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Assistant Secretary for
Conservation and Solar Applications
Heating & Cooling Research & Development Branch

Interim Report: National Program Plan for Passive and Hybrid Solar Heating and Cooling

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EXECUTIVE SUMMARY

Objectives

Passive solar systems have the potential to significantly reduce the energy requirements of buildings and communities and stimulate small business growth and employment opportunities in virtually every part of the nation over the next few years.

The objective of the National Program for Passive and Hybrid Solar Heating and Cooling is to promote the widespread application of passive solar design techniques, appropriately integrated with conservation, active solar systems, and other solar technologies. In those cases where adequate modeling capabilities exist, the potential of passive solar energy has been assessed and specific national goals identified. This plan is one element of the Office of Conservation and Solar Application's Multi-Year Program Plan which addresses the accelerated commercialization of solar energy.

Description of the Technology

Passive solar design attempts, within economic constraints, to maximize the benefits of environmental resources and to minimize dependence on fossil fuels and mechanical equipment. This is accomplished by selectively coupling parts of the building to the part of the environment most appropriate to the energy transfer desired at any given time. Passive heating and cooling and lighting represent an assertive attempt to use the environment through judicious interaction with building elements. Mixed use of other solar technologies (i.e., photovoltaics, etc.) integrated in buildings, communities and cities are considered the longer-term hybrid solar applications.

Passive solar heating systems use elements of the building to collect, store, and distribute energy. Passive cooling also uses elements of the building to store and distribute energy, and, when prevailing conditions are favorable, to discharge heat to the cooler parts of the environment (sky, atmosphere, ground). In all cases, energy transfers to and from the building and within the building rely primarily on natural processes, i.e., conduction, convection, and radiation, with minimal dependence on mechanical equipment such as fans, pumps, and compressors. Mechanical equipment can be used effectively to augument natural energy flows for control purposes and/or when the capital cost and operating energy are justified by improved system performance.

Major Barriers to Widespread Use

Successful examples of passive solar buildings have been demonstrated throughout a broad range of U.S. climates. However, a number of key barriers to widespread use have been identified. The key barriers are summarized as follows:

- Technical
  - Lack of marketable designs and products
  - Limited design tools
  - Lack of adequate performance data
- Economic
  - Higher first costs
- Initial deployment
  - Lack of public and industry awareness and understanding
  - Lack of credible information on economic benefits
- Institutional
  - Building codes, zoning, and land use
- Resource availability
  - Lack of qualified designers
- Environmental
  - None

Program Elements

The National Passive and Hybrid Solar Program is organized around two interrelated program areas: Technology Development and Technology Utilization. Together, these two areas are seen as processes for achieving the accelerated, widespread use of passive solar heating and cooling. Within each area tasks are categorized by the following program elements:

- TECHNOLOGY DEVELOPMENT ACTIVITIES
  - Basic Physical Studies
  - Product Development
  - Design Development and Field Test of Buildings, Communities and City Scale Applications
  - Design Tool Development
  - Performance Data Acquisition
- TECHNOLOGY UTILIZATION ACTIVITIES (Market Development)
  - Commercialization Readiness Assessment - Market Analysis
  - Technology Transfer - Training, Information and Education
  - Stimulation of Technology Delivery Capability - Codes, Standards and Supply Incentives
  - Stimulation of Market Demand - Test Marketing, Federal Building Programs and Demand Incentives
  - Program Support

The importance of each task varies greatly, and the process of establishing priorities is now underway. Work on many of the tasks has already been started. Responsibility for administering the Federal portion of this work has been and will continue to be shared by several branches of the Office of Conservation and Solar Applications and other Federal agencies. It is expected that some of this work will be funded by the private sector and that a substantial portion of the federally funded work will be cost-shared by private contractors.

Federal Program Strategy

Passive solar technology is essentially a design procedure with the additional use of passive components. Successful commercialization relies on first, casting the procedure in a form that is amendable to application by the design profession; second, stimulating the profession to apply the procedure; and third, sensitizing both the consuming market and the financial, utility and real estate segments of the economy to the benefits of the procedures through existing channels. The output of a commercialization program will be energy-conserving, cost-effective buildings with emphasis on community and city needs. More specifically, a passive solar design process and passive solar products will become commonplace.

The commercialization strategy for passive solar energy consists of a set of activities which accelerate the availability and widespread utilization of passive solar systems and designs by the building industry. The selection, mix and timing of activities depend greatly on the nature of the technology, and technical, economic and institutional market factors at work within the marketplace. Commercialization of passive solar systems includes proper use of conservation techniques (e.g., insulation, heat recovery, etc.). Furthermore, the process of commercialization involves a proper balance of both supply and demand activities influenced by public and private sector actions. Consumer needs and protection are addressed.

Status of the Program

Comparable emphasis has been put on systems and market development aspects of the program (although the existence of a broad national research and development effort, now in its third year, has provided a basis for somewhat more detailed planning of systems development activities). This balance is extremely. Clearly, achieving market acailability of products, systems and design is essential to the ultimate success of the program.

In spite of the significance of the work already completed, much important research and development remains to be done, Passive solar design involves a variety of climates, building types, thermal conditioning needs, and human lifestyles. To address these parameters, myriad passive solar techniques exist and the state of development of these systems presents a highly varied picture. For example, storage wall and direct-gain heating systems for skin load dominated buildings (such as single-family residences) have been successfully modeled and extensively analyzed for a range of climates and system variables. Furthermore, since these building techniques lie well within the existing capabilities of the construction industry, it is possible to assess the economic factors with reasonable accuracy and to size systems in accordance with an economic model. A similarly thorough examination will be carried out for residential applications of storage roofs, shaded storage roofs, etc. Passive cooling concepts are generally less well understood and are in need of additional research and development.

Applications of passive solar techniques within more general energy management schemes for commercial buildings are far more complicated and less well understood than residential applications. Preliminary indications are that passive solar has the potential to displace a substantial fraction of the primary energy consumed for space heating and cooling, ventilation, hot water, and electric lighting. These functions represent more than 85% of the total primary energy consumption for the existing stock of U.S. commercial buildings, or 12% of the total U.S. energy consumption. The trade-offs between all these energy issues are extremely subtle, and examination of the problem has just begun. Even less well understood, but of equal importance, are urban-scale applications of passive solar.

Status of the Plan

The Plan contains a full range of systems and market support (commercialization) activities for new and retrofit heating and cooling applications to residential and commercial buildings and designs. In addition to space heating and cooling, the Plan contains several tasks related to domestic hot water and daylighting. Eventually, the Plan will be expanded to cover in detail passive domestic hot water and daylighting as well as combined active and passive technologies for buildings and agricultural applications.

Concepts for a variety of passive systems have been generated. On the basis of past development and analysis, a collection of the more promising systems has been identified in Section F of Paragraph II. These systems have become the basis for scheduling tasks in order to evaluate program goals and milestones overtime. These generic systems will receive Federal support and will be evaluated according to their technical, economic and market characteristics.

It is not assumed that these lists exhaust the promising possibilities, nor is it assumed that Government supported development activity will be limited to this list. Unsolicited proposals for the development of promising, innovative systems outside the scope of the lists are welcomed by the Department of Energy.

Schedules for the completion of various development activities related to each of these systems are presented in the appendices. Future versions of the Plan will present more detailed schedules for each system, estimated start and completion dates for each task, cross-referencing of related tasks, cross-referencing for tasks related to two or more task areas, and a priority ranking of tasks and systems by application.

ACKNOWLEDGEMENT

The Department of Energy expresses gratitude to Wayne Place and Ron Kammerud of the Lawrence Berkeley Laboratory, Michael Holtz of the Solar Energy Research Institute, Scott Noll of the Los Alamos Scientific Laboratory, and the numerous other experts and concerned citizens who contributed their time and energy to assist in the preparation of this Plan.

FOREWORD

This interim report on the National Program Plan for Passive and Hybrid Solar Heating and Cooling was prepared by the U.S. Department of Energy (DOE), Office of Conservation and Solar Applications (Passive Solar Program). The Plan is based on a thorough assessment of the present status of passive and hybrid solar heating and cooling. It is written for those familiar with the basics of solar heating and cooling, but not necessarily having a detailed understanding of passive solar systems. The Plan describes the federal program for passive solar systems for buildings and agricultural and industrial process heat applications,† including those activities to be funded in whole or in part by the federal government.

The Plan is supportive of the Department of Energy's objective to stimulate the development of an industrial, commercial, and professional capability for designing, producing, and distributing solar energy systems, thus contributing toward meeting our national energy requirements through the effective use of solar energy. The development and utilization of passive solar heating and cooling are essential elements for accomplishing this objective.

This report complements several previous national programs for solar heating and cooling of buildings, agricultural and industrial process heat, and solar heating and cooling research and development. It is a comprehensive plan addressing not only research and development needs but also activities necessary to support and stimulate the utilization of passive solar systems. To assure the completeness and appropriateness of the Plan, this interim report will be widely circulated for review and comment by all those concerned with the development and utilization of passive solar systems.

Additionally, it is expected that several organizations, such as the American Institute of Architects; the American Society of Heating, Refrigeration, and Air Conditioning Engineers; the National Association of Home Builders; and the Solar Energy Industry Association will conduct formal reviews of this Plan and provide DOE with comments and recommendations.

A final report on the National Program Plan for Passive and Hybrid Solar Heating and Cooling will be issued in late 1979. Comments should be received no later than 30 August 1979, and should be sent to:

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†The present interim report of the National Program Plan for Passive and Hybrid Solar Heating and Cooling does not include activities related to agricultural or industrial process heat applications. However, this section will be prepared and included in the Final Plan.

Mr. Michael Maybaum
Conservation and Solar Applications
U.S. Department of Energy
Washington, D.C. 20545

It is anticipated that this Program Plan will be revised, amended, and updated on a regular basis as results of and experience with implementation become available.

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INTRODUCTION

This report represents the Department of Energy's National Program Plan for Passive and Hybrid Solar Heating and Cooling of Buildings, Domestic Hot Water, and for Agricultural and Industrial Process Applications. It is part of the federal program of research, development, demonstration, and commercialization to establish solar energy as a viable energy resource for the nation. Authority for the establishment of a vigorous federal solar energy program comes from the Solar Energy Research, Development, and Demonstration Act (P.L. 93-473), signed into law on 26 October 1974.

Program planning of solar energy research, development, demonstration, and commercialization is being carried out under guidelines established by P.L. 93-473 and by four other legislative acts passed by the 93rd and 94th Congresses: the Solar Heating and Cooling Demonstration Act of 1974 (P.L. 93-409), the Energy Reorganization Act of 1974 (P.L. 93-438), the Federal Non-Nuclear Energy Research and Development Act of 1974 (P.L. 93-577), and the Energy Conservation and Production Act of 1976 (P.L. 94-385). Together with the Department of Energy Organization Act of 1977 (P.L. 95-75), which consolidated the energy functions of ERDA, FEA, and several other federal agencies into the Department of Energy, these five laws give authority to DOE to undertake a wide range of activities as part of a research, development, demonstration, and commercialization program aimed at effective energy utilization. This program is spelled out in part in the "Definition Report: National Solar Energy Research, Development, and Demonstration Program" (ERDA-49).

The primary goal of the program is to work with industry in the development and early introduction of economically competitve and environmentally acceptable solar energy systems to help meet national energy requirements. One element of the program, Direct Thermal Application, has as its purpose the accelerated, widespread application of solar heating and cooling and solar process heating systems that are economically viable as well as socially and environmentally acceptable. This program element has two interrelated subprograms: Solar Heating and Cooling of Buildings, and Agricultural and Industrial Process Heat Applications. DOE has prepared program plans for each of these applications--National Program for Solar Heating and Cooling of Buildings (ERDA 76-6) and Program Description: Solar Energy for Agricultural and Industrial Process Heat (ERDA 76-88)--as well as a detailed Solar Heating and Cooling Research and Development Plan (DOE/CS-0008). The present Program Plan is a comprehensive set of activities related to the development and use of passive solar heating and cooling that is only generally outlined in the other three documents.

In this Plan, it is recognized that the application of passive solar heating and cooling involves, to a significant degree, existing materials, components, and assemblies such as glazings, concrete and masonry products, and insulation, that are commonly used in the construction industry. It is the application and design of these materials, components, and assemblies into an architectural form that controls natural energy flows through the structure (from and between collection, storage, and the space) that constitutes most passive solar heating and cooling systems. Furthermore, since many of the key components for passive solar systems exist or are under development, the Plan builds upon this existing technology. By supporting work on a wide range of problems, the Plan seeks to assist the industry (including manufacturers, designers, suppliers, installers, consumers, regulators, lenders, researchers, and legislators) in developing cost-effective components and systems, and the capability to effectively and appropriately use passive solar heating and cooling. The Plan seeks to balance the emphasis on problems surrounding the development of passive solar systems with those problems surrounding the utilization of passive solar systems. Only with a conscious concern for and a directed program in both areas will the accelerated, widespread use of passive solar heating and cooling for buildings and for agricultural and industrial processes occur.

Government's Role

As in all federal program plans, an important issue is the nature and extent of the government's role in the processes of developing a technology and facilitating its use. The stated federal goal of energy related research, development, demonstration, and commercialization is to perform a supplementary role: to support what is not or cannot be supported by the private sector. This focus implies that federal involvement in technology development and utilization should build on an existing industry capability; that the government should engage in areas of research, development, demonstration, and commercialization in which industry cannot; or that the urgency of the problem/need and the degree of the risk is such that federal participation is required to accelerate the development and utilization of a technology.

This intent is clearly stated in legislation establishing the National Solar Energy Research, Development, Demonstration, and Commercialization Program. The Solar Energy Research, Development, and Demonstration Act of 1974 states that it is the policy of the federal government to:

- pursue a vigorous program of research assessment of solar energy as a major source of energy for our national needs; and
- provide for the development and demonstration of practical means to employ solar energy at a commercial scale.

Just as importantly, this Act, as well as the Federal Non-Nuclear Energy Research and Development Act of 1974 and the Solar Heating and Cooling Demonstration Act of 1974, outlines the decision criteria that should be used by federal agencies in the technology development and utilization process. These include:

- a determination of the extent of the problem and whether the objectives of the program are national or widespread in their significance;

- the urgency of the public need for the potential results of the program, the immediate and potential applications of the solar energy that would be collected and converted to useful forms by the program, and the effect of the energy produced in conserving other non-renewable forms of energy and yet facilitating the availability of adequate supplies of energy to all regions of the United States;

- the technological feasibility of the program, including improvements that it might provide in the efficiency of energy production and use, the reduction of waste materials or waste energy, and the potential of the program for production of net energy;

- the potential economic viability of the process that would be developed by the program, as determined by an economic assessment of how competitive its energy products would be with those of processes using either alternative sources of energy or alternative technologies;

- the environmental and social impacts and consequences of the systems produced as a result of the program and, in particular, the impacts of the use of water required at the commercial application stage;

- the potential for the transfer of the technology developed from the federal government to the private sector and to other applications;

- the nature and extent of federal participation, if any, required in the program and, in particular, consideration of the following questions:

  (1) Are there potential opportunities for non-federal interests to recapture the federal investment in the undertaking through normal commercial utilization of proprietary knowledge gained during the project, and are opportunities sufficient to encourage timely results?

  (2) Are there potential opportunities to induce non-federal support of the undertaking through regulatory actions,

end-use controls, tax and price incentives, public education, or other alternatives to direct federal financial assistance?

(3) Is the degree of risk involved in developing and implementing the program too high to encourage non-federal entities to undertake such actions?

(4) Does the magnitude of the investment required to undertake the program appear to exceed the financial capabilities of non-federal entities that might otherwise be encouraged to undertake such actions?

These criteria have been considered during the preparation of this Program Plan. However, it is recognized that our present knowledge of performance and costs of passive solar heating and cooling is limited. Consequently, many of the recommended tasks are directed toward developing the information necessary to more fully determine appropriate government action.

Technology Status

As part of the preparation of this National Program Plan, a meeting† was held with representatives from industry, universities, and federal and state government agencies. The objectives of this meeting were to:

- assess the present state of the art of passive solar heating and cooling, both in terms of the development and utilization of the technology;

- identify major problems limiting improved performance, reduced costs, and/or widespread utilization; and

- recommend short- and long-term tasks to solve these problems.

Subsequently, numerous other meetings were held in support of DOE's Commercialization Readiness Assessment to identify energy technologies that can have a significant near-term impact on energy consumption. These meetings, held throughout the summer and fall of 1978, involved hundreds of individuals from the design professions, commercial and residential construction industry, utilities, lending institutions, state and local governments, national laboratories,

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†The meeting was held in Reston, Virginia, 31 October - 2 November 1977, and was attended by 70 individuals with expertise in passive solar heating and cooling.

regional solar energy centers, manufacturers and suppliers, and consumers. The purposes of these meetings were to assess the commercial readiness of passive solar systems, including a determination of market penetration and energy displacement, and to propose a commercialization strategy for accelerating the widespread application of passive techniques.

From these meetings, a review of the literature, and other discussions, the status of passive solar heating and cooling was defined. The following points became clear.

