: *DE-FC02-80CS30524*

This project pertains to the design development, testing and commercialization of a product called the Thermal Gain Shutter Controller.

The Thermal Gain Shutter Controller uses a unique energy sensor to determine the net energy flow through a solar collector window. The sensor compares the incoming radiant energy with that lost to the outside by convection and conduction at the window surface. Curtains or thermal shutters are opened or closed according to the net energy flow. Since the Controller can be used either to maximize or to minimize the heat intake, it finds application in all seasons and in all parts of the country.

The system consists of two parts, a 1.5 inch diameter Sensor which is epoxied to the collector window and a Power Controller which can operate AC motors as large as 1/2 HP. Installation is simple and requires no adjustments. Operation is not affected by the type or height of the window, the temperature being maintained inside, or the temperature range expected outside. A yearly battery change is the only maintenance required. A battery test switch is provided.

The Controller can be retailed for under $50 but will be sold primarily as a component for resale by other manufacturers. The major market is motorized curtain traverses for homes, supermarkets, public buildings, and factories. Other applications include control of movable panel insulation in high efficiency solar homes and some types of passive water heaters. A simulation shows that the thermal collection capacity of the panel systems can be increased by 10 to 16% by using this system instead of a sunrise/sunset system.



PROJECT TITLE: **MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**

Institution: *Solar Systems Design, Inc.*
Selkirk, New York

Principal Investigator: *Robert Mitchell*

Contract Number: *DE-FC02-80CS30531*

This project's work scope involves the final design and prototype development of a low cost, lightweight movable, nonburning, interior thermal window shutter. Design of the shutter will include high insulating reduced infiltration, field assembly and easy installation characteristics. Cost and performance goals and an engineering field testing plan will also be developed prior to commercialization activities.

PROJECT TITLE: MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS

Institution: *Koolview Co., Inc.*
Madison, Wisconsin

Principal Investigator: *James Boesing*

Contract Number: *DE-AC02-80CS30525*

Passive solar windows serve multiple functions, functions which often place contradictory demands on their performance. Like other elements in the building envelope, they may be considered as valves which partition the interior living and working space from the environment outside. At the same time, they modulate and regulate 1) flows of energy and mass, 2) radiant and convective heat gain and loss, 3) air and moisture transport, and 4) illumination and view. The functional requirements which must be satisfied are frequently in conflict. In many instances, a static device will not suffice, and a managed window is the only viable solution.

The proposed product addresses itself to solving the above problems. When made of the special insulating material chosen and placed on the interior of windows, the proposed thermal barrier will be simple to operate. Like Venetian blinds, it can be manually folded up and down by manipulating a cord which will lock to hold it in any desired position. The product is quite compact when folded up and will allow the window to facilitate solar collection when the sun is shining. When the shade is pulled down, it 1) stops convection along the vertical surface of the glazing, and 2) forms multiple dead air spaces. If constructed with a low emittance material, the surface, in conjunction with the dead air spaces, will develop high resistance to radiant heat flow as well as minimize the flow of convectional air currents.

The product uses a honeycombed structure to create horizontal air spaces paralleling the surface of the glass. It also divides the air adjacent to the surface of the window into smaller horizontal air spaces which will minimize the adverse effects of convection and condensation.

Unique to this product is its ability to operate and insulate without the addition of an edge seal at the sides.

The proposed product will provide the same privacy and control of light as does a typical window shade, while being aesthetically more flexible in its ability to enhance any decor.

The product may be used day or night to control heat loss in the winter and heat gain in the summer. If constructed of a translucent material, it will allow natural illumination in both the up and down position.

PROJECT TITLE:	**PASSIVE SOLAR CATALOG**
Institution:	*Northeast Solar Energy Center* *Cambridge, Massachusetts*
Principal Investigator:	*Didier Thomas*
Contract Number:	*In-house*

The objective of the Passive Solar Marketable Product Development Project is to make available plans and information for passive retrofit applications. This endeavor will include the assessment and selection of appropriate solar applications, the documentation of actual examples of the applications selected, and the publication of information on selected retrofit dwellings. A brochure, with companion application notes detailing construction, will be produced for each retrofit model.

PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*One Design, Inc.* *Winchester, Virginia*
Principal Investigator:	*Tim Maloney*
Contract Number:	*DE-AC02-80CS30526*

One Design has spent seven years designing, prototyping, installing, monitoring, redesigning and now manufacturing waterwall components. The list of tested waterwall configurations is now up to fifteen generations of design. The number and type of installation has grown rapidly and has emphasized residential applications.

Literature has generally described the waterwall as a very attractive design solution but has not hinted at the range of requirements of the ever broadening list of applications. Public awareness of the One Design waterwall resulted in a very broad response from numerous markets and from numerous manufacturers of related products. This upsurge of interest has revealed opportunities for more specialized waterwall types — the subject of this proposal.

The Omnibus Thermal Storage (OTS) Module appears on an early One Design patent, but had not been developed until the manufactured housing market's unusual requirements focused new attention on the concept.

This product is a rotationally molded thermoplastic water container for direct or indirect collection, storage and delivery of solar space heating energy. It is a waterwall module of unusually broad application due to advanced design and variable juxtaposition with other products. It immediately follows a similar (but limited application) version developed exclusively to fit into the space between 2 ft X 8 ft studs in manufactured homes.

The OTS module is made in several sizes. A useful module is nominally 4 ft X 4 ft by 7-1/4 in. thick and, like its predecessor, fits into the stud space of framed walls as well as in numerous other applications. Tension tubes prevent the .050 thick walls from bulging when the modules are site filled with water.

The strength and configuration of the Omnibus modules allow them to be assembled into free standing room dividing office partitions in any variable of their four foot dimensions.

Work under this contract will involve the design development, fabrication and testing of the Omnibus Thermal Storage System. It will also include the establishment of preliminary cost and performance goals and the development of an engineering field test plan.

PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*One Design, Inc.* *Winchester, Virginia*
Principal Investigator:	*Tim Maloney*
Contract Number:	*DE-AC02-80CS30527*

The purpose of this project is to complete engineering field testing of three waterwall modules preparatory to final commercialization. This will be a multistage process involving design development as well as field testing. Current prototypes will require packaging and installation-oriented modifications as requirements of several target markets.

The project will couple evaluation of market needs with comprehensive engineering testing. A major subtask is to identify those submarkets and applications which will provide early acceptance and rapid market penetration. The identification of best product/market pairs will insure that engineering modifications result in the greatest commercial impact.

Target markets have requirements for several different waterwall modules. One Design recognizes that in the construction industry especially, commercial success of a new product or system generally requires that current building practices not be changed. One Design has identified the need for three different types of waterwall modules and expects that market research will identify others.

The following assumptions will be used as guidelines as markets are approached:

Module	Target Market
Isophthalic Black Beauty (IBB)	Architects and individuals building homes
Steel Antistratification (SAS)	Single and multiple family builders
Stud Space Waterwall (SSW)	OEM-manufactured buildings.

All three parts are targeted for greenhouse retrofits of varying scale.

One Design recognizes that a major purpose of this project is to provide a near-term capability to supply commercially viable products. At the conclusion of this phase, One Design will have several performance-proven modules custom designed to fit most building markets. A comprehensive building plan will also have been completed.

PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*Solar Central (Wonder Gardens)* *Mechanicsburg, Ohio*
Principal Investigator:	*Donald Greider*
Contract Number:	*DE-FC02-80CS30528*

This project pertains to the development of a new type of greenhouse for commercial growers and other applications.

Solar Central has been involved with energy conservation equipment for many years and has helped design and build a number of passive heating and cooling systems including several greenhouses. Wonder Gardens has been working on commercial energy conserving greenhouses for several years. This project is a joint effort to produce a new product to serve the commercial growers who need large areas of low-cost environmentally controlled space. Interest has also been displayed by groups such as chicken growers and tennis court clubs.

Design of the proposed system is based on retaining solar heat through the use of movable insulation. In this case the insulation is in the form of foam plastic beads fed from a storage bin into an inflated plastic sheet. The intended prototype is a greenhouse of approximately 6,000 square feet. Projections indicate the possibility of reducing heating needs by 90—100%.

PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*Solar Concept Development Company* *Davis, California*
Principal Investigator:	*Richard Bourne*
Contract Number:	*DE-AC02-80CS30529*

"Sunbin" is a passive collector/water storage system integrated into the lower portion of a conventional exterior wall. The concept is intended for widespread application to the volume home building market, and emphasizes the use of familiar construction materials and interior appearance options.

Development of the Sunbin concept was begun in late 1978. Preliminary work was described in a poster paper prepared for the May 1979 ISES meeting in Atlanta. An initial prototype was constructed, tested, and used as a basis for economic studies. Since that time a second Sunbin design has been developed to widen its potential marketability.

The Sunbin system is designed to solve a number of nagging problems with passive solar space heating concepts. A system of concealed and automatically operated insulators reduces night heat loss through the Sunbin glazing. The insulation also reduces heat transfer from storage to heated space during sunny conditions, to control daytime overheating. The low wall location allows considerable flexibility in quantity and configuration of additional south wall glazing placed for views and direct solar gain.

Solar Concept Development Company intends ultimately to market a "kit" of Sunbin components, including at least the membrane liner, glazing, insulating system, and interior finish panels.

Two versions of Sunbin are proposed for further development. The first version is intended for application in moderate, dry climates where cool night breezes may be used for cooling. The second Sunbin version is designed for application in colder winter climates. A system of concealed, automatically operated insulating blankets reduces night heat loss, and permits use of an inexpensive fixed single glazing.

PROJECT TITLE: **MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**

Institution: *Solar Resources, Inc.*
Taos, New Mexico

Principal Investigator: *Steve Kenin*

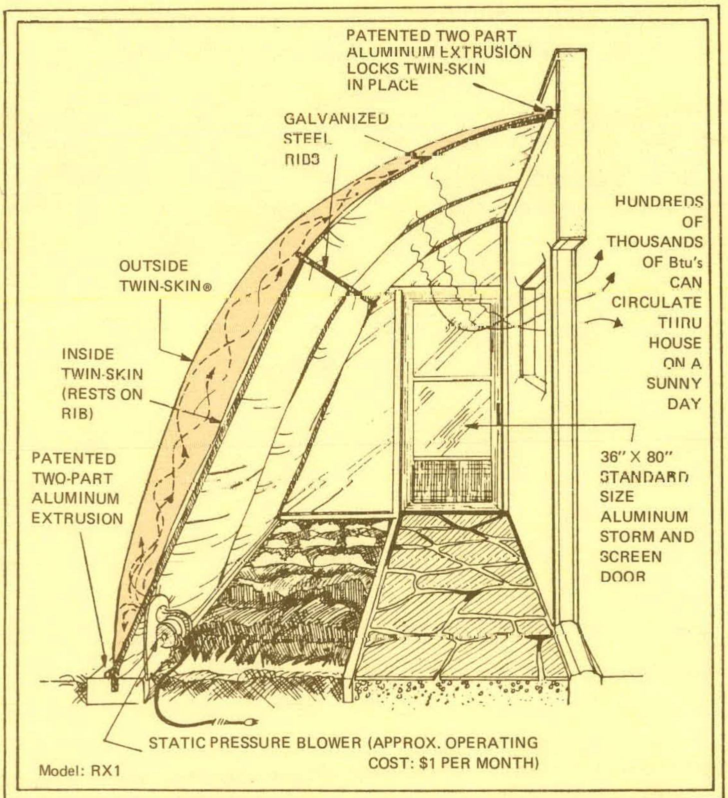
Contract Number: *DE-FC02-80CS30530*

Solar Resources, Inc. is the originator of a solar collection system trademarked SOLAR ROOM for the retrofit space heating of homes. This product has been in development for over six years, and the company is convinced that it is a solar device whose time has come.