- Passive solar systems can provide a major part of a building's thermal energy requirements.
- Passive solar systems are, in general, more cost-effective than active systems.
- For passive heating, potential overall system efficiencies are high because of the low temperatures of collection.
- The state of the art varies greatly for different passive solar systems. Passive cooling is generally much less developed than passive solar heating and, to date, very few passive cooling systems have been successfully demonstrated.
- Passive solar design concepts and climatic regions are so varied that careful analysis is required to determine the most cost-effective systems for different applications.
- Emphasis to date has been directed primarily to new residential buildings. Significant opportunities exist for the use of passive solar systems in new commercial buildings and in existing residential and commercial buildings.
- The two major problems to be addressed are user-oriented design methods and increasing the awareness, knowledge, and understanding of passive solar systems by the building industry and the general public.
- A large body of knowledge and information exists that directly or indirectly relates to passive solar systems. However, this information is generally not widely known or applied to passive solar design. A major effort should be undertaken to identify, collect, evaluate, repackage (if necessary), and disseminate this information.
- The potential for early commercialization and significant energy impact is high because many simple passive solar approaches are cost-effective in almost every part of the country today.

- o Passive systems are based upon the effective use of common building materials and construction techniques resulting in minimum likelihood of malfunction. Their high relability results from using few moving parts, moderate operating temperature ranges of components, and use of time-proven materials.

- o Operating costs are negligible and maintenance is very small compared to capitalization expense.

- o Although development of some specialized products would be helpful, most materials, manufactured products, and construction methods needed for commercialization are now commonly employed in building construction.

- o Few institutional barriers exist to the widespread application of passive systems and those that do exist can be overcome through an effective commercialization program.

- o Widespread use of passive solar systems poses no significant on-site or off-site environmental hazards.

Structure of the Program

The National Passive Program is organized around two interrelated program areas: Technology Development and Technology Utilization. Together, these two areas are seen as processes for achieving the accelerated widespread use of passive solar heating and cooling.

Technology development is simply that process through which an idea is developed to a point of potential widespread application. Its focus is towards research, development, testing and assessment of a technology. The outcome of the technology development process is generally either a product (hardware) or documentation of results (software) leading to the development of user-oriented design methods, or both.

Technology utilization is the process of identifying cost-effective, environmentally and socially acceptable technologies and developing a conducive application environment (market) for those technologies through market development activities. Its activities include determining the readiness of a technology in terms of performance and cost for entering the marketplace, assessing potential markets, identifying and mitigating restrictions to use, performing technology transfer and market development activities, and monitoring and feeding back information within and between the utilization process and the development process.

Structure of the Plan

The National Program Plan for Passive and Hybrid Solar Heating and Cooling consists of four major parts. The first part (Sections A through D) describes the planning context. A definition of a passive solar system is given, as well as a background of federal involvement in passive solar heating and cooling, program goals and objectives, and an overall implementation approach. The second part (Sections E through G) addresses the technology development program area. Background information on the status of and the strategy and emphasis for technology development is provided, followed by descriptions of passive heating and passive cooling systems and an overview of task classifications for technology development. The third part (Sections H through K) describes the technology utilization program area. Again, background information is given on the status of and the strategy and emphasis for technology utilization. This is followed by a narrative description of the technology utilization process and an overview of task classifications for technology utilization.

The fourth part (Appendices) provides detailed information on the tasks and schedules. Appendix A contains brief descriptions of the technology development tasks. Appendix B presents system development schedules for promising passive solar heating and cooling systems selected for intensive development activity. Appendix C contains brief descriptions of the technology utilization tasks. Appendix D presents schedules for utilization tasks selected for near-term implementation. As previously noted, the tasks necessary to develop and introduce agricultural and industrial process systems are not described in this Plan. Appendix E presents the projected energy impact of passive solar space-heating of residences and light commercial buildings. These projections were generated for the Department of Energy document, "Commercialization Strategy Report for Passive Heating."

PART I: PLANNING CONTEXT

SECTION A:
DEFINITION OF PASSIVE SOLAR SYSTEMS

A passive solar building is designed to maximize utilization of the environmental resource while minimizing consumption of the conventional fuels used for heating, cooling, 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 as used in this Plan 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 rationale for these definitions for heating, cooling, and hot water systems is presented below.

Space Heating

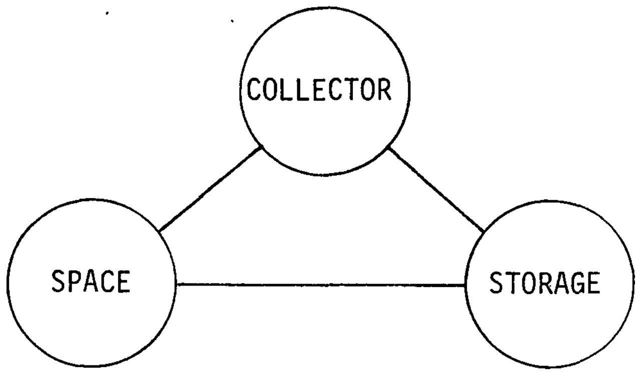
A solar space heating system contains the following elements:

- a *space* (or, more specifically, *contents*) to be heated;
- a *collector* where solar radiation is admitted into the system and converted to heat by an absorber (this may be nothing more than a surface of the normal building envelope);
- *thermal storage* (this may be nothing more than the normal thermal capacity of the building mass.

Possible energy flows exist between:

- collector and storage,
- collector and space,
- storage and space.

In a given system, some of these connections may not exist (or they may be insignificant).



The energy flows will fall into one of two broad categories:

- *forced* (using fans or pumps); or
- *natural* (involving conduction, convection, radiation, etc.).

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 *non-mechanical* sources.

If all of the significant exchanges linking the three elements involve forced flow, the system shall be classified as *active*.

If all of the significant exchanges linking the three elements involve purely natural flow, the system shall be classified as *passive*.

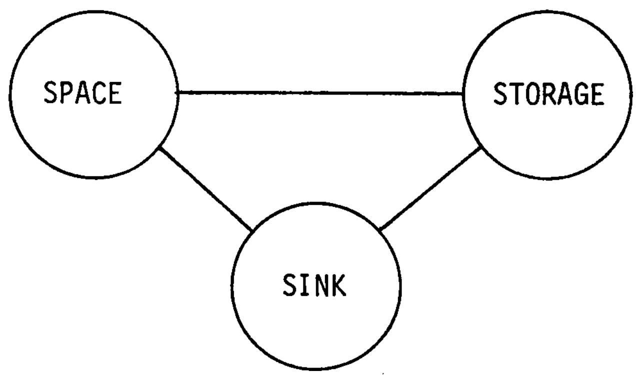
If at least one of the exchanges involves forced flow and at least one involves purely natural flow, then the system shall be classified as *hybrid*.

This Plan encompasses passive and hybrid space heating systems.

Space Cooling

A space cooling system contains the following elements:

- a *space* (or, more specifically, *contents*) to be cooled;
- an *environmental sink* to which heat is discharged (sky, atmosphere, or ground);
- *thermal storage* (this may be nothing more than the normal thermal capacity of the building mass.



If all of the significant exchanges linking the three elements involve forced flow, the system shall be classified as *active*.

If all of the significant exchanges linking the three elements involve purely natural flow, the system shall be classified as *passive*.

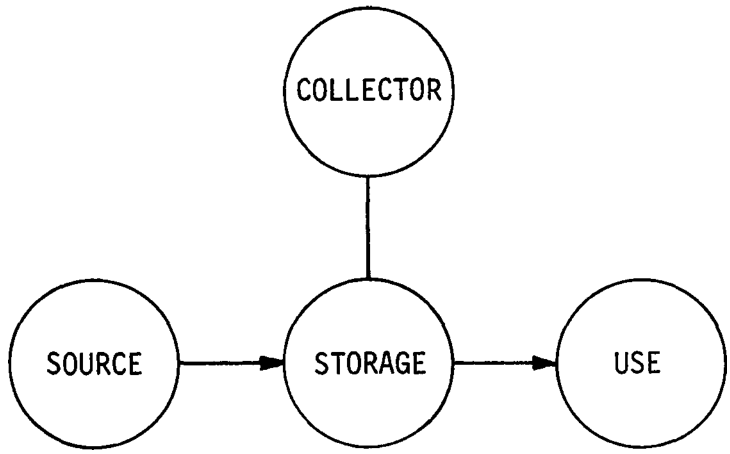
If at least one of the exchanges involves forced flow and at least one involves purely natural flow, then the system shall be classified as *hybrid*.

This Plan encompasses passive and hybrid space cooling systems.

Hot Water

A hot water system consists of four elements:

- *source* (utility, well, etc.),
- *storage tank(s)*,
- *collector(s)*,
- *use point(s)*.



The system is *passive* if:

- The maximum height to which water must be elevated to operate the heating system does not exceed the static head from the utility or the head required for normal operation of the well system.
- The heat flow from collector to storage occurs by purely natural means (conduction, convection, etc.).
- Transport of heated water from storage to use point is accomplished strictly through the use of pressure from the utility or the well pump.

In short, a passive hot water system requires no pumps other than those required for the normal water supply (utility or well).

In addition to passive hot water systems, the Plan will consider hybrid systems using pumps to circulate hot water in delivery loops or to assist in moving heat from collector to storage. The crucial issue is that the static head and friction losses should be small enough to hold promise of a high coefficient of performance. This will normally mean delivery loops of modest length and close proximity of collector and storage.

SECTION B:

BACKGROUND OF FEDERAL INVOLVEMENT IN PASSIVE SOLAR HEATING AND COOLING

The federal government has been involved in funding solar energy research and development for a number of years. Previous to the establishment of the Energy Research and Development Administration in January 1975, which together with the Federal Energy Administration and other federal agencies became the Department of Energy in 1977, solar energy research was funded primarily by the National Science Foundation (NSF) with some support from other federal agencies, such as the Department of Housing and Urban Development (HUD) and the National Aeronautics and Space Administration (NASA). Funding from these agencies of passive solar heating and cooling projects was a small percentage of the small amount available for solar energy research.

Solar energy research and develoment support increased significantly under the NSF/RANN Solar Heating and Cooling of Buildings Program. Begun in 1973, three contractors undertook a study of the technical, economic, societal, legal, and environmental factors influencing the widespread use of solar energy for the heating and cooling of buildings. Passive solar systems, for all practical purposes, were not addressed in any of these studies. Results from these studies led to a number of proof-of-concept experiments funded by NSF and then by ERDA, none of which were passive. However, HUD had during this same time funded an analysis of a passively solar heated and cooled residence privately constructed in southern California.

Passage of the Solar Heating and Cooling Demonstration Act of 1974 provided government funds to demonstrate solar heating by 1977 and combined solar heating and cooling by 1979. Although passive solar systems have not been excluded from funding, very few passive solar projects have been demonstrated in either residential or commercial buildings (3 out of 227 commercial projects and 25 out of 4,000 residential units). This lack of passive demonstration projects is due in part to the limited number of applications received, the lack of awareness and understanding of passive solar systems within the building industry, and the operational characteristics of the demonstration program. To address this problem, HUD sponsored a passive residential design competition during the summer of 1978. Over 550 applications were submitted, resulting in 162 awards: 145 for new homes and 17 for existing homes. HUD now has ten passive buildings instrumented with ten more being planned for the near term. Another HUD demonstration cycle is planned for 1979.

The initial stages of a passive solar research and development program were under way at Los Alamos Scientific Laboratory with the support of ERDA. LASL was developing the capability to predict passive solar system performance through the use of computer simulation and to validate the results through controlled test room experiments. At about the same time, a passive solar research and development plan was being formalized during the preparation of the interim National Program Plan for Research and Development in Solar Heating and Cooling (DOE/CS-0008). In this Plan, five paths for passive solar systems were identified: two for building heating and cooling and three for agricultural and industrial process heat. A more detailed discussion of these paths is presented in the background section of the technology development program area (see page 28). For each path, a number of research and development tasks were identified for funding in whole or in part by the Federal Government.

On the basis of the interim research and development plan, two solicitations for passive solar research and development were issued: Request for Proposal No. 1443, "Controls and Passive Systems for Solar Heating and Cooling,"; and Program Research and Development Announcement No. 0005, "Passive and Hybrid Systems for Solar Heating and Cooling Applications." As a result of these two solicitations, 19 building experiments were funded along with two control, one heat pipe, and one cooling study (Trinity University). In addition to these projects, LASL has continued its work in passive solar heating analysis, monitoring, and testing. The Solar Energy Research Institute has established a Passive Technology Branch emphasizing design tool development, user evaluation, and passive design development. Lawrence Berkeley Laboratory has initiated projects to study radiative and passive cooling as well as potential applications of passive systems in large-scale commercial buildings. Also, the National Bureau of Standards is developing thermal data and instrumentation requirements for monitoring the performance of passive solar systems. Together, these efforts form the basis of the coordinated National Passive Solar Research and Development Program.

Besides the research and development elements of the present program, some work has been supported to look at legislation, tax credits, information availability, and building codes that influence the use of passive solar systems. Also, three national conferences and workshops on passive solar heating and cooling have been sponsored by DOE. On the whole, however, very little has been done in the technology utilization program area.

Passive solar systems have recently received significant attention from two major policy and planning studies: the Presidentially authorized Domestic Policy Review on Solar Energy and the DOE-initiated Commercialization Readiness Assessment. The Draft Domestic Policy Review concluded that passive solar systems can play a vital role in reducing United States energy requirements in space conditioning of buildings. The Commercialization Readiness Assessment built upon this conclusion with a comprehensive analysis of factors influencing the realization of this potential and a Commercialization Plan for the accelerated development and application of passive systems. The conclusions and recommendations from these two policy and planning efforts have been made part of this National Program Plan for Passive and Hybrid Solar Heating and Cooling.

SECTION C:

PROGRAM GOAL AND OBJECTIVES

The goal of the National Passive Program is the displacement of a substantial quantity of non-renewable energy through the rapid development and widespread use of passive solar heating and cooling systems. Appendix E indicates predicted energy market penetration for passive solar heating systems with and without tax credit (as contained in the National Energy Act of 1978). Both cases assume a comprehensive federal program of research, development, and commercialization for passive solar systems. Energy market penetration for passive cooling, large commercial buildings, and agricultural and industrial processes have not been analyzed to date.

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, and informational and educational programs; an awareness and 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, industrial, and agricultural markets.

The National Passive Solar Program is designed to achieve this goal by supporting research, development, and testing 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 heating and cooling systems. With this in mind, the following program objectives have been formulated:

- Conduct a research and development program directed at identifying the technical performance and costs of various passive solar heating and cooling systems and developing the necessary documentation for product development, user-oriented design tools, and commercialization activities.

- Develop and widely disseminate design tools and methods for use by designers, builders, developers, and consumers.

- Develop analytical methods for rigorous technical and economic assessment of passive solar systems.

- Develop a full range of marketable passive products easily integrated with conventional construction materials and practices.

- Assist in the development of marketable passive designs for new and retrofit application in residential and commercial buildings.

- Field test the feasibility of passive solar heating and cooling in new and existing residential and commercial buildings, with special emphasis on the development of low-cost systems for retrofit installations.

- Support passive solar heating and cooling applications in government buildings to promote the utilization of solar energy by all government agencies.

- Operate an information system for collecting, storing, evaluating, reporting, and disseminating technical, environmental, social, and economic data generated by passive solar research, development, market field testing, and commercialization activities.

- Conduct market research studies to determine user acceptance requirements and to identify areas of opportunity for focusing commercialization activities.

- Identify and promulgate the necessary legislation, codes, and incentives to mitigate or eliminate existing legal or institutional restrictions that may discourage the development and use of passive solar systems.

- Continuously re-evaluate when and where federal action should be taken to promote passive solar systems and determine what actions are most appropriate to promote those systems.

- Continuously monitor and assess activities performed under this Plan to ensure that necessary feedback and communication is maintained within and between program areas.

SECTION D:

IMPLEMENTATION

As previously mentioned, DOE has an ongoing, directed National Solar Research, Development and Demonstration Program. The DOE Commercialization Readiness Assessment for Passive Solar Heating has been completed, and the Congressionally-mandated National Plan for Accelerating Commercialization of Solar Energy is still in progress. This National Program Plan for Passive and Hybrid Solar Heating and Cooling builds upon the existing R&D program, incorporates recommendations from the completed Commercialization Plan, and provides input to ongoing commercialization planning activity. It recognizes and incorporates the broad range of activities being managed by numerous federal agencies and national laboratories related to passive solar heating and cooling and integrates these activities into a coordinated Program Plan. Implementation of passive program tasks will utilize to the greatest extent possible the existing elements of the National Solar Energy Program. This will include the following:

- Demonstration Program: The residential and commercial solar demonstration program is likely to be extended until 1982. Another HUD demonstration cycle will be held in 1979, after which the passive residential design competition may be continued at a regional level. Commercial demonstrations of passive systems should be expanded, but done through a directed design development activity.

- Research and Development Program: A directed passive solar research and development program has been initiated and a first round of building experiments and studies has been funded. Passive solar research and development will be expanded to support materials and component studies, assembly development and testing, and systems development and analysis; to determine the cost and performance of a variety of passive solar heating and cooling concepts; and to develop user-oriented design methods for these concepts.

- Information and Education Program: Many efforts are under way to disseminate information on solar heating and cooling to a wide range of audiences. At the same time, educational programs and materials are being developed and implemented. Passive technology utilization activities will build upon these ongoing efforts.