The SOLAR ROOM is a south wall passive/hybrid solar glazing system using thin-film technology. It has been field tested in over one hundred installations across the country and approximately one quarter million dollars have been spent on scientific and market testing thus far. It has also been scientifically tested under the auspices of the Department of Energy.

SOLAR ROOM's most striking feature is its cost. Because it is a system that utilizes a minimum of materials and structural supports, it is inexpensive by solar standards. On a cost/payback basis, it is between 5 and 10 times less expensive than other solar systems of comparable heat output. A typical 30-ft-long SOLAR ROOM, having a collection area of 349 square feet, is generally installed in one or two days by handyman-level labor.

The SOLAR ROOM is an air-inflated tension structure. It is produced in 3-foot increments from 12 feet long to 40 feet long, and is 7 feet wide at its base and 8 or 9 feet high. The size of the



SOLAR ROOM® THE SOUTH WALL SOLAR COLLECTOR™

SOLAR ROOM is scaled to the heat loss characteristics, mass and the microclimate of a given home. Fuel savings range from 30–50%, as reported by SOLAR ROOM users and confirmed under DOE sponsored testing.

A relationship has been generated with Wharton School, University of Pennsylvania, to help insure that Solar Resources, Inc. develops and institutes a control growth business plan. With successful documentation of market research and production design, its stockholders, as well as interested third parties, have committed themselves to capitalize the production facility and marketing program that will be generated.

PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*Sunearth Solar Products Corporation* *Green Lane, Pennsylvania*
Principal Investigator:	*Howard Katz*
Contract Number:	*DE-FC02-80CS30581*

The proposed product is a small, lightweight, ready to install, damper control for Trombe walls.

To ensure large scale market penetration of passive solar designs, it will be necessary to bring down the cost of passive solar construction. Trombe walls are increasingly being constructed from conventional concrete block, the cores of which are filled solid to insure sufficient thermal storage. This approach in most parts of the country has proven to be the cheapest Trombe wall construction technique. To many consumers, a painted exposed block Trombe wall would be an acceptable interior finish if good workmanship at the joints and particularly around the vent openings can be assured. Detailing around the vent openings is an important aesthetic detail.

By providing an integral passive reverse flow damper and trim piece, it should be possible for masons to more quickly (and thus more cheaply) construct Trombe walls. The cost of the vents should more than be paid for by the decrease in wall cost.

As Trombe walls are beginning to be used in climates where mechanical cooling is required, research is beginning to show that having the ability to close off both top and bottom vents is desirable. It becomes important to isolate cooled room air from the heated Trombe wall cavity. The simple do-it-yourself vents are usually located at the top vents only. To locate them at bottom vents is possible, but somewhat more difficult and time-consuming. Also, most do-it-yourself vents have no insulating value, as they are usually composed of very thin film plastic of some kind. While each vent is usually of a relatively small area, the sum of all the vents in a substantially Trombe walled house can easily represent the equivalent of two or three single glazed windows.

The proposed product would have essentially no maintenance costs, little in the way of risk in its use and it would clearly be a great deal more durable than the do-it-yourself alternative.

PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*Sunspool Corporation* *Palo Alto, California*
Principal Investigator:	*H. T. Whitehouse*
Contract Number:	*DE-FC02-80CS30533*

Adequate collector freeze protection is only now being recognized as a crucial aspect of the technical and market viability of solar/DHW systems. The lack of awareness has stemmed, in part, from a lack of understanding of the heat loss mechanisms available to a solar collector and, in part, due to inadequate information of the field performance of existing solar/DHW systems. The former element is coming to light via the enormous freeze damage suffered throughout the United States during the past two winters. These instances of collector damage — frequently occurring in such "benign" climates as Southern California and Florida — are alerting designers, installers, and end users to the synergistic cooling effects which can occur with low outside air temperatures and radiant losses to a clear night sky. The radiant losses, which are particularly difficult for the layperson to comprehend, can give rise to collector temperatures which are significantly below the surrounding air temperature. This radiant phenomena has been used for centuries to freeze water in many countries, and is responsible for the frost patterns which can form in open fields or on automobiles.

This project seeks to develop and commercialize a passive valving mechanism to drain solar collectors used in thermosyphon water heating systems. Specifically, the effort would proceed along two distinct fronts:

- Develop and market a permutation of the Sunspool valve which would feature a refrigerant-operated drive mechanism responding directly to collector and/or ambient air temperatures.

- Explore the technical feasibility and marketability of driving and controlling the electrically-operated Sunspool valve with a small photovoltaic array combined with a simple snap-action thermostat switch for a drain signal.

The present Sunspool configuration has been enthusiastically received. The new passive version of the Sunspool valve is expected to receive similar acceptance from the same marketing channels.

PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*Suntek Research Associates* *Corte Madera, California*
Principal Investigator:	*Craig McCarty*
Contract Number:	*DE-FC02-80CS30583*

Central to the effectiveness of any passive solar heating system are efficient collector surfaces and a building design that effectively utilizes those collection surfaces. Suntek Research Associates developed Heat Mirror™ a thin film transparent insulation, with the expressed intent of providing a material that could drastically increase the thermal performance of glass to yield such efficient surfaces.

This can be achieved at economically advantageous costs, with good solar transmission values, and with outstanding optical clarity. Such high performance insulating glass makes available to passive solar designers a whole new world of freedom to use insulating glass as collector surfaces without the necessity for extreme design measures, high cost, movable insulation systems, and end user inconvenience to reduce energy lost through the collector surfaces.

Suntek Research Associates proposes to perform production and market planning and product evaluation for Superglass™ under Phase 3 of DOE's Marketable Products for Passive Solar Applications Program. Superglass™ is a high thermal performance insulating glass designed for use as a passive solar collection surface that incorporates Heat Mirror™, the transparent insulation film previously developed by Suntek with the aid of DOE funding.

The goal of this program will be to:

- Design and build a prototype Superglass™ production line as a model for training and subsequent technology transfer to insulating glass and window manufacturers throughout the United States. Companies expected to be part of this initial program include: Belknap Glass, Fentron Industries, Cardinal Insulated Glass, Viracon, Inc., Wausau Metals Corp., Rolscreen Company, Season-all Industries, and Capitol Products Corp.
- Produce field and laboratory test units on that production line.
- Make an economic and technical assessment of the product and its production methods.
- Prepare a commercialization plan for Superglass™ that addresses all levels of the complicated but unsophisticated distribution networks of the construction industry.

Achievement of these goals will pave the way to make available a glazing system whose thermal performance far exceeds that of existing systems.

PROJECT TITLE:	**MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**
Institution:	*Syracuse Research Corporation* *Syracuse, New York*
Principal Investigator:	*Clyde H. Beigh*
Contract Number:	*DE-FC02-80CS30584*

The Energy Research Center (ERC) of the Syracuse Research Corporation (SRC) has proposed to perform preliminary design and market assessment of two related products which have high potential for widespread commercialization.

The two products proposed are the most promising among a number of products, techniques, and schemes that have emerged from SRC's passive solar research over the past four years. The first is an insulating shutter which has a number of features that movable insulators presently on the market do not have, such as: excellent thermal performance, aesthetic appeal, applicability to both new and retrofit structures, ruggedness, long life, and economic attractiveness.

The second product is a passive window system strategy which has the thermal performance of an insulating shutter, yet provides daylighting deep within a building and solar thermal gain for conditions of both diffuse and direct sunlight. This system, which is applicable to new commercial structures as well as to existing buildings such as schools and office buildings, will have no moving parts.

A marketing study will be conducted in parallel with the design work of both products. Since the shutter design will be useful both in passively solar heated buildings and in energy efficient nonsolar structures, demand for the product, if packaged properly, could be high. The other design will be useful not only in industrial and commercial installations but also in such applications as school retrofits. Thus demands for it could be equally high.

PROJECT TITLE: **MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**

Institution: *Thermal Technology Corporation*
Snowmass, Colorado

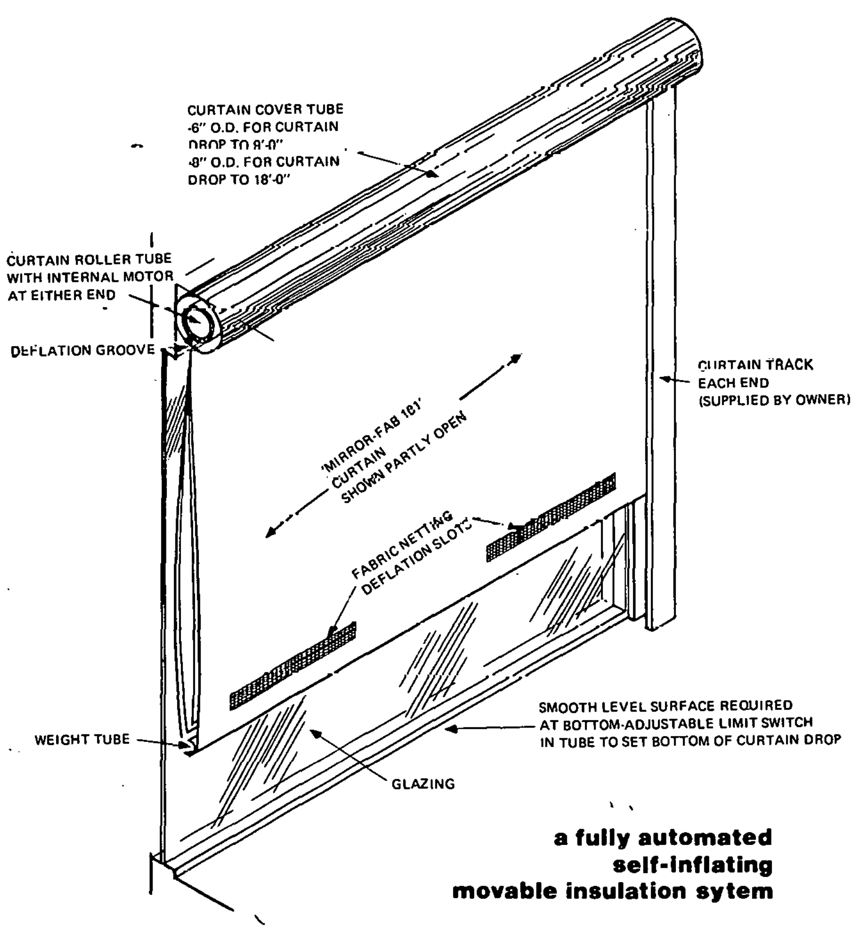
Principal Investigator: *Bill Ashton*

Contract Number: *DE-FC02-80CS30585*

Thermal Technology Corporation was founded to do energy conservation design consulting work and research and development as it related to design and possible product alternatives.

The subject product, an Insulating Curtain Wall (ICW), was initially developed to provide a system to insulate mass walls in passive systems to improve their performance by reducing thermal losses. Field testing both by Thermal Technology Corporation and independently by Los Alamos Scientific Laboratory has been conducted; however, additional independent testing is advisable.