- International Cooperation: There are established lines of communication between solar energy research and development in the United States and other countries, including several bilateral agreements for scientific and technical activities in solar energy. Also, there is great interest in passive solar systems in a number of these countries, and research programs are being initiated. The Plan will strengthen and build upon these relationships by sharing results and undertaking cooperative research and development in passive solar heating and cooling.

- Federal Buildings Program: This program provides a unique opportunity for the use of passive solar heating and cooling in federally-owned buildings. Activities will be directed towards identifying promising candidates within existing and proposed new federal buildings for the integration of developed passive solar heating and cooling systems.

The success of this National Passive Program depends not only on conducting successful research, development, and demonstration projects, but on the integration of passive solar systems into the national economy on a widespread and continuing basis. This requires the intimate involvement of many private organizations and institutions, especially small businesses, in the execution of the Plan and hence its development. If the technological and institutional developments produced by the program are to satisfy the needs of these organizations and institutions, it is essential that they be encouraged to participate in the development of guidelines, criteria, and specifications upon which the program is based. One of DOE's primary considerations in designing approaches and in selecting participants in specific projects will be to ensure the early and continuing participation of these segments of the economy whose acceptance of passive solar heating and cooling is essential to its general adoption.

As with the majority of activities undertaken in support of the National Solar Reserach, Development, and Demonstration Program, performance of specific program tasks will be based primarily on public solicitations, such as Requests for Proposals (RFP's), Program Research and Development Announcements (PRDA's), Program Opportunity Notices (PON's), and Requests for Grant Applications (RFGA's). This process will maintain the involvement of industry, universities, and small businesses in performing identified program tasks. Also, project support is expected to continue from the national laboratories, the Solar Energy Research Institute (SERI), and the regional solar energy centers.

This National Passive Program Plan identifies various major systems for passive solar heating and cooling and then identifies tasks that must be completed to develop and introduce cost-effective passive systems. Since the Passive Program Plan is part of DOE's overall energy program, it has numerous points of contact with other DOE divisions and with other federal agencies. The implementation of this Plan will be coordinated with all appropriate groups by an interagency committee with interest and involvement in passive solar heating and cooling.

PART II:

TECHNOLOGY DEVELOPMENT

SECTION E: BACKGROUND

SECTION F: SYSTEMS DESCRIPTION

SECTION G: TASK CLASSIFICATIONS

SECTION E:

BACKGROUND

Technology development is that process through which an idea is developed to a point of potential widespread application. It generally involves research, development, testing, and documentation. Its domain is broad, encompassing basic physical studies as well as materials, assembly, and system development for a variety of applications (residential, commercial, agricultural, and industrial) and system functions (heating, cooling, lighting, and hot water). The results of the technology development process is either a product, documentation of results leading to user-oriented design methods, or building/system designs based upon products and/or design methods. The process must be sensitive to user needs and market requirements. The designer/researcher must be aware of the issues involved in the process of a technology gaining acceptance within the industry and the market (e.g., standard building practices, codes, and standards; education and training; financing; user attitudes; and market aggregation).

Technology development for passive solar heating and cooling has characteristics that significantly distinguish it from other energy technologies. Passive solar systems are design-oriented rather than product-oriented. The process usually involves the architectural translation of a concept or idea for using solar radiation or other environmental energies incident on a building to reduce the energy requirement of the building. Passive systems normally use common materials, components, and assemblies, but in ways different from traditional design practice. Consequently, the technology development program for passive solar heating and cooling is systems-oriented.

A systems focus does not imply that new materials and assemblies would serve no purpose. On the contrary, new materials and products which are envisioned, and some of which are presently under development, have the potential to profoundly increase the impact of passive solar. The point is that highly effective passive solar systems can be realized now using common materials and building processes. The final success or failure of a passive solar design is based on the ability to organize the elements of the structure in such a manner as to provide for a significant fraction of the energy requirement in a predictable manner.

The specific objectives of the technology development program are to:

- Identify and collect environmental data relevant to the performance of passive systems. Availability of solar radiation and sky properties are of special importance, but work is also needed on atmospheric effects and ground conditions.

- Analyze existing materials and assemblies and develop new materials and assemblies appropriate for passive applications.

- Identify promising passive systems concepts.

- Develop thermal and economic models and computer simulation codes for all presently developed and characterized passive solar heating and cooling systems.

- Validate system models on the basis of data obtained from passive solar buildings and test rooms.

- Use validated computer simulation codes to perform systems studies related to parametric sensitivities, climatic applicability, economic trade-offs, etc.

- Use results of thermal and economic system studies to generate user-oriented design tools.

- Develop marketable products and designs.

Status of Technology Development

Prior to the establishment of a directed national solar heating and cooling research and development program, passive solar research and development was almost entirely carried out by a small group of dedicated researchers and practitioners. These individuals generated a variety of passive concepts, tested them, and eventually incorporated them into their buildings. Most of the time, these individuals' homes were the proving grounds for ideas on passive solar designs. Their decisions were often based as much on intuition and feel as they were on hard technical data and design methods. Although their procedures may not have been analytical in all cases, their results, most often, were impressive. It is in large measure because of these pioneers that passive solar heating and cooling is receiving the high level of attention that it is today.

The advantages of and opportunities for passive solar heating and cooling were well recognized and represented in the National Program Plan for Research and Development in Solar Heating and Cooling (DOE/CS-0008). The R&D plan identified eleven paths† for the

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†A *path* is simply the linking of a method of energy collection or rejection with a particular application.

solar heating and cooling of buildings--of which two were for passive solar systems--and eleven paths for agricultural and industrial applications, of which three were for passive systems. For each path, a number of research and development tasks were identified for government support. A brief description of the five paths to passive solar heating and cooling is presented in this section. A complete listing of all technology development projects funded by the Passive Program is presented in the book, Solar Heating and Cooling Research and Development Project Summaries (DOE/CS-0010, currently being updated).

Heating and Cooling of Buildings

Passive Heating of Space or Structure (Path H-2): This path encompasses a variety of passive solar heating systems. Its focus is broad, with R&D activities in the area of materials characterization and development, assembly evaluation and development, and systems modeling and testing. The schedule of tasks called for the initiation of system studies of existing buildings, basic material and climate studies, and hybrid and control studies during 1978. The status of major activities is as follows:

- Computer simulation model for thermal storage walls completed and in use. Mass storage wall (with and without vents) and water storage wall computer modeling approaches validated by comparison with test room results. Models for direct gain, sun space, and roof storage systems being developed.
- Three thermal storage wall heating systems analyzed for hourly solar/weather data from 29 cities.
- Parametric studies completed for thermal storage wall effect of storage mass, glass area, allowable room temperature, effect of wall thickness and thermal conductivity, ground reflectance, number of glazings, and inlet condition.
- Twenty-five passive solar heated buildings instrumented with two to four months of winter data accumulated for each building.
- Fifteen 5' × 8' × 10' test rooms constructed. One year of data accumulated for various thermal storage wall system configurations in two test rooms. Remainder of test rooms will include experiments on thermic diode panel, direct gain, roof aperture systems, and material and assembly studies. These experiments will be operational during the winter of 1979.
- Twelve building experiments funded to demonstrate passive and hybrid solar heating and cooling systems. Experiments involve a range of systems including direct gain (south aperture and shaded roof aperture), storage walls, storage roof, sun space (greenhouse and solariums), and ponds.

- Three test room experiments funded to study (1) details of convective flows associated with storage walls with vents; (2) polyethylene greenhouse retrofits with a variety of storage materials; and (3) a number of system types interacting with an existing building.

- Seven assembly component studies funded to develop, monitor, and assess various passive system elements, including heat pipes, control techniques, collector assemblies, reflectors, lightweight storage, and thermic diodes.

- Manufactured buildings program initiated to investigate the application of passive techniques to factory-built residential, commercial, and agricultural buildings.

- Design tool program initiated to develop simplified techniques.

- Investigations of macro- and micro-economics of residential applications of passive techniques are ongoing, including the development of a passive system costing technique and economic system optimization procedure.

- Program initiated to identify and evaluate possible roles for passive solar energy within more general energy management schemes for large-scale commercial and industrial buildings.

- Systems studies under way to investigate various passive solar domestic hot water options.

- Detailed thermocirculation model completed for laminar and turbulent flow between parallel plates.

- Passive solar simulation capability being integrated into public domain building energy analysis computer programs.

- User evaluation of speculatively built residential passive solar designs is under way.

- Two user-oriented handbooks for residential design to be completed in FY 1979.

- Performance factors for passive solar heating systems have been defined.

Passive and Hybrid Cooling (Path C-4): This path is concerned with the cooling of buildings through selective interaction with cooler parts of the environment, which can be accomplished in a variety of ways, even during those times of the year when the average dry-bulb temperature is high. Among the common methods of passive cooling are ventilation of the structure (or storage mass) with night air, which works well in climates with large diurnal temperature swings; evaporative cooling, which works well in dry climates; radiative sky cooling, which works well in climates with clear skies; and conduction to the ground, which works well in locations where the average ground temperature is low enough to be consistent with human comfort. The R&D emphasis is directed towards expanding the knowledge of the processes involved, generating and validating thermal simulation computer models, and determining the heat rejection, storage, and absorption characteristics of various designs in different geographic areas.

The schedule of tasks called for continuing system studies of current passive approaches, developing variants of current passive approaches, and performing basic materials and climate studies during 1978 and 1979. The status of these activities is as follows:

- A computer simulation program to model the infrared spectral emission characteristics of the atmosphere under a variety of weather conditions has been funded.

- One test cell funded to test and analyze a combined passive and hybrid night-sky radiation and convective cooling system.

- Data collection and evaluation under way for a roof pond passive heated and cooled house in Las Cruces, New Mexico.

- Computer simulations have been used to calculate the net rate of heat dissipation by the combination of radiation, convection, and evaporation from horizontal surfaces at fixed temperatures in 58 American cities. Simulations are based on hourly meteorological conditions for selected typical June, July, and August data. An assessment of the net cooling rates for tilted surfaces has been conducted for four cities representative of a wide range of climates.

- A detailed spectral radiometer has been developed and four instruments have been deployed in various parts of the U.S. By the fall of 1979, a full summer of data will be available for all four sites.

- A contract has been awarded to refine movable-insulation schemes for thermal storage roof systems.

- An alternative storage roof system using fixed insulation and moving water has been built and monitored.

- A five-year joint U.S.-Saudi Arabia program in passive cooling was begun in FY 1979.

Agricultural and Industrial Process Heat

The following paths and their status are not described in the present interim National Program Plan. However, they will be complated for the final Plan:

- Passive Solar Heating for Shelters and Greenhouses (Path HP);
- Direct Drying of Agricultural and Industrial Products (Path DD);
- Passive Cooling for Agricultural and Industrial Process Applications (Path CP).

Strategy for Technology Development

The strategy for technology development is composed of three elements: basic physical studies, product development, and systems development.

Basic Physical Studies

Because our knowledge of environmental effects is very limited and our present models of these effects inaccurate, studies will be initiated to examine atmospheric and terrain effects and physical properties of sky and ground. The objective of these studies would be to develop accurate models of environmental effects to be used in more detailed computer simulation programs for passive solar heating and cooling system performance calculations.

Two additional basic physical studies will also be initiated: (1) an analysis of existing solar radiation data and recommendations for the type and quality of data needed for passive solar design (vertical surface solar radiation data, for example); and (2) a detailed examination of heat exchange mechanisms based upon basic principles of heat transfer.

Product Development

Although many of the elements of passive solar systems are conventional building materials, new materials need to be developed and existing materials analyzed for use in passive solar designs. Development and analysis projects will be initiated in the following areas: glazings (analysis of the thermal and optical properties of glazing materials alone and in combinations, and development of high transmissivity, high insulation glazings, optical shutters, and optical coatings); absorbers and emitters (studies of existing absorption and emission characteristics of materials); reflectors; insulation;

storage (especially development and analysis of lightweight materials for heat storage at slightly above room temperature); fluids; and sealants.

At the present time, an insufficient number of package assemblies are available for integration into passive solar designs. Projects will be funded to develop and analyze assemblies in the following areas: glazing, reflector, and movable insulation assemblies, alone and in combination; storage assemblies, particularly container designs for mass production and ease of installation; and sensors, actuators, and controls, focusing on light and heat flow control devices.

Projects or studies may also be initiated for fans, pumps, and valves used in hybrid systems; heat exchangers, particularly air-earth heat transfer; and heat pipes and thermal diodes.

Systems Development

This is the most crucial element of the technology development program area. It brings together all of the previous materials, assemblies, and basic physical projects and studies for the concept generation, thermal analysis, testing, and documentation of passive solar heating and cooling systems. The strategy for systems development is as follows:

- Continued development of computer simulation codes for presently developed passive solar heating and cooling systems; continued testing, monitoring, and analysis of existing buildings and test rooms; and validation of system models with test results. The purpose of this strategy element is to generate the needed documentation leading to the preparation of user-oriented design tools such as handbooks, programs for programmable calculators, and detailed computer design methods.

- Concept generation, assessment, and analysis of promising new passive solar heating and cooling systems, including, where appropriate, computer simulation model development, test room construction, model validation, and documentation.

- Initiation of a side-by-side, controlled, adaptable, full-scale test building experiment involving a range of passive solar systems to be located at several sites representing distinct climatic conditions. The objectives of the experiment would be to determine energy yields that can be expected from various passive solar systems in different climatic regions, validate computer simulation analysis models of those systems in full building experiments, establish levels of cost-effectiveness for different types of passive systems in different geographic/climatic regions, and demonstrate the viability of passive solar systems in different parts of the country. (Beyond these development activities, there is the opportunity to increase the awareness and understanding of passive solar heating and cooling within the building industry, the architectural and engineering colleges and universities, and among the general public.)

Emphasis for Technology Development

Because the technical basis for understanding and designing passive solar systems is just emerging, most research and development has focused on small-scale, single-zone structures, primarily residences and test rooms. Several larger passive solar buildings have been built, but characteristically they have resembled the small, single-zone structures. While it is important to continue a technology development emphasis in this area to further understanding and to develop an analysis and design capability, it is clear that the focus must be enlarged. The opportunity for passive solar systems in large, new structures such as schools, office buildings, commercial facilities, and warehouses is large. Additionally, existing residential and commercial structures represent both a challenge and an opportunity for the development and application of passive systems. Beyond the opportunity is the necessity to redesign our existing buildings to better utilize our dwindling fossil fuel resources.

For these reasons, a substantial new effort will be invested in technology development activities addressing large-scale, multi-zone structures and retrofitting existing residential and commercial buildings. Systems concept generation, assessment, computer simulation modeling, full-scale testing, and architectural integration will be stressed. These activities will be tied to the demonstration and the federal buildings programs for possible early application of developed concepts.

SECTION F:

SYSTEMS DESCRIPTIONS

Beyond the general definitions of passive solar heating and cooling are a number of significant factors that influence the performance of passive solar systems and begin to characterize generic types of systems. This section identifies those significant factors for space heating and cooling and presents a scheme for system classification.

Space Heating (Path H2)

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

(1) The characteristics of the collection aperture:
- orientation with respect to south and vertical;
- location relative to the rest of the building structure.

(2) The method of delivering energy to the conditioned space:
- the energy mechanism(s);
- inherent degree of thermal control.

Collection Aperture Characteristics

In the temperate 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

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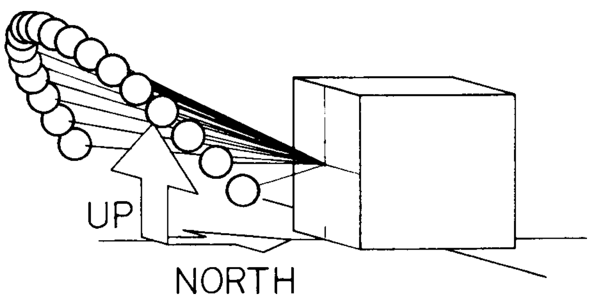
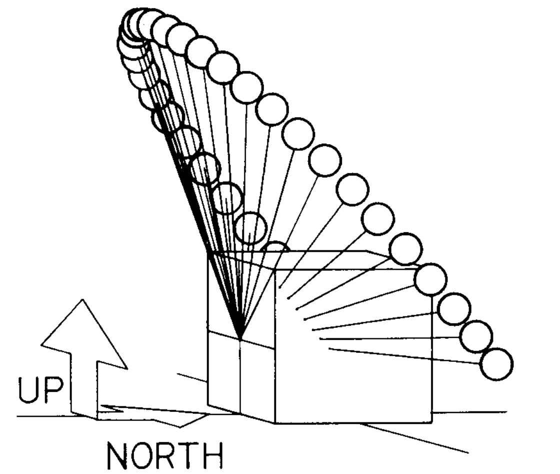
[†]For a more detailed discussion of sun angles see "The Solar Resource: Motion and Amplitude," by Wayne Place, p. 769 of the Proceedings of the Second National Passive Solar Conference, March 1978.

major control of the building's thermal environment.

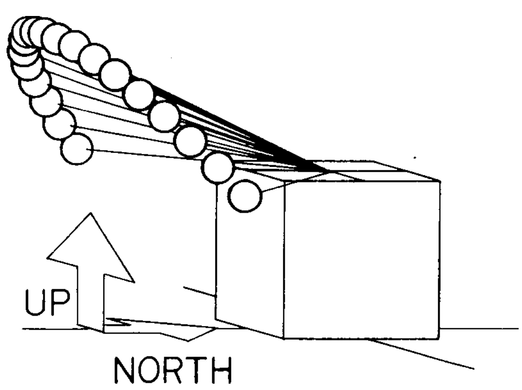
Going to the opposite extreme, horizontal glazing receives modest amounts of direct-beam winter sun, generally at unfavorable angles of incidence, and is subjected to severe direct-beam summer sun, generally at angles corresponding to high glazing transmissivity.



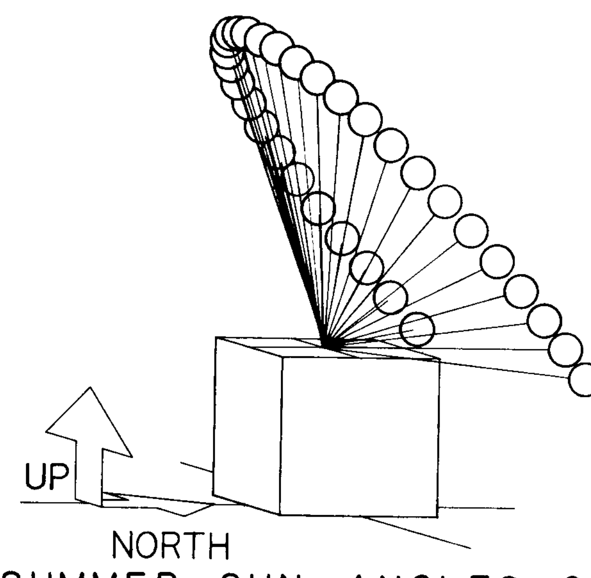
WINTER SUN ANGLES ON SOUTH-FACING SURFACE



SUMMER SUN ANGLES ON SOUTH-FACING SURFACE



WINTER SUN ANGLES ON HORIZONTAL SURFACE



SUMMER SUN ANGLES ON HORIZONTAL SURFACE

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. Remote heating systems can be designed to have simple controls which limit unwanted gains or losses from the building. They also have the advantage of providing additional collection area to supplement energy collected through the building envelope proper.

There are a limited number of energy advantageous combinations of aperture orientation and location:

- A *south aperture* in the building consists of vertical glazing elements in the south wall. Such an aperture accepts solar radiation predominantly from the southern part of the sky (winter sun).

- A *shaded roof aperture* in the building consists of vertical glazing elements and sloping opaque elements on the roof. Such an aperture accepts solar radiation predominantly from the southern part of the sky (winter sun).

- A *roof aperture* in the building consists of horizontal glazing elements on the roof. Unless controlled by special methods, e.g., moving insulation, such an aperture accepts solar radiation predominantly from the upward part of the sky (summer sun).

- A *remote aperture*, i.e., one which is not part of the building envelope proper, can be set at any angle to accept solar radiation from any part of the sky.

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.

- 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.

- 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.

The following matrix indicates the level of control of the thermal environment for each type of system (direct, indirect, or isolated) in terms of solar radiation exposure and thermal coupling of the space to absorbing surfaces or storage mass:

	Direct	Indirect	Isolated
Solar radiation enters space	Yes	No	No
Air temperature floats with absorber and/or storage	Yes	Yes	No

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.

Given these basic definitions, we can classify the common passive heating systems in terms of the following matrix:

	DIRECT	INDIRECT	ISOLATED
SOUTH APERTURE	●	●	●
SHADED ROOF APERTURE	●	●	●
ROOF APERTURE	●	●	●
REMOTE		●	●

Various combinations of aperture location and mechanisms for transferring energy to the occupied space are shown schematically in Fig. II-1. The configurations shown include the currently most common passive heating systems and provide a representative sampling of less common systems which may have equal potential. These combinations by no means exhaust the list of possibilities. Additionally, this figure introduces a general nomenclature for passive system description.

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.

There are an assortment of multi-zone, single-story schemes with solar heating applied to each zone. Some of the more interesting two-zone examples are illustrated in Figure II-2. These systems have the quality that each zone can be individually designed to meet the particular thermal and illumination requirements dictated by the intended function of the space. The extension of these schemes to single-story buildings of three or more zones is obvious.

A more difficult classification problem is large, multi-story buildings. Asymmetric solar excitations, such as occur in south aperture systems, naturally drive a north-south zone separation. Multi-story commercial structures will clearly be north-south zoned in most cases and the functional utilization of the space must be planned in accordance. However, in order to fully implement passive design concepts and maintain flexibility in space utilization, methods of enhancing or suppressing the natural zone structure of the space must be developed. In some cases this can be accomplished by purely passive means; in other cases hybrid schemes involving mechanically-assisted heat transfer will be more appropriate. The problem of energy transport becomes very critical in large-scale buildings, particularly for high-occupancy commercial applications or situations where industrial processes require high ventilation rates. The most appropriate roles for passive solar within more general energy management schemes are not presently identified, and the identification of those roles will require a substantial level of effort in innovative concept generation as well as rigorous technical evaluation. Until these roles are identified and the resulting systems thoroughly investigated, any attempt to develop a comprehensive classification scheme for large-scale buildings would be premature. Some examples of multi-story passive heating schemes are shown in Figures II-3 and II-4.

Table II-1 is a list of space-heating systems selected for intensive development activity. It is not assumed that this list exhausts the promising possibilities, nor is it assumed that government supported development activity will be limited to this list. Unsolicited proposals for the development of promising innovative systems outside the scope of this list are welcomed by the Department of Energy. It is understood that the option of a sun space add-on should be considered for each of the south wall systems. Work on unshaded direct-gain roof elements will emphasize limited collection areas for daylight applications (i.e., skylights). For multi-zone, single-story buildings, the emphasis will be on the natural coupling between zones and simple, effective means of moving energy in order to control zonal differentiation. Consideration should be given to systems in which energy is delivered to each zone and systems in which energy is delivered to some zone(s) and transported by natural or forced means to other zone(s).

Space Cooling (Path C4)

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.

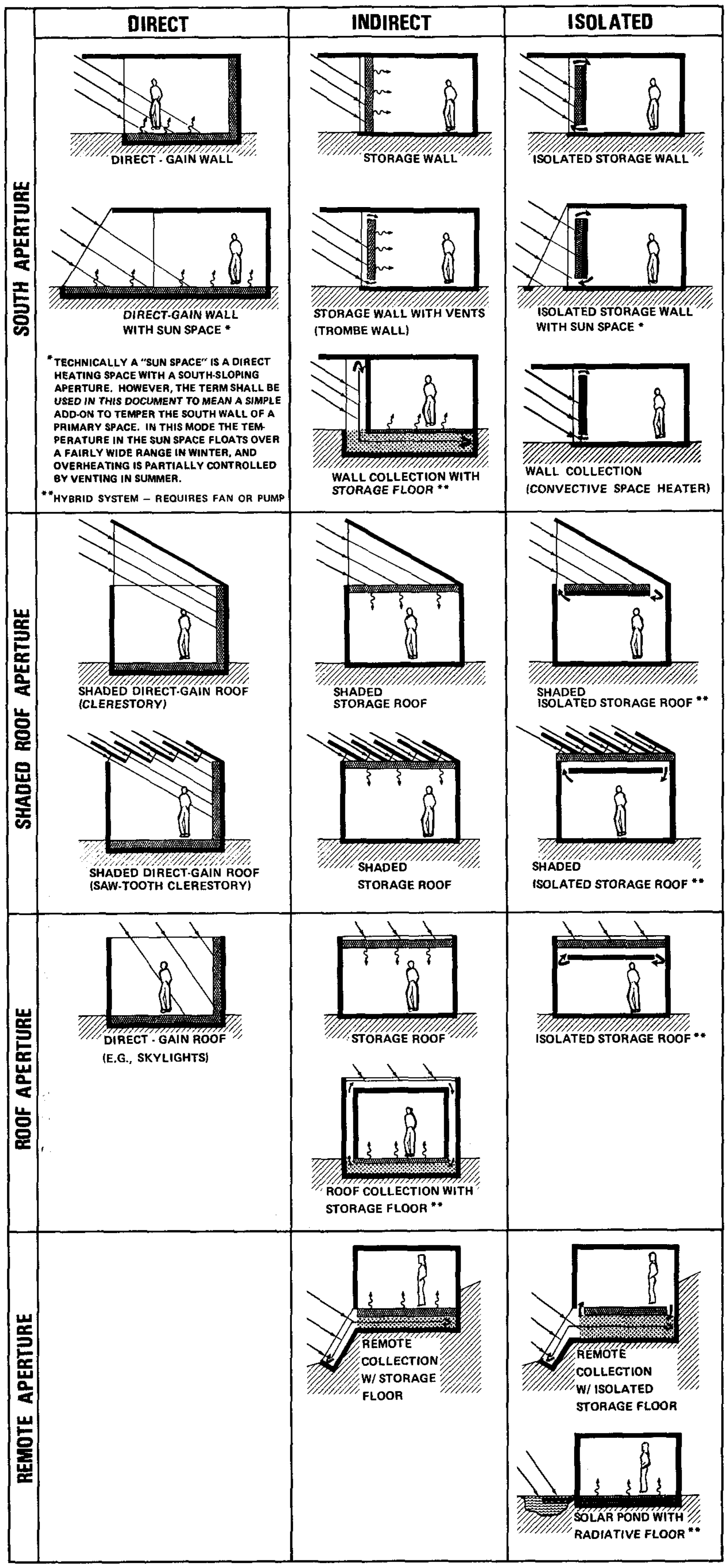
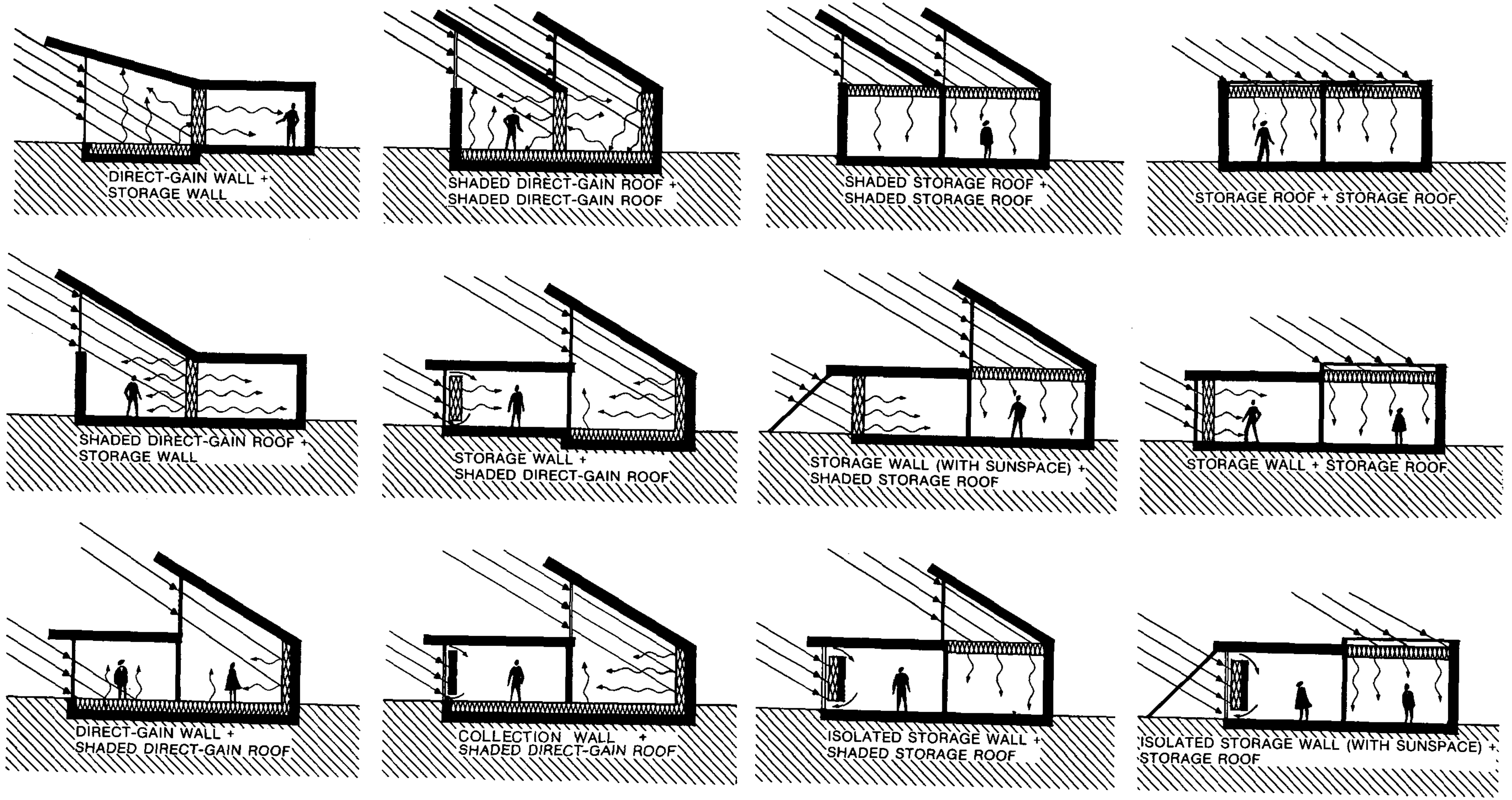