The ICW System develops a high insulation value through the use of several layers of metalized reflective fabrics. Combining the multilayered reflective fabrics with entrapped air spaces, it is possible to practically eliminate heat transfer by radiation, conduction and convection.



a fully automated self-inflating movable insulation sytem

Two product applications (manual and automatic) represent Thermal Technology's major thrust toward commercialization with efforts focusing on the following goals:

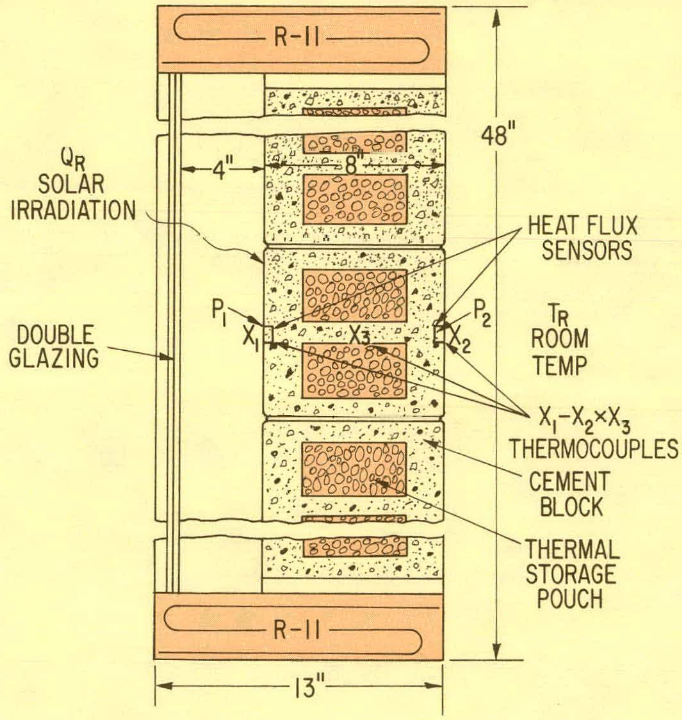
- To profitably manufacture Curtain Wall^{tm}, the passive solar window insulating device developed during the past four years by the Thermal Technology Corporation
- To develop and commercialize a series of complementary window insulating products
- To employ, educate and motivate other individuals committed to building a profitable corporation based on energy conservation.

PROJECT TITLE: **MARKETABLE PRODUCTS FOR PASSIVE SOLAR APPLICATIONS**

Institution: *University of Delaware*
Wilmington, Delaware

Principal Investigator: *Maurice Lang*

Contract Number: *DE-FC02-80CS30586*



The University of Delaware proposes to undertake development work on a new product design to increase the heat capacity and thermal conductivity of cement blocks in masonry construction.

The work scope includes process and product design of the components, cost estimates and a market assessment.

The University of Delaware has a product definition of the phase change thermal energy component it proposes to use on this program. It also has a product and process definition of the final product it proposes to develop for commercial use.

The program goal is to develop a cement block of approximate heat capacity of 850 Btu/block. Four hundred blocks would have the capability of absorbing 300,000 Btu's solar heat on a sunny day—sufficient to provide the daily heat requirement of the average home in the middle-eastern states. The market potential would, therefore, be 400 blocks or a 350 ft^2 portion of the south wall of each residential unit of new construction, a sizable market. The intended final product is a thermal storage material that is packaged in pouches to fit into the cavities of cement blocks. The product is nontoxic and not hazardous to health. It displays no conceptual or composition barriers to prevent acceptance by state or local building code jurisdictions.

The product can further be developed in other similar embodiments which fall into the following, directly or indirectly applicable, categories:

- Phase change material systems
- Interior finish thermal storage panels
- High thermal mass materials for floor storage in direct gain systems
- Design for brick and masonry thermal storage systems
- Precast concrete thermal storage systems.

CHAPTER VII: SOLAR CITIES & TOWNS

These projects represent the initial efforts in developing solutions for applying passive solar to the urban environment. Significant portions of this effort are directed toward cost-effective retrofit applications of existing neighborhoods as well as new urban developments. Parallel commercialization efforts are also underway to disseminate information to the public on the viability of passive solar applications to cities and towns.

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PROJECT TITLE: **MARIN SOLAR VILLAGE**

Institution: *Marin Solar Village Corporation*

Principal Investigator: *Sim Van Der Ryn*

Contract Number: *DE-FG03-80CS30313*

Marin Solar Village is a proposal to build a nationally significant model community on 1271 acres of surplus Federal property at the former Hamilton Air Force Base. It presents an opportunity to provide new jobs, housing, and tax revenues and demonstrate practical, sound, and innovative approaches to today's problems of energy, economics and environment.

The key principle behind Marin Solar Village is *sustainability*: providing for a continuing high quality way of life by reducing dependence on expensive and rapidly depleting fossil fuels.

A nonprofit corporation has been formed to carry out the plan. The Marin Solar Village Corporation will act as the "Master Developer" bringing together the necessary financial, development and planning expertise to successfully carry out the project.

Planning and building costs of Marin Solar Village will be sought from private sources as well as specific public grants. Services will be paid for through taxes generated by the new uses. Net profits returned by the development will be invested by the Corporation in research and education on integrated living systems.

Preliminary planning has suggested the following land uses:

- Rehabilitated Housing (20 acres)
- New Solar Housing (80 acres)
- Corporate Center (55 acres)
- Solar Technology Center (110 acres)
- Energy Production (25 acres)
- Transit Center (35 acres)
- Food Production (120 acres)
- Resource Recovery and Fresh Water Ponds (45 acres)
- Aquaculture (100 acres)
- Marshland (600 acres)
- Sport and Recreation Center (45 acres)
- Village Green (10 acres)

PROJECT TITLE:	**PASSIVE SOLAR POTENTIAL IN URBAN ENVIRONMENTS**
Institution:	*National Bureau of Standards*
Principal Investigator:	*Kalev Ruberg*
Contract Number:	*EA-77-A-01-6010*

Successful passive solar use is a function of the match between available solar radiation at site, and the end use energy requirements of buildings. This match is critical in urban areas where complex shadow paths limit solar access, and where climate driven building energy demand is strongly influenced by internal gains.

This study encompasses the mapping of solar availability against varied building energy end uses for 10 urban commercial, mixed use, and residential building types.

Seven types of urban environments have been defined: the central business district, the neighborhood commercial strip, the residential neighborhood, the highway commercial strip, the suburban office park, the regional shopping centre, and the suburban subdivision. This last environment serves as a baseline for energy use comparison with other buildings and environments.

These seven urban environments contain the 10 building types: high rise office buildings erected after 1950, high rise office buildings erected prior to 1950, low rise office buildings, high rise apartments, low rise apartments, neighborhood commercial strip buildings, row tenements, strip shopping centres, fast food restaurants, regional shopping centres, and single family suburban residences. Although this list of urban building types is not exhaustive, these buildings comprise 80% of the total built area in central cities.

The end use energy loads are being calculated using five heating/cooling energy calculation methods, including DEROB. Solar availability and daylighting potential at the site are being calculated using a program developed at NBS. The variation in end use energy requirements among building types and the differences in solar availability in representative urban environments indicates a wide variation of solar access requirements and passive solar design criteria in these environments.

Data analysis is presently underway and final results will be published upon completion of the study.

PROJECT TITLE: **DESIGN ARTS PROGRAM**

Institution: *National Endowment of the Arts*

Principal Contact: *Marguerite Villecco*

Contract Number: *Interagency Agreement*

The National Endowment for the Arts is jointly involved with the Department of Energy in numerous initiatives to stimulate more widespread use of passive solar energy in the urban environment. Representatives of some of the programs are:

- Solar Urban Design Competition – for urban sites ready for development, at least one city block in area and exhibit mixed use
- Solar Cities Conference – a three day program focusing on Solar Urban Design, Daylighting and Historic Adaption
- Small Grants – in support of necessary energy related applications
- Fashion, Industrial, Interior and Graphic Design – involving diverse efforts to stimulate energy conscious and solar design responses. For example, a competition to design clothing that responds to the thermal resource and image implications of the new energy policy.

PROJECT TITLE: **SOLAR CITIES**

Institution: *Northeast Solar Energy Center*

Principal Contact: *Didier Thomas*

Contract Number: *In-house*

Solar Utilization in Neighborhoods of American Cities and Towns (SUNACT) is a program being developed at the national level to utilize existing or newly-created institutions to encourage neighborhood-level adoption of renewable energy and energy conservation measures. Planning for the SUNACT program is now underway at SERI, and the formulation of this comprehensive plan would be substantially strengthened by the implementation of pilot projects and the establishment of a regional base.

The purpose of this project is to establish a regional operational base for the SUNACT program and support the planning process through field applications.

The project will include the establishment of a regional data base for solar in urban areas and a local network of relevant organizations; pilot projects will also be included.

Planned activities are:

- To establish a data base on solar potential in urban areas
- To identify capabilities and needs of established organizations to support SUNACT goals
- To establish a network in urban areas of the Northeast to facilitate program implementation
- To manage pilot projects in the Northeast
- To support national planning.

PROJECT TITLE: **SOLAR CITIES COMMERCIALIZATION PROJECTS**

Institution: *Northeast Solar Energy Center*

Principal Contact: *Didier Thomas*

Contract Number: *In-house*

The Northeast Solar Energy Center is sponsoring numerous projects to promote more widespread passive solar application in the urban environment. Examples are:

- *Philadelphia Solar Project, Philadelphia, Pennsylvania* — A continuation of an on-going, city-wide effort. Focus on community participation, demonstrations, technical support to the commercial sector, and market development.
- *Massachusetts Energy Office, Boston, Massachusetts* — Technical support and educational activities in support of a locally funded construction program of multi-family buildings using passive design techniques impacting 1000 building units at $25,000,000 of construction.
- *Ehrenkrantz Group, New York City, New York* — Continue development of a prototype design for urban roof top greenhouses.
- *Greater Roxbury Development Corporation, Boston, Massachusetts* — Provide this urban development group with an energy expert, to assess energy efficiency of an on-going rehabilitation construction program.
- *Arrowstreet, Inc., Cambridge, Massachusetts* — A project, co-sponsored by the Massachusetts Municipal Association and the Metropolitan Area Planning Council, to develop an energy management plan for local municipalities.
- *Community Consultants, Inc., Boston, Massachusetts* — An educational project for a low-income neighborhood in Boston. Greenhouse will be the focus for energy awareness.
- *Bonnie Symanski, Boston, Massachusetts* — A 30-minute, 16 mm, color film on low-cost, do-it-yourself solar applications, including solar attics, hot water breadboxes and porch remodeling into sun spaces.
- *Michael McClintock, Boston, Massachusetts* — An urban, rooftop sun space for market rate, high rise housing. Drawings, a case study and an open house are the deliverables.
- *Energy Task Force, New York City, New York* — Construction of a food growing greenhouse on a rooftop in East Harlem, New York City. The four-story building is owned and occupied by a sweat/equity group who remodeled the building.
- *Stephen Hale, Belmont, Massachusetts* — A solar feasibility study for an urban multi-building complex to be rehabilitated into commercial space.