FIGURE II-1: EXAMPLES OF PASSIVE SOLAR HEATING SYSTEMS

FIGURE II-2: EXAMPLES OF SINGLE-STORY, MULTI-ZONE, PASSIVE SOLAR SYSTEMS



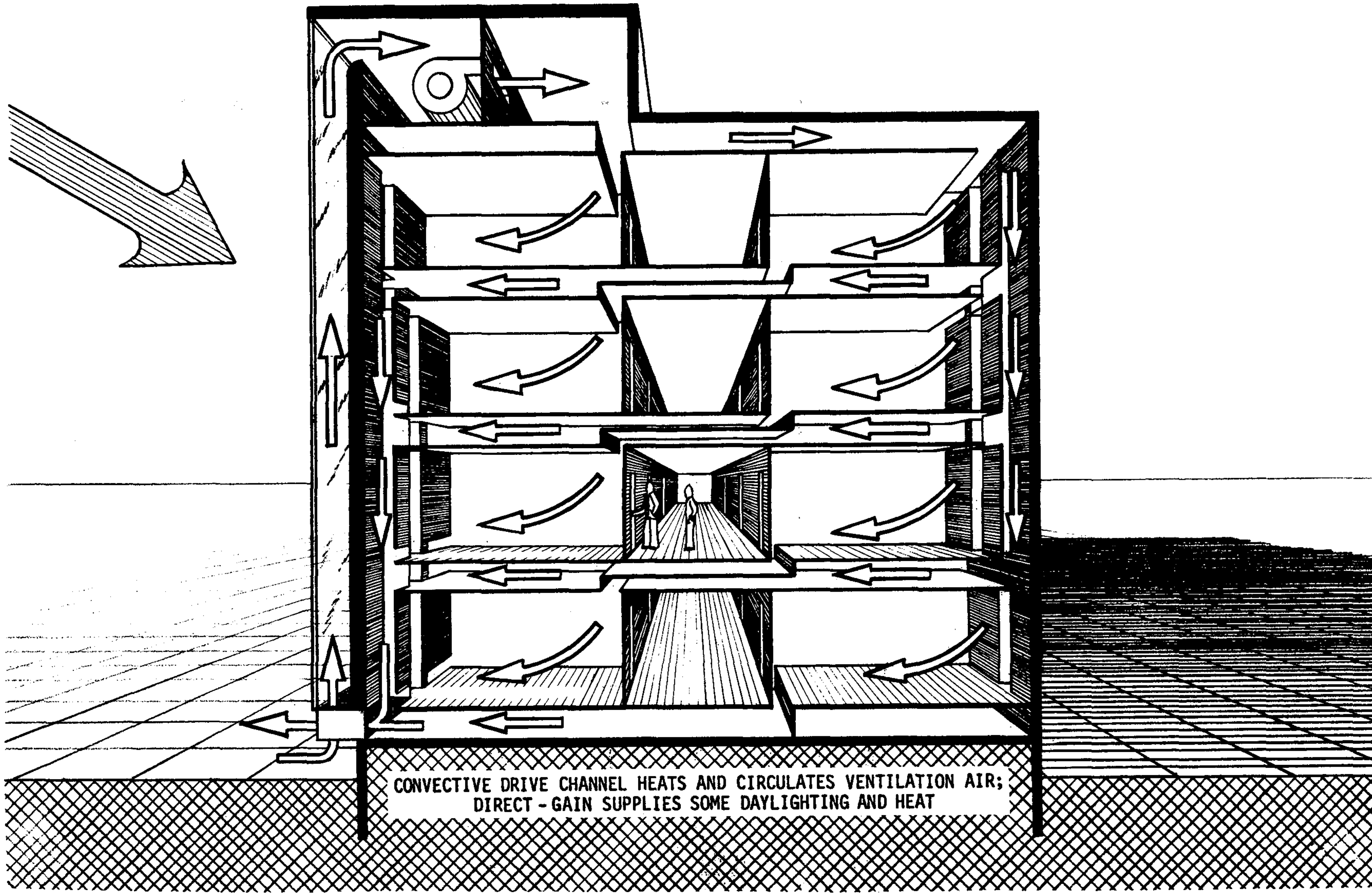


FIGURE II-3: AN EXAMPLE OF A MULTI-STORY, MULTI-ZONE PASSIVE SOLAR HEATING SYSTEM

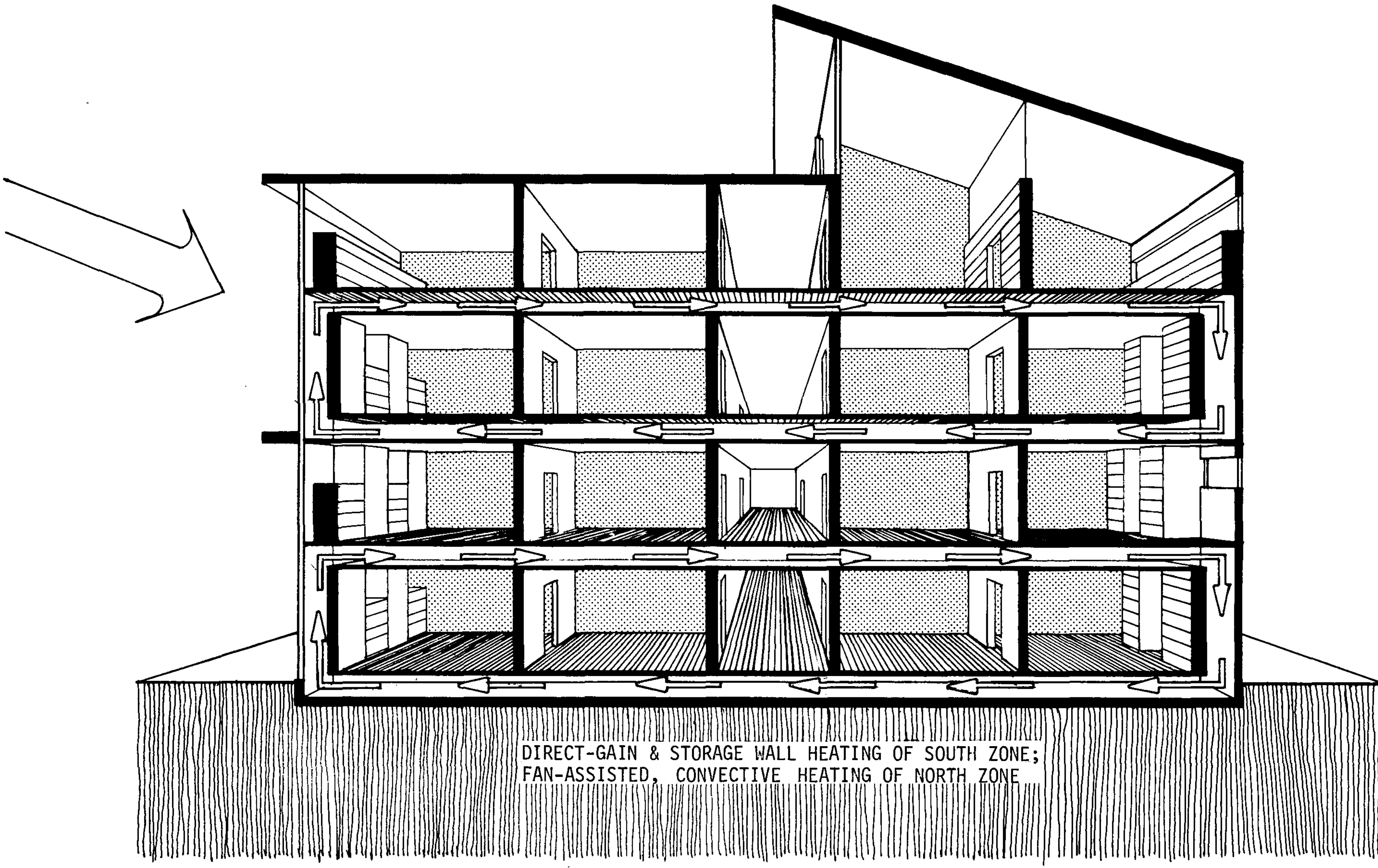


FIGURE II-4: AN EXAMPLE OF A MULTI-STORY, MULTI-ZONE PASSIVE SOLAR HEATING SYSYEM

TABLE II-1

Heating Systems for Development

SINGLE ZONE:

South Aperture:

1. Direct-Gain Wall
2. Storage Wall (with and without vents)
3. Isolated Storage Wall (with vents and/or moving insulation)
4. Collection Wall (with storage floor, wall, or ceiling)
5. Collection Sun-Space (with storage floor, wall, or ceiling)
6. Combinations of 1 through 5

Shaded Roof Aperture:

7. Shaded Direct-Gain Roof
8. Shaded Storage Roof

Roof Aperture:

9. Direct-Gain Roof
10. Storage Roof
11. Collection Roof (with storage floor, wall, or ceiling)
12. Combinations of 7 through 11

Remote Aperture:

13. Remote Collection with storage floor
14. Remote Collection with isolated storage (e.g., solar ponds)
15. Ground Preheat

MULTIZONE:

Single Story
Multi-Story
Community and Urban Projects

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 special 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.

The following table summarizes the environmental sinks, along with the primary mechanisms involved in the energy transfer:

Sink	Primary Energy Transfer Mechanism
Sky	Radiation
Atmosphere	Convection†
Ground	Conduction
Water	Convection

†Includes evaporation

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).

- *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).

- *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).

As in the case of heating, we can classify passive cooling systems in terms of a matrix:

	DIRECT	INDIRECT	ISOLATED
SKY	●	●	●
ATMOSPHERE	●	●	●
GROUND	●	●	●
WATER	●	●	●

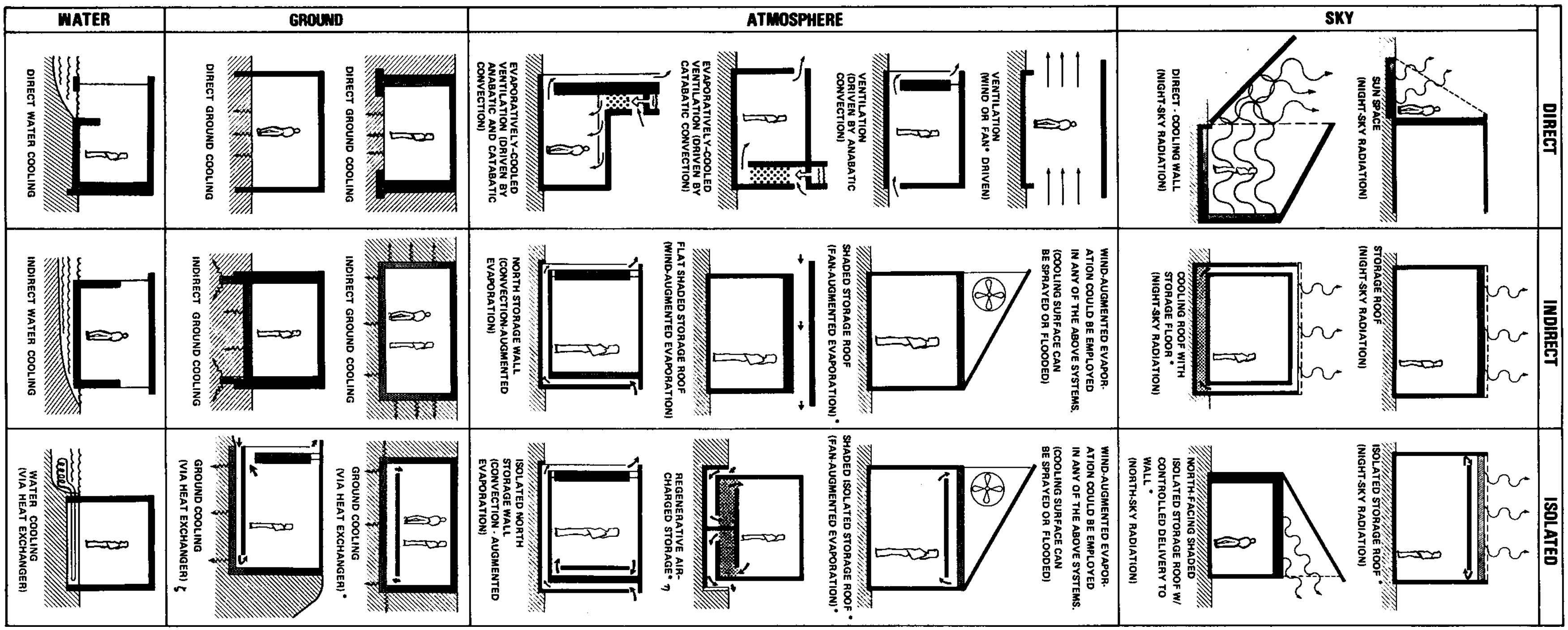
A representative sample of combinations of the environmental thermal energy sinks and mechanism for transferring energy to the occupied space are shown in Figure II-5. The configurations shown include the currently most common passive cooling systems and a representative sampling of less common systems which may have equal potential. These combinations by no means exhaust the list of possibilities. The figure also introduces a general nomenclature for passive cooling system description.

As in the case of passive space heating, roles for passive cooling in more general energy management schemes for large-scale commercial buildings remain to be identified and evaluated. An example of a multi-story passive cooling scheme is shown in Figure II-6.

Table II-2 is a list of promising space cooling systems selected for development activity. In general, our understanding of passive heating is considerably more advanced than for passive cooling. As a consequence, the list of cooling schemes identified for attention contains a number of approaches which may provide to have little merit. Emphasis has been placed on systems whose elements can serve both a heating and a cooling function, and whenever possible the heating system nomenclature is retained. For example, a storage roof cooling system uses all the same elements as a storage roof heating system, except that the air space, which may be necessary to reduce winter losses, might need to be eliminated for summer cooling. Also listed in the table are several promising cooling schemes whose elements do not serve a heating function. For many advanced heating systems there does not exist a well-defined cooling system employing some or all of the same elements. For example, there are several well-understood storage wall heating systems, but no well-defined schemes for using that mass with comparable effectiveness in the cooling mode. Despite the lack of well-defined concepts, the idea of using storage walls in the cooling mode appears to merit further consideration. Similarly, the list contains other cooling systems derived from heating systems, such as shaded storage roof, and cooling roof with storage floor.

It is not assumed that this list of space-cooling systems exhausts the promising possibilities, and proposals for development of innovative systems are welcomed.

FIGURE II-5: EXAMPLES OF PASSIVE SOLAR COOLING SYSTEMS



* HYBRID SYSTEM – REQUIRES FAN OR PUMP.

η REGENERATIVE AIR-CHARGED STORAGE SUPPLIES FRESH AIR (I.E., IT SUPPLIES OXYGEN AND REMOVES POLLUTANTS), AND THEREFORE CAN BE REGARDED AS A VENTILATION SYSTEM (I.E., A DIRECT SYSTEM). HOWEVER, SINCE THE EVAPORATION AND AIR-FLOW RATES CAN BE ADJUSTED OVER A WIDE RANGE IN ACCORDANCE WITH THE THERMAL DEMAND OF THE SPACE, THE SYSTEM HAS THE CONTROL CHARACTERISTICS OF AN ISOLATED SYSTEM.

ζ THIS SYSTEM SUPPLIES FRESH AIR AND THEREFORE QUALIFIES AS A VENTILATION SYSTEM. HOWEVER, SINCE THE FLOW RATE CAN BE ADJUSTED ACCORDING TO THERMAL DEMAND, IT HAS THE THERMAL CONTROL CHARACTERISTICS OF AN ISOLATED SYSTEM.

DAYTIME OPERATION: SOLAR CHIMNEY DRAWS AIR THROUGH COOL ROCKBED AND THEN THROUGH BUILDING

NIGHTTIME OPERATION: FAN (OR TIME-LAG SOLAR CHIMNEY) DRAWS COOL NIGHT AIR THROUGH ROCKBED

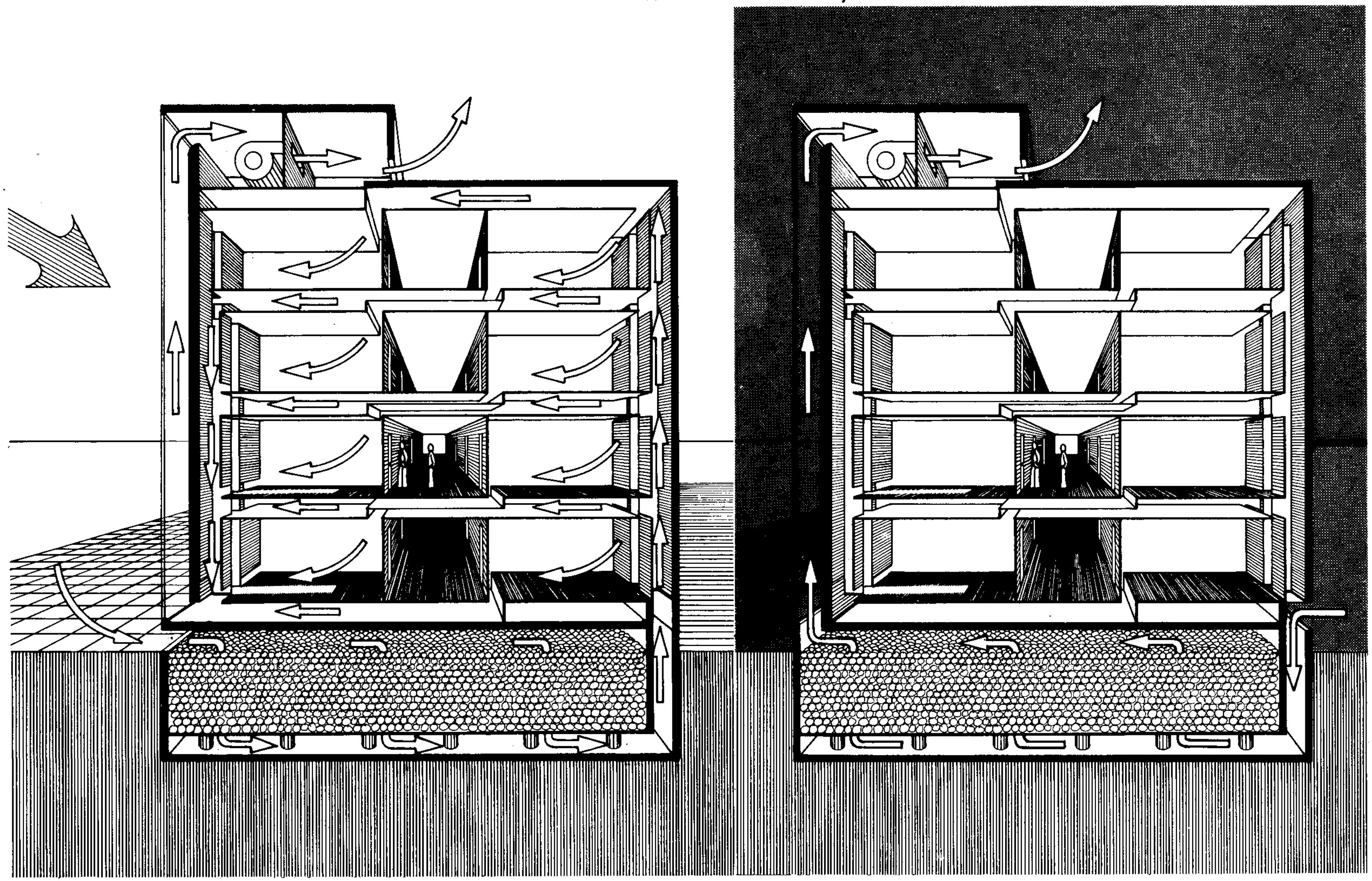


FIGURE II-6: AN EXAMPLE OF A MULTI-STORY, MULTI-ZONE PASSIVE COOLING SYSTEM

TABLE II-2

Cooling Systems for Development

SINGLE ZONE:

Sky and/or Atmospheric Sink:[a]

1. Storage Roof[b,c]
   - Without movable exterior insulation
   - With movable exterior insulation
   - With controlled optical shutter
   - With fluid pumped around insulation[d]
   - With heat pipes

2. Storage Wall[b,c] (indirect and isolated)
   - Without movable exterior insulation
   - With movable exterior insulation
   - With controlled optical shutter
   - With fluid thermosyphoning around insulation
   - With fluid pumped around insulation[d]

3. Low-Mass Cooling Roof[b,c,d]

4. Low-Mass Cooling Wall[b,c,d]

5. North-Facing Shaded Storage Roof

6. South-Facing Shaded Storage Roof[b,c]
   - Without movable insulation
   - With movable insulation

7. Vegetation Shielding of Structure
   - Using vines
   - With earth berming and sod roof covering

8. Remote Cooling Ponds[d,e]

Atmospheric Sink:[f]

9. Direct Ventilation of Space
   - Simple air movement
   - Evaporative cooling

10. Evaporative Cooling via Low-Mass Heat Exchangers

(continued)

TABLE II-2 (continued)

11. Evaporatively and/or Night-Air Charged Storage[b]
    - Storage walls
    - Storage floors
    - Shaded storage roofs
        - south-facing (with and without shading)
        - attics[d]
        - flat
    - Regenerative Air Charged Storage[d,g]

12. Convective Cooling of Building Surfaces Protected by Shading Devices (e.g., double roofs)

13. Dessicant Dehumidification
    - Dual plate dessication
    - Three rotation dessicant wheel
    - East and west walls (with solar action)
    - Fluid dessicant

Ground Sink:

14. Indirect
    - Through envelope elements
    - Via high conductivity structural elements reaching deep underground

15. Isolated (closed[d] and ventilation air precooling)
    - Via buried ducts
    - Under floor
    - Via heat pipes

Water Sink:

16. Structure to Water-Body Heat Exchange[d]

17. Thermal wells[d]

<u>MULTI-ZONE</u>:

Single Story

Multi-Story

Community and Urban Projects

(continued)

TABLE II-2 (continued)

Legend

a Radiation to the sky will normally be present, as well as convective transfer to (or from) the atmosphere. In all system studies, evaporation should also be considered for exchanging discharge to the atmosphere. (Consider flooding or spraying, as appropriate.)

b Thermal mass can also serve as storage in the heating mode.

c If used for both heating and cooling, glazing must be at least seasonally movable.

d Hybrid system requiring fan or pump.

e For large bodies of water this is equivalent to water sink cooling.

f Wherever heat exchange via air movement is involved, all applicable mechanisms for moving the air should be considered, e.g., wind (with and without scoops and towers), anabatic convection (including solar chimneys, Trombe walls, greenhouses, and natural cooling towers), catabatic convections, fans, etc.

g Regenerative air charged storage is capable of supplying fresh air (i.e., delivering oxygen and removing contaminants) and can therefore be regarded as a ventilation system. However, since the evaporation and air flow rates can be adjusted over a wide range in order to meet the thermal demand of the living space, the system has the thermal control properties of an isolated system.

SECTION G:

TASK CLASSIFICATIONS

This section describes the areas by which the tasks are classified. The technology development tasks themselves are contained in Appendix A with systems development schedules presented in Appendix B. Tasks are classified in three general categories: Basic Physical Studies, Product Development, and System Development. The sub-categories within these classifications are identified in Table II-3.

This classification scheme recognizes that the system development process plays a central role in motivating tasks in the basic physical studies and product development areas, in addition to the tasks which are directly related to the development of passive systems. The systems development process steps and their relationship to the two supporting task areas and to the technology utilization tasks is shown schematically in Figure II-6. For clarity, the major activities performed during the process are shown to the left of the schematic flow diagram.

Following is a brief description of the type of activities to be undertaken in each task area.

Basic Physical Studies Tasks

Basic physical studies are concerned with environmental and physical phenomena that can influence the performance of passive solar heating and cooling systems. The following activities have been identified for study:

Name of Study	Description of Study
Solar Radiation	Analysis of existing solar radiation data and recommendations for the type, quality, and disposition of data required for the design of passive solar heating and cooling systems.
Sky Properties	Collect data on sky radiation properties in different geographic locations. Analyze and assess applicability of radiative cooling in various parts of the country. Develop programs for computer simulation of atmosphere.

Name of Study	Description of Study
Atmospheric Effects	Assemble existing design-related information on wind velocity, relative humidity, ambient dry-bulb temperature, dewpoints, etc., and extend measurements of these quantities as appropriate. Develop computer simulations of the effects of these factors on the operation and efficiency of the various passive heating and cooling systems.
Ground Properties	Expand as required the data base for ground temperature and conductivity for various soil types and conditions. Develop computer simulation programs for ground-thermal effects. Validate computer code against test results.
Terrain	Assess impact of natural terrain and the built environment on passive solar heating and cooling systems and identify range of suitable sites. In particular, the effects of the environment on solar availability and wind patterns will be addressed.
Heat Exchange Mechanisms	Examine heat exchange and heat transfer processes which are appropriate to passive solar heating and cooling applications. Consideration will be given to heat flow within fluids, between different fluids, and between fluids and solids.

Product Development Tasks

Tasks in the product development category include design, development, testing, and evaluation of both materials and assemblies of materials which will either enhance passive system performance or simplify the implementation of a passive design. Materials tasks are concerned with evaluating existing materials for their applicability to passive solar design concepts and the development of new materials and components to solve specific problems encountered in passive solar design. Activity in this area includes gathering and publishing data on existing materials which are of special interest to passive solar system designers.

An assembly is an organization of materials and/or components into a functional portion of a passive solar system. This generally involves traditional building materials and products that are "assembled" to form collection elements (i.e., glass and framing into window assemblies), storage elements (i.e., concrete or masonry units for thermal storage wall), and other functional elements of passive solar systems (i.e., absorbers, reflectors, insulation, and controls). The tasks in this area are directed toward the evaluation of these materials and products in complete assemblies and the development of entirely new assemblies for passive solar heating and cooling applications. Activity in this area includes gathering and publishing data oriented toward passive solar building designers.

Project Area	Description of Activity
Glazings	Organize existing information. Where necessary, analyze the thermal and solar optical properties of glazing materials alone and in combination, and develop high transmissivity glazings, optical shutters, heat mirrors, and coatings with other advantageous properties such as I.R. transparency or directional sensitivity of optical properties. Characterize the performance of glazing assemblies in terms of in-use optical and thermal transmission and reflection and in terms of infiltration. Develop movable glazing assemblies.
Absorbers and Emitters	Examine existing absorption and emission characteristics of materials with emphasis on those used in radiative cooling systems. Develop selective absorbers and emitters for heating and cooling applications. Develop absorber/storage and emitter/storage combinations. Develop schemes for cooling radiators.
Reflectors	Examine properties of existing reflective materials. Test as required. Organize and publish data. Develop heat mirrors and other innovative reflective materials; develop ground plane reflectors and reflector/movable insulation combinations.
Insulation	Review available insulation material properties and determine applicability to passive design approaches. Organize and publish data. Develop movable insulation systems alone and in combination with glazing, reflector, and storage assemblies.
Storage	Characterize existing materials, searching for improved combinations, and develop lightweight and/or high heat capacity storage materials. Develop high thermal mass masonry and concrete structural systems, water containers, and containerization for phase change materials.

Project Area	Description of Activity
Shading Devices	Characterize existing devices (awnings, external and internal shades, etc.) and devise other elements for protecting glazing and other parts of the structure from excess solar gain.
Heat Exchangers	Survey and assess existing heat exchangers for passive applications. Develop, as necessary, earth-air and structure-water exchangers which work well with small pressure drop and low flow rates.
Fluid Flow Motivators	Develop promising schemes for solar chimneys and towers, wind scoops and towers, catabatic chillers, high efficiency fans and pumps, etc.
Fluids and Sealants	Examine existing fluids from the point of view of corrosion, specific heat transfer, and latent heat transfer. Consider possibilities of reverse thermosyphoning. Develop improved sealants around dampers and movable insulation and improve integration of glazing systems into the building envelope.
Evaporative Chillers	Develop promising schemes for industrialized, retrofitable direct evaporative chillers, regenerative air charged storage chillers, catabatic chillers, and low-mass heat exchange chillers.
Humidifiers and Dehumidifiers	Emphasis will be on developing dessicant dehumidifiers and high-efficiency mechanical dehumidifiers for application in closed passive cooling buildings.
Sensors, Actuators, and Controls	Evaluate existing sensors, actuators, and controls for performance, cost, durability, and reliability. Identify need for and develop new devices.
Combination Assemblies	Develop designs for factory or site-built combinations of glazing, absorbers/emitters, reflectors, insulation or storage that will simplify the construction of passive systems. Both economic advantages and fabrication simplifications will motivate these tasks.
Miscellaneous	Assorted peripheral products of some promise will be considered.

Systems Development Tasks

The full development of a passive solar system encompasses the following activities:

Name of Activity	Description of Activity
Concept Generation and Assessment	Develop basic physical descriptions of systems including their thermal processes and proposed modes of operation. This activity is followed by a preliminary evaluation of the systems in terms of technical and economic potential. It is assumed that this activity would occur at several critical points during the development of a system, but special attention will be given to the preliminary assessment which occurs immediately after concept generation.
System Specification	This activity results in the engineering realization of a concept. It includes the detailed physical description of the system and the manner in which it is integrated with the conventional building structure and systems. Materials and fabrication procedure identification, controls and operating strategies definition, etc., are part of the specification procedure.
Systems Analysis (Thermal Modeling, Economic Analysis, Human Comfort, Environmental Analysis, etc.)	This theoretical proof-of-concept activity consists of a complete analysis of the specified passive solar heating and/or cooling system. This evaluation will include thermal and economic considerations, environmental impact if appropriate, technical feasibility, and human comfort and human interaction factors as necessary. This analysis will establish preliminary performance criteria and will be used in the definition of thermal performance factors and development of specifications for instrumentation appropriate to monitoring of performance factors in subsequent testing activities.
Data and Instrumentation Requirements	Definition of thermal performance factors and development of specifications for instrumentation appropriate to monitoring the performance factors of full-scale buildings.

Name of Activity	Description of Activity
Performance Data Acquisition (Test Rooms and Instrumented Buildings)	Controlled experiments involving parts of systems or miniature systems. This is the first step in the engineering proof-of-concept. The final engineering proof-of-concept includes controlled experiments involving full-scale buildings. These case studies are utilized to provide final validation for the systems analysis activities described above.
System Studies	Studies dealing with thermal and economic performance sensitivity, climatic applicability, control strategies, economic trade-offs, and other system optimization considerations.
Performance Criteria	Results of experiments and studies will be used to establish performance expectations.
Design Tools	Results of the systems studies tasks and data collected from the product development tasks, performance data acquisition tasks, and system analysis tasks will be documented and published in forms appropriate to all levels of the building community. Handbooks, rules-of-thumb, guidelines, hand-held calculator programs, and other aids will be made publicly available.
Market Field Tests	The final step in the technology development process is the testing of the marketability of the end-products: the design concepts, the design tools, the associated materials and hardware. The market field testing program will assess the compatibility of the technology with the marketplace and with the users of the technology who produce the marketable designs and products.

TABLE II-3

Technology Development Task Classifications

I. BASIC PHYSICAL STUDIES	A. Solar Radiation B. Sky Properties C. Atmospheric Effects D. Ground Properties E. Terrain F. Heat Exchange Mechanisms
II. PRODUCT DEVELOPMENT TASKS (MATERIALS AND ASSEMBLIES)	A. Glazing Mat'ls & Assemblies B. Absorber & Emitter Mat'ls & Assemblies C. Reflector Mat'ls & Assemblies D. Insulation Mat'ls & Assemblies E. Storage Mat'ls & Assemblies F. Shading Devices G. Heat Exchangers H. Fluid Flow Motivators I. Fluids and Sealants J. Evaporative Chillers K. Humidifiers and Dehumidifiers L. Sensors, Activators, and Controls M. Combination Assemblies N. Miscellaneous
III. SYSTEM DEVELOPMENT TASKS	A. Concept Generation & Assessment B. System Specification (Architectural & Engineering Definition) C. System Analysis (Thermal Modeling, Economic Analysis, etc.) D. Data & Instrumentation Requirements E. Performance Data Acquisition (Test Rooms & Instrumented Buildings) F. System Studies (Parametric Sensitivity, Climatic Applicability, etc.) G. Design Tools (Handbooks, Computer Codes, etc.) H. Performance Criteria I. Market Field Tests

- Architectural/Engineering Definition
- Design Development
- Thermal Modeling
- Economic Analysis
- Human Comfort
- Environmental Analysis
- Architectural/Engineering
- Evaluation
- Validation of Analysis Technique
- Test Rooms/Small-Scale Testing
- Instrumented Buildings/ Full-Scale Tests
- Parametric Sensitivity
- Climatic Applicability
- Control Strategies
- Rules of Thumb
- Handbooks
- Computer Programs
- Competitions
- Marketable Design Development

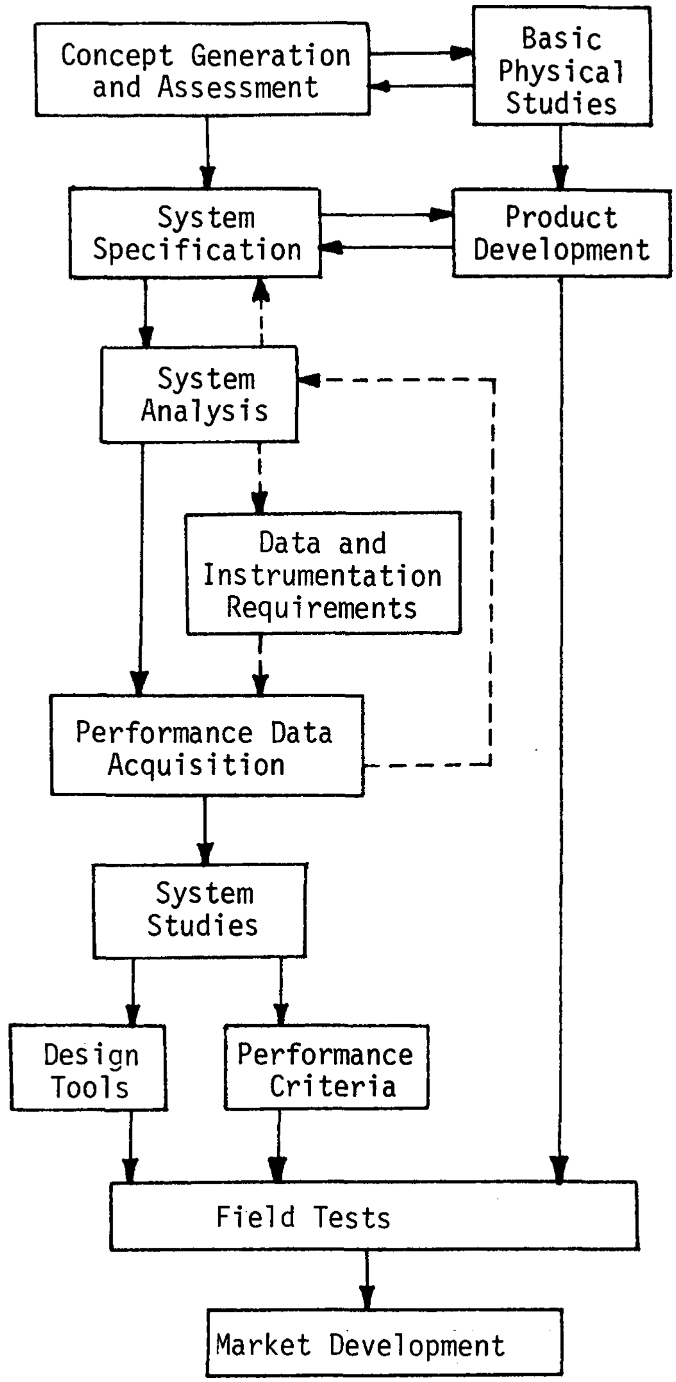


FIGURE II-7. System Development Process

PART III:

TECHNOLOGY UTILIZATION

SECTION H: BACKGROUND

SECTION J: PROCESS DESCRIPTION

SECTION K: TASK CLASSIFICATIONS

SECTION H:

BACKGROUND

Technology utilization is the process of identifying cost-effective and environmentally and socially acceptable technologies and developing a conducive application environment (market) for those technologies. It is concerned with moving a technology from research, development, and field testing to widespread acceptance and application in the marketplace through market development activities. This purposeful movement of a technology is often called the commercialization process.

The commercialization of passive solar systems is distinctly different from commercialization of hardware-oriented technologies. In the latter case the components and systems are typically visible entities, the contribution of which to the welfare of the consumer being easily determined and/or readily apparent. Passive solar systems, on the other hand, are generally integral parts of the building design. The passive solar components are not easily distinguishable from the remainder of the structure; they often consist of materials which are already common in the building industry (e.g., glass, masonry, insulation, etc.).

Passive solar energy utilization is primarily a design procedure. Successful commercialization relies, first, on casting the procedure in a form that is amenable to application by the design profession; second, on stimulating the profession to apply the procedure; and third, on sensitizing both the consuming market and consumer-supporting financial, utility, and real estate segments of the economy to the benefits of passive design through existing communication channels.

The specific objectives of the technology utilization (market development) program are to:

- Determine the technical, market/economic, environmental, and institutional readiness of passive cooling and domestic hot water systems for commercialization. This objective has been accomplished for passive solar heating. If appropriate, prepare a detailed commercialization plan.

- Conduct detailed market research studies to determine user acceptance requirements and to identify areas of opportunity for focusing commercialization activities.

- Operate a technology transfer program for collecting, storing, evaluating, reporting, and disseminating technical, market/economic, environmental, and social data generated by passive solar research, development, market field testing, and commercialization activities.

- Widely disseminate passive solar design tools to designers, builders, and consumers.
- Establish an effective education and training program for architects, engineers, builders, developers, construction tradespeople, lending officials, and code officials.
- Stimulate the passive design delivery capability of the construction industry by assuring solar access, establishing effective performance criteria, reducing codes and standards hurdles, and introducing economic incentives.
- Stimulate and accelerate the demand for passive solar designs through a coordinated program of consumer education; utility involvement; federal, state, and local facilities programs; tax credits; and design competitions.