PROJECT TITLE:	**SOLAR CITIES SOLICITATION**
Institution:	*Regional Solar Energy Centers*
Principal Contacts:	*Didier Thomas (NESEC), Kal Turkia (SSEC)* *David Pagony (MASEC), Bill Davis (WSUN)*
Contract Number:	*In-house*

A cornerstone of the Solar Cities Program will be a competitive solicitation. This solicitation will be issued independently in each of the regional solar energy centers. Regional solicitations will be designed to maximize the potential opportunities for the use of conservation and renewable resources in cities and towns on a region specific basis. National coordination in both the development of the solicitations and the selection of projects will be provided by DOE and SERI. This coordination effort is aimed primarily at assuring: 1) a reasonable and appropriate level of programmatic homogeneity between regions; 2) consistency with the national program goals, objectives, and strategies; 3) a minimum of duplication of projects and project outputs on a regional and nationwide basis.

Initial solicitations will focus on building projects with a strong potential for conservation and passive solar design. Projects that are large scale (multibuilding, block-scale, or mix-use) or will serve as clearly applicable models (physical or process) for a large number of similar applications will receive priority. Priority will also be given to projects which develop management and organizational formats that are particularly relevant to facilitating the use of conservation and renewable energy technologies.

Assistance to projects will have two primary thrusts. First, Solar Cities resources will be provided to fund the incremental cost of feasibility analysis and design necessary to maximize the competitive position of energy conscious alternative design. Second, Solar Cities resources will be used to assist a project developer in dealing with institutional barriers to the use of conservation and renewable resources such as problems with solar access, zoning, and building codes.

PROJECT TITLE: **A WORKING CONFERENCE ON DESIGNING SUSTAINABLE CITIES**

Institution: *Sim Van Der Ryn/Calthorpe & Associates*

Principal Contact: *Peter Calthorpe*

Contract Number: *EG-77-C-01-4042*

The objective of these tasks is to organize, conduct and report on a conference designed to study such items as integrated solar applications in urban areas, solar district heating, utilization of shared walls in buildings, reduced use of automobiles through higher densities and mixed use planning, and local food production.

The proposed conference will be a week long working situation in the second quarter of FY 1980. Approximately 30 experts with various fields of expertise in energy technologies, urban design, architecture, finance and public policy will be invited to participate. Selected participants will be commissioned to prepare background papers to be used as input to the conferences' discussions and work sessions.

The primary purpose of the conference will be to study potentials for integrating solar technologies and energy conservation concepts in designs for four prototypical case studies: 1) redesigning/retrofitting an inner city neighborhood; 2) building a new community on the periphery of an existing urban area; 3) redesigning/retrofitting an existing suburban neighborhood; 4) building a new community outside a metropolitan area.

The product of the conference will be a final report consisting of three sections. Section One will include an edited, background paper discussed during the conference. Section Two will describe the four prototypical sites with associated and energy related data. Section Three will present recommendations for implementing the design concepts developed during the conference. Specific reference will be made to the activities and support needed by Federal, State and Local governments, community action organizations, and the private sector.

PROJECT TITLE: **SOLAR CITIES**

Institution: *Solar Energy Research Institute*
Golden, Colorado

Principal Investigator: *Richard Busse*

Task Number: *In-house*

The purpose of the solar cities and towns program is to accelerate the use of solar energy in the nation's urbanized areas. The focus is on large scale and widespread application of passive solar techniques. The program is dedicated to solving institutional problems (legal, financial, etc.) as well as technical problems associated with the use of solar energy in urbanized areas.

The program is a joint effort of DOE, SERI, the four RSEC's, National Bureau of Standards (NBS), Los Alamos Scientific Laboratories (LASL), and The National Endowment of the Arts (NEA). SERI provides day-to-day supervision and coordination for the program. SERI also has responsibilities for program planning; supports the program through communications activities; and performs analytic tasks in the areas of economics, legislation, and environmental impact.

Each RSEC has responsibility for implementation of the program in their respective region. NBS provides technical support, LASL provides input in market potential analysis, and NEA operates a small grants program which augments the impact of overall "Solar Cities" effort.

CHAPTER VIII: AGRICULTURAL BUILDINGS

This segment of the program will address agricultural applications of passive solar technology. Representative projects will include space heating for farm and animal shelters, drying of agricultural products, and applications for animal and produce storage.

The effort is divided into two general categories: systems development and market development. Systems development will focus on research, development, testing and final assessment of applications having potential widespread usage. Market development will investigate such factors as market readiness, performance, cost effectiveness, environmental acceptance as well as, promotional activities to facilitate more rapid implementation.

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PROJECT TITLE: **STUDY OF THERMAL PERFORMANCE OF A HYBRID SOLAR RESIDENCE AT LIVING HISTORY FARMS**

Institution: *Ames Design Collaborative*
Ames, Iowa

Principal Investigator: *Ray D. Crites*

Contract Number: *EG-77-G-04-4136*

Living History Farms was formed in 1967 as a nonprofit, educational, historical foundation to buy land and develop and operate three farms which tell the story of Midwestern agricultural development. These farms are located near Des Moines, Iowa. The three farms include a Pioneer Farm of 1840 and a Horse Farm of 1900 (both are operating), and a Farm of Today and Tomorrow which is currently being developed. The Farms are open daily for visitors and serve over 100,000 people annually.

The main objective of the project is to study the thermal performance of a solar heated residence, in order to develop a design formula that will incorporate passive concepts in optimal ways and provide a building design prototype.

The residence to be studied uses several passive solar energy concepts, including a solar pond. These concepts have been used in previous designs, but have never been combined to the degree they will be used in this research.

It is estimated that (except for the electricity energy needed to operate fans and water pumps) this composite passive system will provide 100 percent of the heating needs for the house.

During the cooling season, however, the house will operate only partially in the passive mode, using a heat exchange unit.

The thermal performance of the building will be monitored by pyranometers and thermocouples.

Also, this project will develop a computer model of the passive solar house coincident with actual house construction. This new model (and the hybrid models' prediction accuracy) will be perfected using the measurement data obtained from the solar house.

The solar pond, which is an integral part of the residence for the Farm of Today and Tomorrow, is a body of water with a salt gradient in the upper part of the pond which effectively prevents convective motion in that part of the pond. This water is transparent to visible light, but opaque to infrared radiation. Heat in the form of sunlight reaches the bottom and can escape only via conduction. Since the thermal conductivity of water is very low, heat escapes very slowly. This makes the pond not only a solar collector, but also a thermal storage device. Due to the large phase lag of water, heat collected in the summer can be stored in the bottom of the pond and used throughout the winter.

The solar pond was constructed in May 1979, and during the summer was monitored for thermal performance. No maintenance was attempted, resulting in less than optimal temperatures. Several problems, however, involving transparency and stability have been identified and will be important for other solar ponds.

PROJECT TITLE:	**PASSIVE AND HYBRID SOLAR MANUFACTURED HOUSING AND BUILDINGS**
Institution:	*W. H. Porter, Inc., Port-R-Span® and Nebraska Solar Front® Holland, Michigan*
Principal Investigator:	*William H. Porter*
Contract Number:	*DE-AC02-80CS30389*

The objective of this project is to manufacture a farrowing-nursery building for hog confinement which uses a minimal amount of winter heat and is relatively cool in the summer.

Various approaches have been made to use solar in heating hot confinement buildings. The most common has been a solar attic. Here the air is heated by passing through an attic with fiberglass glazing The system only works when the sun shines and has numerous drawbacks.

The solar attic overheats the wood framing reducing the structural strength of the wood trusses. The solar orientation is bad for the wintertime since the solar glazing in the roof is on a 3/12 or 4/12 pitch. There is no advantage at night to the solar attic and in the summer temperature is increased instead of lowered.

Another approach used by others to heat hog buildings has been to use block walls in a modification of the Trombe wall with outside pulling over black concrete blocks. These southern facing modified Trombe walls are not cost effective since the high air changes per hour quickly reduce the day temperature.

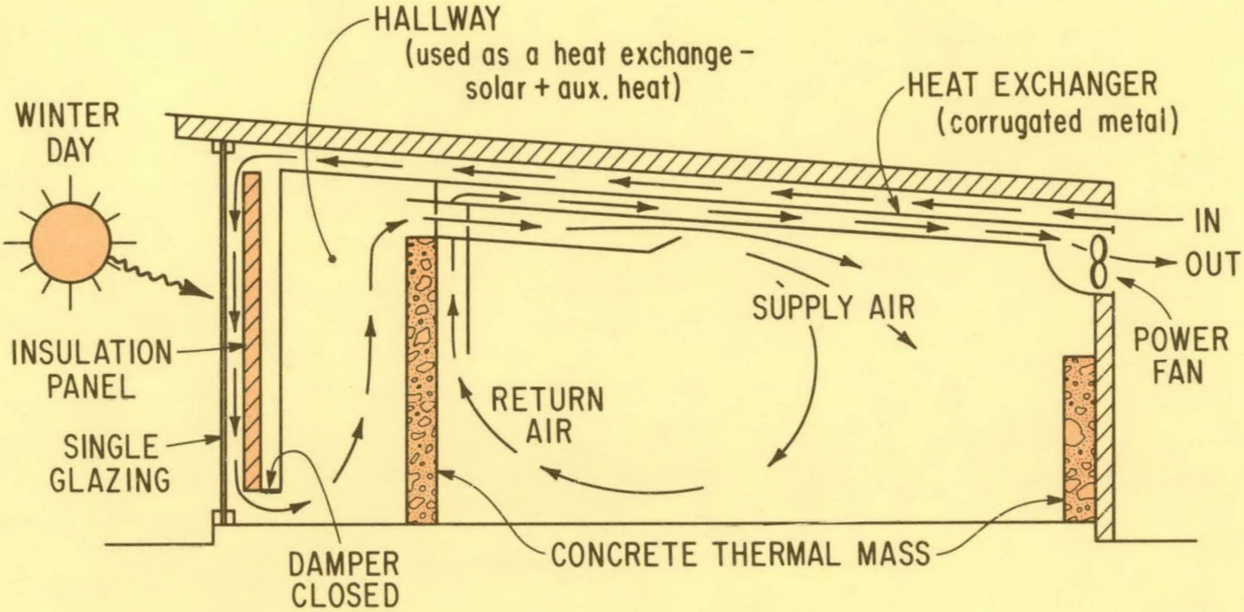
W. H. Porter's solution to the problem is to build in a heat exchanger which acts like a powered convection loop pulling air in through a heat exchanger and then past a southern facing solar panel. Air is mixed in the aisle and tempered by a wood stove with an automatic blower and controls. The air is then passed into the farrowing or nursery room at the right temperature. The farrowing room is held at exactly 70°F and the nursery at 75°F.