Status of Technology Utilization (Market Development)

Only limited passive commercialization activities are occurring throughout the country, most of which are non-federally funded. A few of these activities are described below.

- HUD has sponsored in conjunction with DOE and SERI a passive residential design competition resulting in 162 awards.
- The states of Minnesota and Illinois have sponsored residential design competitions.
- TVA, Wisconsin Power and Light, Pacific Gas & Electric, and many other utilities are investigating the peak load sharing potential of passive systems and consumer loan programs to finance solar system costs.
- New Mexico, California, Oregon, and Colorado have income tax credits for passive systems.
- Virginia has a property tax exemption provision for passive systems.
- California, New Mexico, and several other states have initiated passive solar education courses for builders and designers.
- Four regional solar energy centers have been established by DOE to assist in the accelerated commercialization of solar energy technology.

- Certain localities (e.g., Davis, California) have modified building codes and zoning regulations to accommodate passive systems.

- SERI has completed a technology readiness assessment of passive solar heating and cooling focusing primarily on economic performance projections.

- Several publications and pamphlets on passive systems have been completed for designers and builders including a passive solar bibliography and a survey of passive solar buildings.

Even though passive systems exist which have proven potential for energy savings, the rate of new passive buildings construction indicates a lack of and need for commercialization activities. Passive solar designs have not reached the general marketplace. This is partially due to the lack of adequate economic and thermal performance data for various passive designs. To have a major impact in the marketplace, a definite need exists for an organized and concentrated program to promote the awareness of, supply of, and demand for passive solar systems.

Strategy for Technology Utilization

The commercialization strategy for passive solar heating and cooling systems is based on the following considerations:

- Regional and local conditions play an important role in the commercialization of passive solar systems. The building design and construction industries and the consumer market are more regionally and locally oriented than are most consumer-hardware industries.

- The commercialization of passive solar systems must emphasize education of an existing industry rather than the development of a new one. The building industry exists with established constituencies and practices; it must be sensitized to the passive solar concepts and benefits.

- Passive solar design is more an attitude and a design process than a technology. Commercialization activities must recognize the motivational and knowledge-intensive characteristics of passive design and respond accordingly.

The strategy for technology utilization is composed of four elements: commercialization readiness assessment, technology transfer, stimulation of technology delivery capability, and stimulation of market demand.

Commercialization Readiness Assessment

Prior to the commercialization of any technology, it is necessary to know the technical, market/economic, environmental, and institutional readiness of the technology to enter the marketplace. This includes identifying the benefits to be achieved by commercializing the technology, as well as the barriers that must be mitigated. The readiness assessment and benefits analysis result in a commercialization plan describing a coordinated set of development and utilization activities to move the technology into the marketplace. This would include market research to characterize the market for various passive systems by consumer group, by user type, by application, by geographic location, and by alternative fuel costs.

A commercialization readiness assessment has been performed for passive solar heating. The results and recommendations of this assessment have been included in this Plan. Assessments need to be performed for passive cooling, domestic hot water, and agricultural and industrial processes.

Technology Transfer

Just as important as having a demand for passive solar designs and products is having an established building community capability to meet those demands. Technology transfer is the means to develop within the building community a capability to design, build, finance, and market passive solar systems. The commercialization strategy for passive systems includes the establishment of a technology transfer system composed of three activities: data management, education and training, and information dissemination.

The purpose of data mangement will be the development and maintenance of a data and information base on passive systems. It will consolidate present data and information on passive systems (e.g., performance, market potential, economic viability, design tools, etc.) and be updated as information and data from tasks called for in this Plan become available. It is essentially a resource for supporting other commercialization activities.

A primary use of this resource will be the preparation of training materials and programs for regionally and state implemented workshops and seminars. Initially, education and training activities will be directed toward architects, engineers, and builders as key elements in the passive technology delivery system. Subsequent education activities will focus on planners, lenders, government officials, and realtors.

The purpose of the third activity of the technology transfer system will be the dissemination of information to various user groups influential in commercializing passive solar systems. This activity will include determining user requirements, evaluating information appropriateness, converting the information to a useful form, disseminating the material through established user communication channels, and monitoring and evaluating the effectiveness of the program.

Stimulation of Technology Delivery Capability

The decision to use a passive system is based upon many factors, such as client desires, designer awareness and understanding, regulatory acceptance, and lender approval. Removing some of the uncertainties during this decision-making process may greatly stimulate the application of passive techniques. Several areas where this may be appropriate are solar access, building codes and standards, and performance criteria. Additionally, incentives may be proposed to encourage a positive decision regarding the application of a passive system.

Stimulation of Market Demand

A market demand is essential to the commercialization of a technology. The demand can be real or perceived, and is depressed by a lack of awareness, knowledge, and decision-making data, as well as by risks (real or imagined) related to new design concepts, systems, or practices. Therefore, stimulation of market demand is generally necessary to overcome initial prejudices or traditional attitudes. Strategies for stimulating market demand include consumer education, utility programs, government building programs, design competitions, and financial incentives.

Emphasis of Technology Utilization

The lack of design tools and marketable passive building designs has been identified as an important obstacle. However, the completion of these two development activities is not an essential prerequisite to starting the commercialization efforts. The first generation of passive solar heating design tools has almost been completed and final steps have been taken in the process of generating marketable designs. The first phase of commercialization can be initiated immediately and carried out in parallel with marketable design development. Emphasis will be on detailed market research to carefully identify areas of opportunity and to focus commercialization activites.

The cornerstone of phase two, and indeed of the entire commercialization effort, is education and information dissemination. A key element in the commercialization of passive systems is the ability of the building community to effectively integrate passive solar approaches into their normal design and construction processes.

The goals of commercialization will be met when passive solar design is accepted as "standard practice" by both design professionals and building trades; in other words, when common materials and passive solar products are used in such a way as to maximize the benefits of the environmental resource with minimal dependence on mechanical equipment and conventional fuels. Education of the key participants in the building industry (designers, builders, developers, planners, lenders, regulatory officials, etc.) and expansion of existing professional design and trade organization education and information programs will greatly stimulate near-term use of passive concepts.

An important parallel activity is consumer education. Involvement of the consumer at all stages of the commercialization process is important to the testing and refinement of ideas. The role of the consumer in molding the ultimate outcome of the process is just as critical in the early stages as it is later on, and failure to achieve an appropriate level of early involvement can lead to critical mistakes. Furthermore, a demand in the marketplace is a crucial stimulant to rapid development in the delivery sector. Since the building industry has little difficulty selling its present product, it appears that little or no commitment will be made until a consumer demand is perceived.

A secondary, but still very significant, emphasis will be on the use of incentives to stimulate both the supply and demand sectors--e.g., tax credits and small business loans for builders and accelerated depreciation and income tax credits for commercial and private consumers. Also of significance in stimulating both the delivery and demand sectors will be various government-sponsored building programs involving public buildings and design-build competitions.

SECTION J:

PROCESS DESCRIPTION

The process of achieving widespread utilization (commercialization) can be divided into the following elements:

- commercialization readiness assessment,
- technology transfer,
- stimulation of technology delivery capability,
- stimulation of market demand.

These elements represent a continuum and often overlap one another. Each is also connected in various ways to the technology development process. For example, one portion of the commercialization readiness assessment is a thorough technical evaluation, considering operational status, capital and operating expenses, technical barriers, etc., to determine the readiness of the technology to enter the marketplace. Many times, results from this evaluation identify further development activity that must occur before accelerated commercialization takes place.

A primary function of the commercialization process is the identification of industry and consumer needs so that technology development and utilization activities can be selected, modified, or redirected to meet those needs. In this respect, all commercialization activities are designed to address or involve the various groups that represent or influence the technology delivery system. These groups include legislators, regulatory officials, lenders, lawyers, architects, engineers, builders/developers, manufacturers, suppliers, installers, craftsmen, and consumers. Each group has specific informational, educational, and motivational requirements that must be considered if one hopes to stimulate the commercialization process. Therefore, to best determine what these requirements are for each group, it is crucial that they be involved in the commercialization planning process. As tasks are initiated, evaluation by these same groups is needed to determine the effect of the activities toward achieving the commercialization objective.

A more detailed description of the utilization elements is presented below.

Commercialization Readiness Assessment

As a first step in the utilization process, it is necessary to assess the readiness of a technology to enter the marketplace and to be successfully applied. This would include an assessment of a technology in terms of (1) technical readiness (operational status, capital and operating expenses, current developments underway, and technical barriers); (2) market/economic readiness (market description, economic analysis, market penetration, and market barriers); (3) environmental readiness (environmental compliance and environmental barriers); and (4) institutional readiness (institutional barriers and manufacturer status). This is generally followed by a benefits analysis which assesses (in the case of energy technologies) energy impacts, recipients of benefits, and cost impacts.

The commercialization readiness assessment provides a comprehensive look at a technology and serves as a basis for deciding whether further commercialization planning is warranted. Those technologies deemed "ready" for commercialization--i.e., those with no major technical, cost, or institutional barriers--proceed to primarily market research studies and commercialization strategy development. Both of these planning tasks are designed to focus commercialization efforts and give priority to certain systems, applications, geographic locations, and user groups.

Technology Transfer

A second step in the utilization process involves intervening in the marketplace with those groups who, directly or indirectly, influence the use of a technology. The primary intent is to familiarize them with the technology--its development status, its technical and economic potential, its marketability, and its application requirements. Technology transfer generally involves data management, education and training, and information dissemination. It is concerned with communication, the purposeful transfer of information to change an individual's behavior. This requires the appropriate selection of communication channels, as well as information content and format.

Technology transfer activities must have well-defined methods and channels of feedback. The influence or effect of an activity must be quickly determined so that corrective actions can be taken when necessary. Technology transfer activities can also play a significant role in identifying new needs or requirements that may be addressed by new or modified tasks either in the development or utilization areas.

Stimulation of Technology Delivery Capability

A knowledgeable delivery sector may not by itself accelerate the commercialization of a technology. It may be necessary to modify certain industry ground rules or to provide additional protection or assurances to motivate the user community to adopt a technology. This element of the utilization process is responsible for characterizing the technology delivery system and identifying key points in this system where stimulation may be effective in accelerating the use of a technology. The types of activities that may be appropriate to stimulate application of passive systems include: assuring solar access through zoning or deed modifications; modifying building codes to allow innovative passive design approaches; developing standards for passive solar materials and components; and legislating incentives to support small business development.

Stimulation of Market Demand

Perhaps the most important element of the commercialization process is the creation or enhancement of market demand for the technology. The success of the commercialization process is measured by market demand for the technology and the ability of the industry to meet this demand. Market demand can be stimulated in many ways. For passive systems this includes consumer education; utility programs; solar energy in public buildings programs; national, regional, and state design/build competitions, and financial incentives. The difficult task is the selection of those actions which will most effectively stimulate a rapid and enduring market response.

The technology development and utilization processes must be regularly assessed in terms of effectiveness in achieving program goals. To do this, acceptable evaluation criteria and measurement techniques are needed. Just as important, comments and recommendations from the user community and the public are necessary to evaluate the program and to initiate new tasks or modifications to existing tasks.

As with any government sponsored program, determining when government involvement is and is not appropriate requires careful consideration. Government action can stifle the development and utilization of a technology or it can provide effective support and direction. Timing can be the most critical element of government involvement. As part of the program analysis activity, the role of the government will be carefully assessed.

SECTION K:

TASK CLASSIFICATIONS

This section describes the areas by which the tasks are organized. The technology utilization tasks themselves are contained in Appendix C with schedules for some of these tasks presented in Appendix D.

Table III-2 provides an overall picture of the task classification scheme. Because the general nature of the activities that occur in each of these areas has been given in the preceding section, no further description of these activities is provided here.

TABLE III-1

Technology Utilization Task Classifications

I. COMMERCIALIZATION READINESS ASSESSMENT	A. Technical Readiness B. Market/Economic Readiness C. Environmental Readiness D. Institutional Readiness E. Benefits Analysis F. Commercialization Planning
II. TECHNOLOGY TRANSFER	A. Data Management B. Education and Training C. Information Dissemination
III. STIMULATION OF TECHNOLOGY DELIVERY CAPABILITY	A. Solar Access B. Building Codes and Standards C. Performance Criteria D. Incentives
IV. STIMULATION OF MARKET DEMAND	A. Consumer Education B. Utility Programs C. Solar Energy in Federal Facilities D. Solar Energy in State/Local Bldgs. E. National, Regional, and State Design/Build Competitions F. Policy Studies G. Incentives

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PART IV: APPENDICES

APPENDIX A:

TECHNOLOGY DEVELOPMENT TASKS

The following classification scheme is used to organize the technology development tasks:

I. BASIC PHYSICAL STUDIES	A. Solar Radiation B. Sky Properties C. Atmospheric Effects D. Ground Properties E. Terrain F. Heat Exchange Mechanisms
II. PRODUCT DEVELOPMENT TASKS (MATERIALS AND ASSEMBLIES)	A. Glazing Mat'ls & Assemblies B. Absorber & Emitter Mat'ls & Assemblies C. Reflector Mat'ls & Assemblies D. Insulation Mat'ls & Assemblies E. Storage Mat'ls & Assemblies F. Shading Devices G. Heat Exchangers H. Fluid Flow Motivators I. Fluids and Sealants J. Evaporative Chillers K. Humidifiers and Dehumidifiers L. Sensors, Activators, and Controls M. Combination Assemblies N. Miscellaneous
III. SYSTEM DEVELOPMENT TASKS	A. Concept Generation and Assessment B. System Specification (Architectural and Engineering Definition) C. System Analysis (Thermal Modeling, Economic Analysis, etc.) D. Data and Instrumentation Requirements E. Performance Data Acquisition (Test Rooms and Instrumented Buildings) F. System Studies (Parametric Sensitivity, Climatic Applicability, etc.) G. Design Tools (Handbooks, Computer Codes, etc.) H. Performance Criteria I. Market Field Tests

Listed below are specific tasks which have been identified as significant to the development of passive solar technology. The tasks have been further classified as applying to passive solar heating (H), passive solar cooling (C), or both (H,C). Where possible, the tasks are specific; in many areas where passive technology is not well developed, general tasks have been defined.

Many of the tasks are important to two or more of the passive systems which have been recommended for development; for this reason, individual tasks are not cross-referenced to systems and definitive time schedules have not been provided. The general time frame for system development provided in Appendix B indicates only those tasks from the list which are of crucial significance to the systems with which they are associated.

I. BASIC PHYSICAL STUDIES TASKS

A. Solar Radiation

I.A.1 (H)

Increase the number of sites where solar radiation on a south-facing vertical surface is recorded. Use this data to refine existing methods of estimating vertical surface solar radiation from measured horizontal solar data.

I.A.2 (H)

Devise a technique for separating sky radiation from ground-plane reflected radiation. Develop a system for describing and characterizing the local terrain at these sties. Make this information available through the existing data network and other appropriate mechanisms.

I.A.3 (H,C)

Define solar design years appropriate to passive heating and cooling systems. Of special significance is the beam to diffuse radiation ratio, its hourly variation, and the parameterization in terms of local observables. The effect of local solar persistence should be included.

I.A.4 (C)

Investigate methods of parametric expression of daylighting effectiveness in terms of beam and diffuse radiation.

I.A.5 (H,C)

Assess the impact of sky-light polarization on daylighting effectiveness.

I.A.6 (H,C)

Assess the adequacy of existing sky-light polarization data in terms of daylighting. Extend measurements as necessary.

B. Sky Properties

I.B.1 (C)

Develop, test, and deploy infrared sky radiometers for measuring the spectral atmospheric emission parameters in various parts of the country. These measurements will be utilized to assess the potential effectiveness of emitting surfaces for radiative cooling systems.

I.B.2 (C)

Parameterize the infrared emission characteristics of the sky in terms of common observables and interpret the parameterizations in terms of effective sky temperature.

I.B.3 (C)

Define a radiative cooling design day which separates the visible and infrared portions of the spectrum for both daytime and nighttime periods.

I.B.4 (C)

Empirical monitoring of full spectral run (i.e., non-spectral) on horizontal at a wide variety of cities in U.S. representative of a variety of climate types. Special attention should be given to humid southeastern and Gulf Coast climates not included in the DOE Solar Meterological Research and Training sites.

I.B.5 (C)

Empirical monitoring of non-spectral IR atmosphere and ground radiation received on tilted surfaces including sensitivity to type of ground surface and presence of vegetation.

I.B.6 (C)

Develop a calibration facility which can provide highly accurate absolute calibration of the various non-spectral infrared radiometers and net radiometers available.

I.B.7 (C)

Assess the potential for dehumidification by radiative cooling from a surface below the dewpoint temperature using both selective and non-selective radiating surfaces.

C. Atmospheric Effects

I.C.1 (H)

Study energy loss effects of wind stripping of still air layer at the surfaces of buildings. The study should consider a variety of materials, surface textures, and building configurations, with special emphasis on glazings.

I.C.2 (H,C)

Investigate methods of parametric reduction of weather data for use in passive heating and cooling system analysis and design. Define and develop a design night relevant to ventilation cooling systems. The design conditions should include windspeed, dry bulb temperature, and dewpoint.

I.C.3 (H,C)

Study effects of wind and temperature on infiltration in standard building constructions.