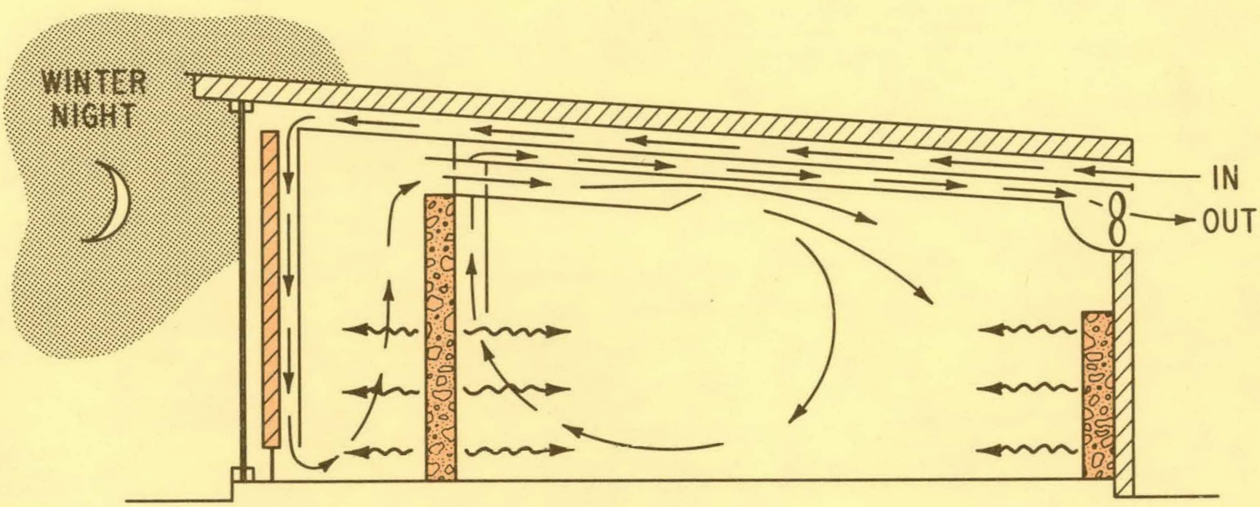
Concrete mass walls are used to surround the rooms. It provides mass where the temperature must be closely controlled. The following diagrams show the proposed method of operation.

The W. H. Porter building is a monoslope instead of the more conventional gabled structures more frequently used for farrowing-nursery. The monoslope allows for higher southern exposure and minimum northern exposure. The building is of frame and panel construction using tubular box steel beams and sandwich foam cored panels. The panels span 8 ft. between box beams. This design allows for integrating the heat exchanger as part of the building. The roof sandwich panel acts as the top of the heat exchanger and the box steel framing acts as sides for the exchanger. Using the building as part of the design reduces the costs and makes the building not only energy efficient but also economical to manufacture and use.

The integral design of a heat exchanger into a building is one of the technical accomplishments of this project.

The building's internal air flow pattern is radical and efficient. The use of a hallway to temper-mix and preheat air from several heat sources is a departure from conventional construction. The hallway also serves as a connection for rooms which can be isolated for disease and sanitary conditions. All materials, systems and structural components of the building have been analyzed for multiple functions and used accordingly.





Construction of the first building should take place the fall of 1980. Operation through the winter months will prove the system. The cost of operation of this structure will be compared to buildings of similar size. From these comparisons, the economic value of the new design will be determined.

With the economics of this new design established, marketing will start in the spring of 1981.

APPENDIX A:

Alphabetic list of contractors/projects by market application

Acorn Structures, Inc.
Box 250
Concord, Massachusetts 01742

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.4)
Contract Number: DE-FC02-80CS30363
Duration: 10/1/79–12/31/80
Funding: $56,185

Ames Laboratory
Iowa State University
Ames, Iowa 50011

Title: **Direct Gain Optical Study** (Page 4.1)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Ames Laboratory
Iowa State University
Ames, Iowa 50011

Title: **User-Oriented Education** (Page 4.2)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Ames Laboratory
Iowa State University
Ames, Iowa 50011

Title: **Water Filled Storage Walls** (Page 4.3)
Contract Number: EW-7405-Eng-82
Duration: 10/1/79–Continuing
Funding: $70,000

Architectural Alliance, Inc.
400 Clifton Avenue South
Minneapolis, Minnesota 55403

Title: **Solar Energy Using a Hybrid Solar System** (Page 4.6)
ntract Number: EG-77-G-04-4146
ration: 9/30/77–9/1/80
Funding: $29,975

Association of Collegiate Schools of Architecture
1735 New York Avenue N.W.
Washington, D.C. 20006

Title: **Design and Energy: A Student Competition** (Page 4.8)
Contract Number: DE-FG01-80CS22003
Duration: 10/14/79–10/15/80
Funding: $72,250

Battelle Memorial Institute
505 King Avenue
Columbus, Ohio 43201

Title: **Evaluation of Heat Pipe Application for Passive Systems** (Page 4.12)
Contract Number: EG-77-C-04-4222
Duration: 9/19/77–6/19/79
Funding: $237,882

Davis Alternative Technology Assoc.
P.O. Box 503
Davis, California 95616

Title: **Suncatcher Monitoring and Performance Evaluation Project** (Page 4.10)
Contract Number: DE-AC02-79CS-30169
Duration: 9/30/77–4/30/81
Funding: $25,554

Dynamic Homes, Inc.
525 Roosevelt Avenue
Detroit Lakes, Minnesota 56501

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.13)
Contract Number: DE-FC02-80CS30370
Duration: 10/1/79–10/31/80
Funding: $47,005

Ecotope
2332 E. Madison
Seattle, Washington 98112

Title: **Incorporation of Evapotranspiration Routines into Greenhouse Analysis Tools** (Page 4.14)
Contract Number: SERI HM-9-8308-1
Duration: 6/22/79–12/31/80
Funding: $24,000

Energy Engineering Group
P.O. Box 130, 1115 Washington Avenue
Golden, Colorado 80401

Title: **Analytical and Experimental Investigation of the Trombe Wall** (Page 4.15)
Contract Number: DE-AC02-79CS30244
Duration: 8/1/79–5/31/81
Funding: $80,000

First Manufactured Homes, Inc.
9602 S. University Avenue
Lubbock, Texas 79423

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.16)
Contract Number: DE-FC02-80CS30371
Duration: 10/1/79–11/30/80
Funding: $61,700

Fleetwood Hobmar Homes, Inc.
1345 Natchez Avenue, South
Minneapolis, Minnesota 55416

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.20)
Contract Number: DE-FC02-80CS30372
Duration: 10/1/79–12/31/80
Funding: $10,460

Guerdon Industries, Inc.
P.O. Box 35290
Louisville, Kentucky 40232

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.18)
Contract Number: DE-FC02-80CS30373
Duration: 10/1/79–12/31/80
Funding: $49,827

Iowa Energy Policy Council
215 E. 7th Street
Des Moines, Iowa 50319

Title: **Iowa – Project Passive** (Page 4.21)
Contract Number: DE-AC02-79CS30156
Duration: 6/1/79–10/31/82
Funding: $20,000

Living Systems
Route 1, Box 170
Winters, California 95694

Title: **Thermosiphoning Cool Pool** (Page 4.22)
Contract Number: DE-FG02-77CS34153
Duration: 9/30/77–2/28/81
Funding: $129,582

Londe-Parker-Michels, Inc.
6096 Lemay Ferry Road
St. Louis, Missouri 63129

Title: **Passive Solar Retrofit** (Page 4.24)
Contract Number: EG-77-G-04-4127
Duration: 9/8/77–9/30/80
Funding: $26,222

Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

Title: **Convective Loop Test Program** (Page 4.25)
Contract Number: In-house
Duration: Continuing
Funding: $250,000

Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

Title: **Data Analysis of Mobile/Modular Home II** (Page 4.26)
Contract Number: In-house
Duration: Continuing
Funding: $22,000

Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

Title: **Economics of Passive Solar Versus Conservation** (Page 4.28)
Contract Number: In-house
Duration: Continuing
Funding: $20,000

s Alamos Scientific Laboratory
). Box 1663
Los Alamos, New Mexico 87544

Title: **Monthly Solar Load Ratio for Attached Sunspaces** (Page 4.30)
Contract Number: In-house
Duration: Continuing
Funding: $123,000

Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

Title: **Passive Solar Design Handbook** (Page 4.31)
Contract Number: In-house
Duration: Continuing
Funding: $109,000

Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

Title: **Passive Test Room Program** (Page 4.32)
Contract Number: In-house
Duration: Continuing
Funding: $122,000

Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

Title: **Phase-Change Thermal Storage Evaluation** (Page 4.34)
Contract Number: In-house
Duration: Continuing
Funding: $12,000

Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

Title: **Similarity Studies of Interzone Heat Transfer by Free Convection** (Page 4.33)
Contract Number: In-house
Duration: Continuing
Funding: $85,000

Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

Title: **Study of Off-Peak Electrical Auxiliary Heating in Passive Buildings** (Page 4.36)
Contract Number: In-house
Duration: Continuing
Funding: $92,000

Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544

Title: **Thermal Performance of Passive Components or Buildings**
Contract Number: In-house
Duration: Continuing
Funding: $252,000

Market Facts
1750 K Street N.W.
Washington, D.C. 20006

Title: **Market Research/Program Support** (Page 4.38)
Contract Number: SERI BO-9-8376-1
Duration: 6/1/80–10/30/80
Funding: $93,000

Memphremagog Group, Inc.
P.O. Box 456
Newport, Vermont 05855

Title: **Performance Evaluation Program Support** (Page 4.39)
Contract Number: SERI-AM-9-8223-1
Duration: 2/1/80–5/31/80
Funding: $71,500

Mid-American Solar Energy Complex
8140 26th Avenue South
Minneapolis, Minnesota 55240

Title: **Institutional** (Page 4.40)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Mid-American Solar Energy Complex
8140 26th Avenue South
Minneapolis, Minnesota 55240

Title: **Market Test (Design/Build Teams)** (Page 4.41)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Mid-American Solar Energy Complex
8140 26th Avenue South
Minneapolis, Minnesota 55240

Title: **MASEC Solar 80 Program** (Page 4.42)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Mid-American Solar Energy Complex
8140 26th Avenue South
Minneapolis, Minnesota 55240

Title: **Passive Small Workshops** (Page 4.43)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Mid-American Solar Energy Complex
8140 26th Avenue South
Minneapolis, Minnesota 55240

Title: **Passive Solar Vocational-Technical Training Institute** (Page 4.44)
Contract Number: In-house
Duration: Continuing
Funding: In-house

NAHB Research Foundation
P.O. Box 1627
Rockville, Maryland 20850

Title: **Passive Solar Design/Single Family Residences** (Page 4.45)
Contract Number: DE-FG02-79CS30300
Duration: 9/25/79–3/4/81
Funding: $130,000

National Fenestration Council
3310 Harrison Street
Topeka, Kansas 66611

Title: **Optimizing Solar Utilization through Glazing Usage in Residential Buildings** (Page 4.46)
Contract Number: DE-FG03-80CS30229
Duration: 12/1/79–7/17/81
Funding: $70,000

National Homes Manufacturing Company
P.O. Box 7680
Lafayette, Indiana 47903

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.47)
Contract Number: DE-FC02-80CS30377
Duration: 10/1/79–12/31/80
Funding: $145,019

Northeast Solar Energy Center
470 Atlantic Avenue
Boston, Massachusetts 02110

Title: **Consumer Education** (Page 4.48)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Northeast Solar Energy Center
470 Atlantic Avenue
Boston, Massachusetts 02110

Title: **Incentives** (Page 4.49)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Northeast Solar Energy Center
470 Atlantic Avenue
Boston, Massachusetts 02110

Title: **Passive Market Design Development** (Page 4.50)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Northeast Solar Energy Center
70 Atlantic Avenue
Boston, Massachusetts 02110

Title: **Public Information**
(Page 4.51)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Northern Homes of Pennsylvania, Inc.
Route 2, Box 515
Chambersburg, Pennsylvania 17201

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.52)
Contract Number: DE-FC02-80CS30378
Duration: 10/1/79–10/31/80
Funding: $49,872

Pan Abode, Inc.
4350 Lake Washington Blvd., North
Renton, Washington 98055

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.53)
Contract Number: DE-FC02-80CS30379
Duration: 10/1/79–12/31/80
Funding: $35,364

Princeton Energy Group
245 Nassau Street
Princeton, New Jersey 08540

Title: **Passive Water Wall and Focusing Roof Aperture Solar Heating Building Experiment** (Page 4.54)
Contract Number: EG-77-G-04-4149
Duration: 9/30/77–5/31/80
Funding: $62,317

Public Service Company of New Mexico
P.O. Box 2267
Albuquerque, New Mexico 87103

Title: **Analysis of the Passive Solar/Electric Utility Interface** (Page 4.55)
Contract Number: DE-AC04-79CS30173
Duration: 12/10/79–12/31/83
Funding: $43,500

Ryan Homes, Inc.
100 Ryan Court
Pittsburgh, Pennsylvania 15205

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.56)
Contract Number: DE-FC02-80CS30380
Duration: 10/1/79–12/31/80
Funding: $40,545

Silvercrest Industries
8700 Stanton Avenue
Buena Park, California 90620

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.57)
Contract Number: DE-FC02-80CS30381
Duration: 10/1/79–9/30/80
Funding: $45,500

Skytherm Processes and Engineering
2425 Wilshire Boulevard
Los Angeles, California 90057

Title: **Skytherm Design Evaluation/Phoenix**
(Page 4.58)
Contract Number: ET-78-G-03-1842
Duration: 9/19/77–9/30/80
Funding: $51,980

Skytherm Processes and Engineering
2425 Wilshire Boulevard
Los Angeles, California 90057

Title: **Skytherm Production Research/Atascadero**
(Page 4.59)
Contract Number: EM-78-G-03-1825
Duration: 2/1/78–3/1/80
Funding: $112,700

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Basic Physical Studies**
(Page 4.60)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Denver Metro Home Builders Program**
(Page 4.61)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Passive Building Performance Evaluation at the Class B Level** (Page 4.62)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Passive Building Performance Evaluation at the Class C Level** (Page 4.63)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Passive Solar Manufactured Buildings**
(Page 4.64)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Environmental Engineering Company
2524 E. Ravine Drive
Fort Collins, Colorado 80524

Title: **Solar Index**
(Page 4.65)
Contract Number: DE-AC02-78ET-20090
Duration: Continuing
Funding: $200,000

Southern Solar Energy Center
61 Perimeter Park
Atlanta, Georgia 30341

Title: **Codes and Standards**
(Page 4.66)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Southern Solar Energy Center
61 Perimeter Park
Atlanta, Georgia 30341

Title: **Passive Market Analysis**
(Page 4.67)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Southern Solar Energy Center
61 Perimeter Park
Atlanta, Georgia 30341

Title: **Passive Retrofit Project**
(Page 4.79)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Southern Solar Energy Center
61 Perimeter Park
Atlanta, Georgia 30341

Title: **Regional Cooling Design**
(Page 4.68)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Southern Solar Energy Center
61 Perimeter Park
Atlanta, Georgia 30341

Title: **Residential Passive Market Test Project**
(Page 4.70)
Contract Number: In-house
Duration: Continuing
Funding: In-house

otal Environmental Action, Inc.
hurch Hill
Harrisville, New Hampshire 03450

Title: **Determination of Passive System Costs and Cost Goals** (Page 4.72)
Contract Number: EM-78-C-01-5233
Duration: 9/1/78–12/31/80
Funding: $115,000

Ueland & Junker
1616 Walnut Street, Suite 1500
Philadelphia, Pennsylvania 19103

Title: **Solar Atrium: A Hybrid Solar Heating and Cooling System** (Page 4.74)
Contract Number: EG-77-G-04-4135
Duration: 9/19/77–2/1/81
Funding: $42,528

Unibilt Industries, Inc.
4671 Poplar Creek Road
Vandalia, Ohio 45377

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.76)
Contract Number: DE-FC02-80CS30384
Duration: 10/1/79–12/31/80
Funding: $52,969

University of California/San Diego

LaJolla, California 92093

Title: **Controls for Passive Solar Heated Houses** (Page 4.78)
Contract Number: DE-AC02-80CS30260
Duration: 6/15/80–6/14/81
Funding: $80,000

University of Delaware
Institute of Energy Conversion
Neward, Delaware 19711

Title: **Application of Phase Change Materials in Passive Solar Systems** (Page 4.80)
Contract Number: DE-FG04-79CS34146
Duration: 9/30/77–9/30/79
Funding: $59,130

University of South Dakota
Dept. of Earth Science/Physics
Vermillion, South Dakota 57069

Title: **Passive Solar Heating of Buildings with an Attached Greenhouse** (Page 4.82)
Contract Number: DE-AC02-79CS30242
Duration: 8/31/79–8/30/80
Funding: $20,000

Usry, Inc.
1415 Chamberlayne Avenue
Richmond, Virginia 23261

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.84)
Contract Number: DE-FC02-80CS30385
Duration: 10/1/79–11/1/80
Funding: $23,290

Utah State University
Dept. of Landscape Archit.
Logan, Utah 84322

Title: **Passive Cooling of Plants** (Page 4.85)
Contract Number: SERI AM-9-8261-1
Duration: 3–31/79–3/31/82
Funding: $5,228

W. Scott Morris
P.O. Box 4815
Santa Fe, New Mexico 87502

Title: **Natural Convection Solar Heating Systems** (Page 4.86)
Contract Number: DE-AC02-79CS30243
Duration: 9/15/79–9/14/81
Funding: $30,350

Western Solar Utilization Network
715 S. W. Morrison
Portland, Oregon 97205

Title: **Education Program** (Page 4.87)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Western Solar Utilization Network
715 S. W. Morrison
Portland, Oregon 97205

Title: **Institutional**
(Page 4.88)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Western Solar Utilization Network
715 S. W. Morrison
Portland, Oregon 97205

Title: **Market Testing and Applications**
(Page 4.90)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Western Solar Utilization Network
715 S. W. Morrison
Portland, Oregon 97205

Title: **Training, Information and Education Programs**
(Page 4.91)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Wick Building Systems, Inc.
400 South Mitchell Road
Chillicothe, Missouri 64601

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 4.92)
Contract Number: DE-FC02-80CS30387
Duration: 10/1/79–12/31/80
Funding: $83,016

COMMERCIAL BUILDING PROJECTS

AIA Research Corporation
1795 New York Avenue, NW
Washington, D.C. 20006

Title: **National Passive Program Support Research**
(Page 5.2)
Contract Number: DE-AC02-79C30120
Duration: 2/12/79–10/31/80
Funding: $249,995

Alaska Department of Transportation
P.O. Box F, 2301 Peger Road
Fairbanks, Alaska 99708

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.1)
Contract Number: DE-FC02-80CS30321
Duration: 10/1/79–12/31/80
Funding: $40,892

Argonne National Laboratory
9800 South Cass Avenue
Argonne, Illinois 60439

Title: **Long Term Ice Storage for Cooling Applications Using Passive Freezing Techniques** (Page 5.3)
Contract Number: 49583
Duration: Continuing
Funding: Continuing

Banes Company, Inc.
P.O. Box 6437
Albuquerque, New Mexico 87197

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 5.4)
Contract Number: DE-FC02-80CS30364
Duration: 10/1/79–12/31/80
Funding: $46,740

Banwell, White and Arnold
West Wheelock Street
Hanover, New Hampshire 03755

Title: **White Mountain School Faculty Housing and Dormitory** (Page 5.6)
Contract Number: EG-77-G-04-4139
Duration: 9/30/77–9/30/80
Funding: $25,000

Bessemer Board of Education
412 17th Street North
Bessemer, Alabama 35020

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.8)
Contract Number: DE-FC02-80CS30324
Duration: 10/1/79–5/30/80
Funding: $50,750

Bureau of Science Education
State Education Department
Albany, New York 12234

Title: **Secondary School Solar Curriculum** (Page 5.5)
Contract Number: DE-AC01-77-CS34039
Duration: Continuing
Funding: $632,000

Butler Manufacturing Company
P.O. Box 917, Penn Valley Park
Kansas City, Missouri 64141

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 5.10)
Contract Number: DE-FC02-80CS30366
Duration: 10/1/79–9/30/81
Funding: $335,818

Butler Manufacturing Company
P.O. Box 917, Penn Valley Park
Kansas City, Missouri 64141

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 5.11)
Contract Number: DE-FC02-80CS30367
Duration: 10/1/79–12/31/80
Funding: $71,100

Carnegie-Mellon University
5000 Forbes Avenue
Pittsburgh, Pennsylvania 15213

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.12)
Contract Number: DE-FC02-80CS30326
Duration: 10/1/79–12/31/80
Funding: $42,859

CCB/Cumali Associates
2930 Lakeshore Avenue
Oakland, California 94610

Title: **Passive Solar Calculation Methods** (Page 5.14)
Contract Number: EM-78-C-01-5221
Duration: 6/1/77–12/31/79
Funding: $83,000

City of Boston
City Hall
Boston, Massachusetts 02201

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.16)
Contract Number: DE-FC02-80CS30327
Duration: 10/1/79–6/1/80
Funding: $14,428

City of Mount Airy
P.O. Box 70
Mount Airy, North Carolina 27030

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.17)
Contract Number: DE-FC02-80CS30329
Duration: 10/1/79–12/31/80
Funding: $31,706

City of Lincoln
555 South 10 Street
Lincoln, Nebraska 68508

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.18)
Contract Number: DE-FC02-80CS30328
Duration: 10/1/79–3/31/80
Funding: $21,670

City of Philadelphia
1020 Municipal Services Building
Philadelphia, Pennsylvania 19107

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.20)
Contract Number: DE-FC02-80CS30330
Duration: 10/1/79–9/30/80
Funding: $13,130

Colorado Mountain College
182 West 6th, Box 1367
Glenwood Springs, Colorado 81601

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.22)
Contract Number: DE-FC02-80CS30331
Duration: 10/1/79–9/1/80
Funding: $34,400

Colorado State University
Solar Engineering Application Lab.
Fort Collins, Colorado 80523

Title: **REPEAT Facility (Reconfigurable Passive Evaluation Analysis and Test Facility)** (Page 5.24)
Contract Number: DE-AC02-80CS30259
Duration: 11/1/79–7/31/83
Funding: $300,000

Comal County Mental Health Center
158 W. Austin Street
New Braunfels, Texas 78130

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.28)
Contract Number: DE-FC02-80CS30333
Duration: 10/1/79–10/1/80
Funding: $22,897

Community United Methodist Church
1600 West Broadway
Columbia, Missouri 65201

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.26)
Contract Number: DE-FC02-80CS30334
Duration: 10/7/79–11/20/80
Funding: $52,138

Consolidated Properties, Inc.
32 E. Main Street
Berryville, Virginia 22611

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 5.29)
Contract Number: DE-FC02-80CS30369
Duration: 10/1/79–9/30/80
Funding: $25,129

Deadwood Creek Services, Inc.
Box 15
Deadwood, Oregon 97430

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.34)
Contract Number: DE-FC02-80CS30336
Duration: 10/1/79–11/30/80
Funding: $18,390

Department of Aging, Baltimore County
21 West Susquehanna Avenue
Towson, Maryland 21204

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.30)
Contract Number: DE-FC02-80CS30323
Duration: 10/1/79–12/31/80
Funding: $32,000

Department of the Army
Construction Engineering Research Laboratory
Champaign, Illinois 61820

Title: **Enhancement of BLAST Computer Program** (Page 5.32)
Contract Number: DE-AC02-79CS30239
Duration: 6/1/79–5/31/80
Funding: $62,000

Early Insights
14154 W. 1st Drive
Golden, Colorado 80401

Title: **Characterization of Potential Markets for Passive Solar Technologies** (Page 5.35)
Contract Number: SERI AM-9-8307-1
Duration: 6/18/79–9/30/80
Funding: $8,000

⁻-rth Tech Research Corporation
75 Mayfield Road
Odenton, Maryland 21113

Title: **Experimental Investigation of Thermal Properties of Soils** (Page 5.36)
Contract Number: DE-AC03-80SF11509
Duration: 8/30/80–8/30/82
Funding: $254,450

Energy Alternatives, Inc.
508 Nevada Highway
Boulder City, Nevada 89005

Title: **Development of a Compact Dual-Effect Regenerative Evaporative Cooler** (Page 5.37)
Contract Number: DE-FC03-80SF11507
Duration: 9/30/80–11/30/81
Funding: $92,414

Energy Materials Research Company
1028 Keith Avenue
Berkeley, California 94708

Title: **Development of a Temperature Switchable Desiccant Material** (Page 5.38)
Contract Number: DE-FC03-80SF11506
Duration: 9/30/80–9/30/81
Funding: $29,000

Energy Materials Research Company
1028 Keith Avenue
Berkeley, California 94708

Title: **Radiative Cooling Material Development** (Page 5.39)
Contract Number: DE-FC03-80SF11504
Duration: 9/30/80–11/30/81
Funding: $88,732

Environmental Research Laboratory
The University of Arizona
Tucson, Arizona 85706

Title: **Passive Cooling Experimental Facility Hot/Arid Climate** (Page 5.40)
Contract Number: DE-AC03-80SF10816
Duration: 8/18/80–8/17/83
Funding: $974,000

Eureka Laboratories
215 26th Street
Sacramento, California 95816

Title: **Experimental Investigation of Thermally Induced Ventilation in Atria** (Page 5.41)
Contract Number: DE-AC03-80SF11511
Duration: 9/30/80–9/30/82
Funding: $245,000

Georgia Tech Research Institute
Dept. of Architecture
Atlanta, Georgia 30301

Title: **Investigation of Passive Cooling Techniques for Hot-Humid Climates** (Page 5.42)
Contract Number: DE-AC02-77CS30238
Duration: 6/1/79–10/1/82
Funding: $234,545

Girl Scouts of Greater Philadelphia
1411 Walnut Street
Philadelphia, Pennsylvania 19102

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.44)
Contract Number: DE-FC02-80CS30338
Duration: 10/1/79–12/31/80
Funding: $24,550

Gulf States Manufacturers, Inc.
P.O. Box 1128
Starkville, Mississippi 39759

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 5.46)
Contract Number: DE-FC02-80CS30374
Duration: 10/1/79–12/31/80
Funding: $52,000

Gunnison County
200 E. Virginia Avenue
Gunnison, Colorado 81230

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.48)
Contract Number: DE-FC02-80CS30339
Duration: 10/1/79–11/30/80
Funding: $55,655

Hispano-American Multi-Service Center
617 E. North Street
Indianapolis, Indiana 46204

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.49)
Contract Number: DE-FC02-80CS30340
Duration: 10/1/79–9/1/80
Funding: $18,474

Institute of Public Administration
1717 Massachusetts Avenue
Washington, D.C. 20036

Title: **Commercialization Program Support** (Page 5.52)
Contract Number: SERI XM-9-8242-1
Duration: 2/1/80–5/31/80
Funding: $93,500

Irvine Unified School District
2941 Alton Avenue
Irvine, California 92714

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.50)
Contract Number: DE-FC02-80CS30341
Duration: 10/1/79–12/30/80
Funding: $42,245

Gordon D. Kieffer
021 Turner Street
Wausau, Wisconsin 54401

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.53)
Contract Number: DE-FC02-80CS30343
Duration: 10/1/79–10/15/80
Funding: $8,212

Ron Lau
1547d Pacific Avenue
Santa Cruz, California 95060

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.54)
Contract Number: DE-FC02-80CS30344
Duration: 10/1/79–12/31/80
Funding: $34,000

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Title: **Heat Transfer Analysis** (Page 5.56)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Title: **Infrared Sky Radiation/Radiation Assembly Test Facility** (Page 5.57)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Title: **Model Cooling Systems** (Page 5.58)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Title: **Passive Solar Design** (Page 5.59)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Title: **Performance Studies** (Page 5.60)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Madison Industries of Georgia
). Box 131
ᴗᴗnyers, Georgia 30207

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 5.61)
Contract Number: DE-FC02-80CS30375
Duration: 10/1/79–12/31/80
Funding: $55,855

Martin Marietta Aerospace
P.O. Box 179
Denver, Colorado 80201

Title: **SOLPAS Development** (Page 5.62)
Contract Number: DE-AC01-78CS35243
Duration: 10/1/78–6/30/80
Funding: $109,500

Massachusetts Institute of Technology
Department of Architecture
Cambridge, Massachusetts 02139

Title: **Crystal Pavilion – Total Passive Heating Using New Glass Selective Transmitters** (Page 5.63)
Contract Number: DE-AS02-77CS34513
Duration: 11/1/78–3/3/80
Funding: $111,100

Mennonite Home
5353 SE Columbus
Albany, Oregon 97231

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.64)
Contract Number: DE-FC02-80CS30345
Duration: 10/1/79–9/1/80
Funding: $98,540

Miami University
Department of Architecture
Oxford, Ohio 45056

Title: **Patoka Nature Center** (Page 5.66)
Contract Number: EG-77-04-4090
Duration: 9/30/77
Funding: $13,000

Mid-American Solar Energy Complex
8140 26th Avenue South
Minneapolis, Minnesota 55240

Title: **Marketing Activities** (Page 5.67)
Contract Number: In-house
Duration: Continuing
Funding: Continuing

Mid-American Solar Energy Complex
8140 26th Avenue South
Minneapolis, Minnesota 55240

Title: **Solar Utilities Development** (Page 5.68)
Contract Number: In-house
Duration: Continuing
Funding: Continuing

National Bureau of Standards

Washington, D.C. 20234

Title: **Passive Solar Test Procedures, Codes, and Standards** (Page 5.69)
Contract Number: EA-77-A-01-6010
Duration: Continuing
Funding: $769,000

New Mexico State University

Las Cruces, New Mexico 88003

Title: **Performance Evaluation of Experimental Passive Skytherm House** (Page 5.70)
Contract Number: EY-76-S-04-4157
Duration: 9/25/77–7/30/80
Funding: $55,751

Northeast Solar Energy Center
470 Atlantic Avenue
Boston, Massachusetts 02110

Title: **Market Research** (Page 5.72)
Contract Number: In-house
Duration: Continuing
Funding: Continuing

Northeast Solar Energy Center
470 Atlantic Avenue
Boston, Massachusetts 02110

Title: **Outreach Activities** (Page 5.73)
Contract Number: In-house
Duration: Continuing
Funding: Continuing

Northeast Solar Energy Center
470 Atlantic Avenue
Boston, Massachusetts 02110

Title: **System Design** (Page 5.74)
Contract Number: In-house
Duration: Continuing
Funding: Continuing

Office of Physical Planning
MacMillan Bldg., Princeton University
Princeton, New Jersey 08540

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.75)
Contract Number: DE-FC02-80CS30346
Duration: 10/1/79–7/31/80
Funding: $12,780

Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, Tennessee 37830

Title: **Reflective Insulating Blind/Passive Heating and Cooling Techniques** (Page 5.76)
Contract Number: In-house
Duration: Continuing
Funding: $100,000

W. H. Porter, Inc. Poligon[R]
4240 136th Avenue, P.O. Box 1112-B
Holland, Michigan 49423

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 5.78)
Contract Number: DE-FC02-80CS30388
Duration: 10/1/79–11/1/80
Funding: $18,000

Princeton Communications Park Associates
RD 4, Box 864, Mapleton Road
Princeton, New Jersey 08540

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.80)
Contract Number: DE-FC02-80CS30348
Duration: 10/1/79–12/31/80
Funding: $44,040

Rensselaer Polytechnic Institute

Troy, New York 12181

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.82)
Contract Number: DE-FC02-80CS30350
Duration: 10/1/79–2/1/80
Funding: $80,781

Rocks and Trees Cooperative Land Preserve
Box 1001
Middletown Springs, Vermont 05757

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.84)
Contract Number: DE-FC02-80CS30351
Duration: 10/1/79–12/31/80
Funding: $4,409

St. Mary's Parish
310 Duke Street
Alexandria, Virginia 22314

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.86)
Contract Number: DE-FC02-80CS30362
Duration: 10/1/79–9/1/80
Funding: $32,500

Security State Bank of Wells
32 S. Broadway
Wells, Minnesota 56097

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.88)
Contract Number: DE-FC02-80CS30353
Duration: 10/1/79–1/15/81
Funding: $94,250

Robert W. Smedley
?1 S. Broadway
Littleton, Colorado 80121

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.90)
Contract Number: DE-FC02-80CS30354
Duration: 10/1/79–12/31/80
Funding: $28,800

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Design Methodologies for Passive Commercial Buildings** (Page 5.92)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **International Programs** (Page 5.93)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **National Program Support** (Page 5.94)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Parametric Studies** (Page 5.95)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Passive Communication Activities** (Page 5.96)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Passive Market Research** (Page 5.97)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Simulation Validation Project** (Page 5.98)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Southern Solar Energy Center
61 Perimeter Park
Atlanta, Georgia 30341

Title: **Information Transfer** (Page 5.99)
Contract Number: In-house
Duration: Continuing
Funding: Continuing

Spancrete Industries, Inc.
10919 W. Bluemound Road
Milwaukee, Wisconsin 53226

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 5.100)
Contract Number: DE-FC02-80CS30382
Duration: 10/1/79–12/31/80
Funding: $62,926

Structures Unlimited, Inc.
P.O. Box 4105
Manchester, New Hampshire 03108

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 5.101)
Contract Number: DE-FC02-80CS30383
Duration: 10/1/79–11/30/80
Funding: $41,746

State of California
921 Tenth Street
Sacramento, California 95814

Title: **Commercialization of Passive Solar Energy** (Page 5.108)
Contract Number: DE-AC02-79CS30245 & -79CS30246
Duration: 6/1/79–3/1/80
Funding: $21,650

Sunbelt Communications, Ltd.
2000 Indian School Road N.W.
Albuquerque, New Mexico 87104

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.102)
Contract Number: DE-FC02-80CS30355
Duration: 10/1/79–9/1/80
Funding: $12,958

Sunflower Solar, Inc.
1864 Sullivan Road
College Park, Georgia 30337

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.104)
Contract Number: DE-FC02-80CS30356
Duration: 10/1/79–11/30/80
Funding: $28,200

Syracuse Research Corporation
Merrill Lane
Syracuse, New York 13210

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.106)
Contract Number: DE-FC02-80CS30357
Duration: 10/1/79–9/1/80
Funding: $43,000

Plato Touliatos
2018 Brooks Road
Memphis, Tennessee 38116

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.109)
Contract Number: DE-FC02-80CS30359
Duration: 10/1/79–12/31/80
Funding: $21,388

Trinity University
715 Stadium Drive
San Antonio, Texas 78284

Title: **Development of a High Efficiency Vapor Compression Dehumidifier** (Page 5.110)
Contract Number: DE-FC03-80SF11505
Duration: 9/30/80–12/31/81
Funding: $96,250

Trinity University
715 Stadium Drive
San Antonio, Texas 78284

Title: **Evaporative, Radiative and Convective Cooling Processes and Systems** (Page 5.111)
Contract Number: DE-AC03-77CS31600
Duration: Continuing
Funding: $100,098

Trinity University
715 Stadium Drive
San Antonio, Texas 78284

Title: **Passive Test Facility** (Page 5.112)
Contract Number: DE-AC03-79CS30201
Duration: 4/1/79–12/31/80
Funding: $360,000

Underground Space Center
University of Minnesota
Minneapolis, Minnesota 55455

Title: **Thermal Modeling of Earth Contact Structures** (Page 5.114)
Contract Number: DE-AC03-80SF11508
Duration: 9/30/80–12/31/81
Funding: $383,359

iversity of Central Florida
'0 State Road 401
Cape Canaveral, Florida 32920

Title: **Passive Cooling by Natural Ventilation** (Page 5.115)
Contract Number: DC-AC03-80SF11510
Duration: 8/30/80–8/30/82
Funding: $405,274

University of Pennsylvania
Dept. of Arch., 110 Fine Arts Bldg.
Philadelphia, Pennsylvania 19174

Title: **Development of Passive Design Curricula for Professional Schools of Architecture** (Page 5.116)
Contract Number: DE-AC02-79CS30241
Duration: 7/2/79–9/30/81
Funding: $405,012

University of Southern California
Mechanical Engineering Department
Los Angeles, California 90007

Title: **Elementary School Solar Curriculum** (Page 5.117)
Contract Number: EY-76-S-03-0113
Duration: Continuing
Funding: $254,000

The University of Texas

Austin, Texas 78712

Title: **DEROB Development** (Page 5.118)
Contract Number: DE-AC02-80CS30254
Duration: 6/1/80–6/30/83
Funding: $50,000

Walker Field Public Airport
P.O. Box 2400
Grand Junction, Colorado 81502

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.119)
Contract Number: DE-FC02-80CS30360
Duration: 10/1/79–8/31/80
Funding: $38,907

Western Solar Utilization Network
715 S. W. Morrison
Portland, Oregon 97205

Title: **Alternative Strategies for Working Capital** (Page 5.120)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Western Solar Utilization Network
715 S. W. Morrison
Portland, Oregon 97205

Title: **Information/Outreach Program** (Page 5.121)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Western Solar Utilization Network
715 S. W. Morrison
Portland, Oregon 97205

Title: **State Special Projects** (Page 5.122)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Western Solar Utilization Network
715 S. W. Morrison
Portland, Oregon 97250

Title: **Systems Development** (Page 5.123)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Willow Park II Community Improvement Association
P.O. Box 103
Missouri City, Texas 77459

Title: **Passive Solar Commercial Buildings Design Assistance and Demonstration** (Page 5.124)
Contract Number: DE-FC02-80CS30361
Duration: 10/1/79–12/31/80
Funding: $19,012

Ying Manufacturing Company
1957 West 144th Street
Gardena, California 90249

Title: **Nocturnal Air Cooling for Nonresidential Buildings** (Page 5.125)
Contract Number: EG-77-G-04-4140
Duration: 9/30/77–12/31/79
Funding: $58,718

SOLAR PRODUCT PROJECTS

ABRI
888 Mass Avenue
Cambridge, Massachusetts 02139

Title: **Marketable Products for Passive Solar Applications** (Page 6.1)
Contract Number: DE-FC02-80CS30518
Duration: 9/15/80–8/31/81
Funding: $122,000

Capitol Products
P.O. Box 3070
Harrisburg, Pennsylvania 17105

Title: **Marketable Products for Passive Solar Applications** (Page 6.2)
Contract Number: DE-FC02-80CS30519
Duration: 9/15/80–5/31/82
Funding: $89,605

Communico/Crimsco
5001 East 59th Street
Kansas City, Missouri 64130

Title: **Marketable Products for Passive Solar Applications** (Page 6.4)
Contract Number: DE-FC02-80CS30520
Duration: 8/1/80–8/15/81
Funding: $71,502

Dow Corning Corporation
P.O. Box 1592
Midland, Michigan 48640

Title: **Marketable Products for Passive Solar Applications** (Page 6.5)
Contract Number: DE-FC02-80CS30521
Duration: 8/1/80–7/31/81
Funding: $58,567

Four Seasons Solar Products Corporation
910 Route 110
Farmingdale, New York 11735

Title: **Marketable Products for Passive Solar Applications** (Page 6.6)
Contract Number: DE-FC02-80CS30522
Duration: 8/1/80–4/81
Funding: $90,000

Hitek, Inc.
42673 Amos Creek Drive
Sweet Home, Oregon 97386

Title: **Marketable Products for Passive Solar Applications** (Page 6.7)
Contract Number: DE-FC02-80CS30523
Duration: 9/15/80–7/31/81
Funding: $58,164

trel Service Company
_ ɔx 1247
Nashua, New Hampshire 03061

Title: **Marketable Products for Passive Solar Applications** (Page 6.8)
Contract Number: DE-FC02-80CS30524
Duration: 9/15/80–3/31/81
Funding: $15,352

Kool View Company, Inc.
6701 Scybold Road
Madison, Wisconsin 53719

Title: **Marketable Products for Passive Solar Applications** (Page 6.10)
Contract Number: DE-FC02-80CS30525
Duration: 9/15/80–3/31/82
Funding: $50,070

Northeast Solar Energy Center
470 Atlantic Avenue
Boston, Massachusetts 02110

Title: **Passive Solar Catalog** (Page 6.11)
Contract Number: In-house
Duration: Continuing
Funding: In-house

One Design, Inc.
Mountain Falls Route
Winchester, Virginia 22601

Title: **Marketable Products for Passive Solar Applications** (Page 6.12)
Contract Number: DE-FC02-80CS30526
Duration: 8/1/80–1/31/82
Funding: $86,667

One Design, Inc.
Mountain Falls Route
Winchester, Virginia 22601

Title: **Marketable Products for Passive Solar Applications** (Page 6.13)
Contract Number: DE-FC02-80CS30527
Duration: 8/1/80–9/30/81
Funding: $169,932

Solar Central
7213 Ridge Road
Mechanicsburg, Ohio 43044

Title: **Marketable Products for Passive Solar Applications** (Page 6.14)
Contract Number: DE-FC02-80CS30528
Duration: 9/15/80–9/30/81
Funding: $92,341

Solar Concept Development Co.
P.O. Box 601
Davis, California 95616

Title: **Marketable Products for Passive Solar Applications** (Page 6.15)
Contract Number: DE-FC02-80CS30529
Duration: 9/15/80–2/28/82
Funding: $71,710

Solar Resources, Inc.
P.O. Box 1848
Taos, New Mexico 87571

Title: **Marketable Products for Passive Solar Applications** (Page 6.16)
Contract Number: DE-FC02-80CS30530
Duration: 9/15/80–3/31/81
Funding: $93,045

Solar Systems Design, Inc.
R.D. 3, Box 239
Selkirk, New York 12158

Title: **Marketable Products for Passive Solar Applications** (Page 6.9)
Contract Number: DE-FC02-80CS30531
Duration: 9/15/80–7/31/81
Funding: $37,000

Suncarth Solar
R.D. 1, Box 337
Green Lane, Pennsylvania 18054

Title: **Marketable Products for Passive Solar Applications** (Page 6.18)
Contract Number: DE-FC02-80CS30581
Duration: 9/15/80–3/31/81
Funding: $12,229

Sunspool Corporation
439 Tasso Street
Palto Alto, California 94301

Title: **Marketable Products for Passive Solar Applications** (Page 6.19)
Contract Number: DE-FC02-80CS30533
Duration: 9/15/80–7/31/81
Funding: $75,172

Suntek Research Associates
3961 E. Bayshore Road
Palo Alto, California 94301

Title: **Marketable Products for Passive Solar Applications** (Page 6.20)
Contract Number: DE-FC02-80CS30583
Duration: 8/1/80– 7/31/81
Funding: $85,631

Syracuse Research Corporation
Merrill Lane
Syracuse, New York 13210

Title: **Marketable Products for Passive Solar Applications** (Page 6.21)
Contract Number: DE-FC02-80CS30584
Duration: 9/19/80–2/28/81
Funding: $22,168

Thermal Technology Corporation
Box 130
Snowmass, Colorado 81654

Title: **Marketable Products for Passive Solar Applications** (Page 6.22)
Contract Number: DE-FC02-80CS30585
Duration: 9/22/80–5/31/81
Funding: $81,512

University of Delaware
1 Pike Creek Center
Wilmington, Delaware 19711

Title: **Marketable Products for Passive Solar Applications** (Page 6.24)
Contract Number: DE-FC02-80CS30586
Duration: 9/15/80–7/31/81
Funding: $11,765

SOLAR CITIES AND TOWNS PROJECTS

Marin Solar Village Corporation
975 Grand Avenue
San Rafael, California 94904

Title: **Marin Solar Village** (Page 7.1)
Contract Number: DE-FG03-80CS30313
Duration: 12/1/79–12/31/80
Funding: $133,000

National Bureau of Standards

Washington, D.C. 20234

Title: **Passive Solar Potential in Urban Environments** (Page 7.2)
Contract Number: EA-77-A-01-6010
Duration: Continuing
Funding: Continuing

tional Endowment of the Arts
01 East Street NW
Washington, D.C. 20506

Title: **Design Arts Program**
(Page 7.3)
Contract Number: Interagency Agreement
Duration: Continuing
Funding: Continuing

Northeast Solar Energy Center
470 Atlantic Avenue
Boston, Massachusetts 02110

Title: **Solar Cities**
(Page 7.4)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Northeast Solar Energy Center
470 Atlantic Avenue
Boston, Massachusetts 02110

Title: **Solar Cities Commercialization Projects**
(Page 7.5)
Contract Number: In-house
Duration: Continuing
Funding: In-house

Regional Solar Energy Centers —
Varied Locations

Title: **Solar Cities Solicitation**
(Page 7.6)
Contract Number: In-house
Duration: Not Applicable
Funding: In-house

Sim Van Der Ryn/Calthorpe & Associates
Drawer F
Inverness, California 94938

Title: **A Working Conference on Designing Sustainable Cities** (Page 7.7)
Contract Number: EG-77-C-01-4042
Duration: 12/1/79–12/31/80
Funding: $89,885

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Title: **Solar Cities**
(Page 7.8)
Contract Number: In-house
Duration: Continuing
Funding: In-house

AGRICULTURAL BUILDING PROJECTS

Ames Design Collaborative
2108 5th Street
Ames, Iowa 50010

Title: **Study of Thermal Performance of a Hybrid Solar Residence at Living History Farms** (Page 8.1)
Contract Number: EG-77G-04-4136
Duration: 9/19/77–8/31/80
Funding: $54,500

W. H. Porter, Inc. - Port-R-Span
4240 136th Avenue, P.O. Box 1112-B
Holland, Michigan 49423

Title: **Passive and Hybrid Solar Manufactured Housing and Buildings** (Page 8.2)
Contract Number: DE-FC02-80CS30389
Duration: 10/1/79–11/1/80
Funding: $8,452

APPENDIX B:

Alphabetic list of contractors by State