I.C.4 (C)

Develop algorithms for wind-augmented evaporative cooling.

I.C.5 (C)

Assess potential for evaporative cooling in a variety of climates, including relatively humid regions.

I.C.6 (C)

Assess microclimate effects of evaporative cooling in high population density applications.

I.C.7 (C)

Assess the merits and problems with using small-scale test models to study ventilation effects.

I.C.8 (C)

Investigate air flow patterns within existing building envelopes in densely-built environments and in natural terrain. Study effect of building openings, architectural form, and room placement on ventilation cooling of occupants and structure.

D. Ground Properties

I.D.1 (H,C)

Perform a state-of-the-art investigation of ground temperatures and ground conductivities. Private and government sources (including military) should be surveyed.

I.D.2 (H,C)

Extend the Department of Agriculture ground temperature measurements to greater depths and a greater climatic range.

I.D.3 (H,C)

Carry out studies of ground conductivity and temperature for various soil types and conditions as affected by ground water. Develop a method of characterizing the thermal conductivity and heat capacity in terms of local measurements.

I.D.4 (H,C)

Define a design year for soil thermal properties for a variety of climatic regions.

I.D.5 (H,C)

Identify factors which influence heat transfer through soil and devise methods of manipulating these factors.

E. Terrain

I.E.1 (H,C)

Initiate studies to assess the potential of passive heating and cooling systems in terms of available sites. Attention should be given to shadowing, local wind patterns, and reflectivity of the terrain. Both natural terrain and the built environment should be considered in new and retrofit applications.

I.E.2

Assess and characterize the effect of local terrain features on wind-driven ventilation cooling (both in terms of simple air movement and direct evaporative cooling). Also consider the effect on evaporative cooling of external surfaces and convective interference with radiative cooling of external surfaces.

I.E.3 (C)

Assess and characterize the effect of local terrain features on wind-driven ventilation cooling.

F. Heat Exchange Mechanisms

I.F.1 (H)

Perform in-depth theoretical and experimental studies of air flow in storage walls with vents. Consider spacing between glazing and storage, collection surface texture, storage configuration, and inlet and outlet configuration. Generate heat transfer coefficients from fundamental principles.

I.F.2 (H,C)

Investigate the infiltration aspects of simple doors and doors with airlocks.

I.F.3 (H,C)

Investigate temperature-driven and pressure-driven convective heat transfer in bulk fluids within a space and through openings in walls. The purpose will be to develop algorithms for integration into existing computer codes to describe thermal operation of passive systems. Validate with experimental data.

I.F.4 (H,C)

Generate convective heat transfer coefficients appropriate to various passive configurations starting with fundamental principles. Validate using experimental data. Investigate heat transfer coefficients at the interface between air and a solid surface. Parameterize the coefficients as functions of the measurable boundary conditions.

I.F.5 (H,C)

Investigate the effects of flow passage size and system layout on the performance of low velocity, natural convection solar heating and cooling systems which utilize rock bed thermal storage. Analyze the stability of the flow through the rock bed and the effects of turns, duct sizes, and obstructions on the air flow characteristics of the system.

I.F.6

Investigate natural heat exchange mechanisms used in the indigenous architecture of hot regions throughout the world.

I.F.7 (H,C,)

Investigate horizontal and vertical heat transfer (both convective and conductive) in water as functions of container configuration and the location of the aperture through which energy is delivered to or extracted from the water.

I.F.8 (C)

Generate and investigate windscreen configurations which enhance wind-augmented evaporation cooling.

I.F.9 (C)

Investigate air flow patterns in actual building situations. Correlate observed patterns with natural ventilation through openings in the building envelope.

I.F.10 (H,C)

Develop simplified quantified methods for determining air mass heat transfer.

II. PRODUCT DEVELOPMENT TASKS

A. Glazing Materials and Assemblies

II.A.1 (H)

Develop infrared reflection coatings. Emphasize increasing the solar spectrum transmittance of the coating while retaining the reflection characteristics. Study the effect of IR reflection and solar transmission on collection performance for both flat black absorber and selective absorber surfaces.

II.A.2 (H)

Determine the effect of glass surface conditions on collector performance. Include an evaluation of traditional glass surface figuring and etching.

II.A.3 (H)

Continue development of surface etching processes for reducing reflectivity on both glass and plastics. Determine the types of glass or plastic most appropriate for this treatment, their potential for mechanical surface failure, the effect on them of diret and repeated washing, and their cost-effectiveness.

II.A.4 (H,C)

Investigate/develop "optical shutter" glazings in the following categories:

- Electric-field actuated, variable-plasma-edge semiconductor films.
- Electric-field actuated, variable-color-center-density films.
- Thermally actuated reflective films.

II.A.5 (H,C)

Develop durable coatings for plastic glazings. Compare the cost of applying a coating of polymeric plastic on PVC film to the cost of building the stabilizer into the polymeric material.

II.A.6 H,C)

Collect and publish existing designer-oriented information on glazing materials, components, and assemblies appropriate to passive heating and cooling systems. Extend information base as necessary to cover the full spectrum of relevant topics related to in-use transmission, heat loss, infiltration, etc.

II.A.7 (H,C)

Test, as required, available glazings individually and in combination. Investigate the reflectivity, absorptivity, transmissivity, and diffusion effects as a function of angle of incidence, radiation wavelength, and material age. Document hourly and daily transmitted solar radiation through various combinations of glazings as a function of:

- angle of glazing,
- sun angle and intensity.

Experimental data are desirable because of the poorly understood effects that diffusion in the first layer can have on the transmission of subsequent layers. Non-optical data should also be acquired; flammability, outgassing, and aging effects are of special importance.

II.A.8 (H,C)

Investigate means for applying both IR reflective and antireflective coatings uniformly in large volume production. Consider coatings for glass and plastics, and study the cost implications of the production process.

II.A.9 (H,C)

Generate and evaluate concepts for movable glazing for south-aperture and roof aperture systems.

II.A.10 (C)

Survey existing IR-transparent materials to identify promising candidates for use with sky-cooling radiators.

II.A.11 (C)

Develop IR-transparent materials for use with sky-cooling radiators. Assess optical compromise for combined heating and cooling.

II.A.12 (C)

Generate and test concepts for glazing which incorporate mechanical reflective shutters for daylighting control.

II.A.13 (H,C)

Develop plastic materials capable of withstanding long-term exposure to visible and ultraviolet radiation while dry or in contact with water and/or chemical additives (e.g., antifreeze solutions). Materials which show promise should be checked for τ, α, and ρ in the infrared.

B. Absorber and Emitter Materials and Assemblies

II.B.1 (H,C)

Collect and publish existing designer-oriented information on absorber coatings and emitter coatings appropriate to passive solar applications. Durability and safety considerations will be included in this documentation. Institute a survey of existing selectivity absorbing coatings and assess potential for application to masonry storage units, containers for water and PCM storage, and other building materials. Durability and safety issues will be addressed.

II.B.2 (H)

Investigate additives for water which can be used to "fine tune" the absorptivity of water in clear storage tubes. Emphasis should be placed on high absorptivity in the UV and IR. Devise variable absorbers for use in clear, water storage containers.

II.B.3 (H,C)

Collect and publish existing designer-oriented information on collectors and radiators which might be appropriate to passive solar applications. Information on installation and application experience, durability, safety, performance, etc. will be included.

II.B.4 (C)

Institute a survey of existing selective emitters and assess feasibility for applications to passive solar cooling.

II.B.5 (C)

Identify desired properties of selected emitters for use in radiative sky-cooling applications.

II.B.6 (C)

Develop selective emitters with properties appropriate for use in radiative sky-cooling applications.

II.B.7 (C)

Undertake a comprehensive program to measure the infrared optical properties of candidate materials for radiative cooling systems. Materials with appropriate absorptance/emittance characteristics will be used in fabrication of radiative cooling panel/windscreen systems. These prototype configurations will be tested and evaluated in test bed measurements.

II.B.8 (C)

Perform a state-of-the-art investigation of surface coatings and finishes which control solar loading on the building envelope and/or have selective spectral properties. Military and aerospace technologies will be included as prospective sources for data, materials properties, measurement facilities, and other pertinent information.

II.B.9 (C)

Generate and investigate windscreen schemes for minimizing atmospheric heating of sky-cooling radiators.

II.B.10 (C)

Develop wall and ceiling radiant cooling panels.

II.B.11

Develop retrofittable low-mass radiative cooling modules with daytime solar and ambient heat rejection.

II.B.12

Develop combined radiative heating and cooling modules which are regionally optimized.

C. Reflector Materials and Assemblies

II.C.1 (H)

Collect and publish existing designer-oriented information on reflector materials and assemblies which might be appropriate to passive solar applications. Durability and performance will be emphasized.

II.C.2 (H)

Generate and test schemes for ground reflectors for south aperture systems.

II.C.3 (H)

Generate and test schemes for combination reflector and movable insulation assemblies for a broad range of passive systems.

II.C.4 (C)

Develop coverings which lower the mean radiative temperature of interior surfaces (e.g., surface window coverings).

II.C.5 (C)

Generate and assess schemes for movable reflectors which shield a vertical radiative cooling surface or aperture from radiation from near the horizon. More generally, investigate materials and assemblies for rejecting infrared radiation from the warmer parts of the sky in order to enhance radiative cooling.

D. Insulation Materials and Assemblies

II.D.1 (H,C)

Collect and publish existing designer-oriented information on shades, shutters, and moving insulation which have been successfully applied to, or show promise for, passive heating and/or cooling systems.

II.D.2 (H,C)

Generate and test schemes for moving insulation for south, roof, and shaded roof apertures. Emphasize potential for integration with glazing, reflector, and storage assemblies.

II.D.3 (H,C)

Develop low-cost insulative sheathings for application to the outside of masonry and other high-mass structures. Emphasis should be placed on ease of application, resistance to weather and fire, and minimizing material and application costs.

E. Storage Materials and Assemblies

II.E.1 (H)

Develop and test a variety of clear containers suitable for placing in direct sunlight. Schemes should be generated both for south aperture and roof aperture applications.

II.E.2 (H)

Generate and test concepts for innovative high-heat capacity, high-absorptivity furnishings suitable to direct heating systems (e.g., water furniture). Select promising examples for testing and use in direct heating systems. Special attention will be paid to durability of the storage assemblies.

II.E.3 (H)

Generate and test concepts for water storage floors suitable for direct heating systems.

II.E.4 (H)

Investigate methods for combating aqueous corrosion of the various materials used for water tanks and heat exchangers. Include chemical additives and electrolytic processes. Consideration will be given to toxicity and to relevant potability requirements.

II.E.5 (H)

Identify and test non-corrodible liners for water storage tanks. These liners might be made of plastic, fiberglass, or other materials.

II.E.6 (H)

Investigate the use of unconventional materials such as concrete composites for water storage tanks.

II.E.7 (H,C)

Compile data, in user-oriented form, pertaining to existing storage assemblies suitable for passive solar applications. Information should include conductivity, specific heat, latent heat, cost (on regional basis), durability, reliability, modular dimensions, etc.

II.E.8 (H,C)

Generate and test concepts for masonry and concrete structural elements with additives to yield high heat capacity and conductivity.

II.E.9 (H,C)

Develop inexpensive techniques of encapsulating phase-change materials. Emphasis should be placed on energy exchange and durability.

II.E.10 (H,C)

Develop phase-change material storage assemblies appropriate to passive heating and cooling application. Of importance are modules adapted to operation in vertical orientation and modules adapted to operation at temperatures and orientations appropriate to roof or other evaporative cooling systems.

II.E.11 (H,C)

Investigate thermal losses from underground storage assemblies. Include effects of conductive heat transfer in soils and mass transfer due to groundwater movement.

II.E.12 (H,C)

Develop phase-change materials with several transition temperatures.

II.E.13 (H,C)

Develop high heat capacity replacement fillers for rock beds. Particular attention should be given to the wide range of economic factors, e.g., return would be high for regenerative air-charged storage since rapid cycling implies modest storage capacities will displace substantial amounts of energy.

II.E.14

Evaluate heat exchange properties under low flow rates for hollow wall masonry construction, and evaluate optimal channel shapes and proportions for maximum heat transfer.

II.E.16

Investigate problems of organism growth inside hollow masonry walls and rock beds under high humidity conditions.

F. Shading Devices

II.F.1 (H,C)

Assess the energy benefits and operational characteristics of various shading products presently on the market, such as awnings, external louvres, venetian blinds, etc.

II.F.2 (H,C)

Generate schemes for internal and external fixed and variable shading devices appropriate to vertical, horizontal, and sloping glazing.

II.F.3 (C)

Develop double roof modules and other shading devices to reduce solar loading on building surfaces.

G. Heat Exchangers

II.G.1 (H,C)

Survey existing heat exchangers and assess applicability to passive systems (e.g., for solar ponds, ground cooling, etc.).

II.G.2 (H,C)

Generate concepts for heat exchangers designed to use the ground as a source or sink for heat. Select promising schemes for development and testing.

II.G.3 (H,C)

Investigate heat exchange processes in salt-gradient stabled ponds. Develop heat exchanger designs appropriate to that application.

II.G.4

Develop high heat transfer wall elements for indirect ground cooling systems.

II.G.5 (H,C)

Determine appropriate depths for earth-air heat exchange pipes for various applications.

II.G.6 (H,C)

Identify pipe materials and joining methods appropriate to earth-air heat exchangers.

II.G.7 (H,C)

Establish range of optimum pipe diameters for earth-air heat exchangers.

II.G.8 (C)

Assess the need for fungus control in earth-air heat exchangers and develop methods as needed.

II.G.9 (H,C)

Generate concepts for earth-air heat exchangers.

II.G.10 (H,C)

Assess heat exchanger state of the art for applicability and appropriateness to ground cooling. Particular emphasis should be placed on heat exchanger performance (pressure drop and heat transfer under low flow rates).

H. Fluid Flow Motivators

II.H.1 (H,C)

Assess the state of the art of heat pipe technology. Consider the appropriateness of the operational characteristics and performance of currently available components and systems.

II.H.2 (H,C)

Generate and assess concepts for inexpensive heat pipes for application to passive buildings. Consider transport of energy from collection to storage and storage to space in heating systems, and from space to storage and storage to environment in cooling systems. Build and test most promising schemes.

II.H.3 (H)

Generate and test concepts for using heat pipes in passive solar hot water systems.

II.H.4 (H,C)

Develop and test fans and pumps specifically sized and designed for application to passive and/or hybrid systems.

II.H.5 (C)

Generate and assess schemes for wind scoops and wind towers as fabricated construction components.

II.H.6 (C)

Generate and assess schemes for low-mass and time-delayed solar chimneys for use in moving air for various passive cooling schemes. Also consider other "natural draft" cooling towers. Do thermal studies to assess ideal orientation, thermal mass, and glazing materials.

II.H.7 (H)

Develop retrofit convective heaters (remote and wall) and greenhouses.

I. Fluids and Sealants

II.I.1 (H,C)

Investigate heat transfer fluids that expand on cooling to provide the possibility of a reverse thermosyphon.

II.I.2 (H,C)

Collect and publish existing designer-oriented information on sealants, appropriate to passive solar applications.

II.I.3 (H,C)

Develop sealants for use around dampers, movable insulation, and movable glazing.

II.I.4 (H,C)

Survey and characterize existing sealants for use in reducing infiltration through glazing assemblies. Investigate silicones, ethylene terpolymerhydroxide (rubber) adhesive, polyvinyl butyral, EPDM, organic tars, etc. Study outgassing temperature stability, UV degradation, strength characteristics, cost of materials and installation, durability, toxicity, etc.

II.I.5 (H,C)

Develop effective sealing mechanisms and materials for large area moving insulation panels subject to wind loading.

J. Evaporative Chillers

II.J.1 (C)

Evalute thermal potential and range of application of direct evaporative coolers presently on the market. If warranted, investigate feasibility of improving design and performance of evaporative cooling units.

II.J.2 (C)

Generate and evaluate schemes for evaporative chillers based on water sprays rather than on wetted pads.

II.J.3 (C)

Generate and evaluate concepts for a retrofittable indirect evaporative cooler with remote storage.

II.J.4 (C)

Generate and evaluate concepts for a retrofittable window evaporative cooler to function with attic fan.

II.J.5 (C)

Generate and evaluate schemes for direct evaporative cooling using catabatic convection to drive air flow.

II.J.6 (C)

Generate and evaluate schemes for combining counterflow heat exchangers with evaporative cooling of air exiting from the building.

II.J.7 (C)

Evaluate existing regenerative air-charged storage schemes and identify any additional development which might be required.

K. Humidifiers and Dehumidifiers

II.K.1 (H)

Generate and assess schemes for passive solar humidifiers.

II.K.2 (C)

Develop more efficient conventional dehumidifiers for handling the latent load in various passive cooling schemes.

II.K.3 (C)

Generate and evaluate schemes for dual plate dessication systems.

II.K.4 (C)

Generate and evaluate schemes for three rotation dessicant wheels.

II.K.5 (C)

Generate and assess concepts for passive dehumidification devices.

II.K.6 (C)

Assess existing dessicant materials and identify need for new material properties.

L. Sensors, Actuators, and Controls

II.L.1 (H,C)

Develop and test sensors and controls which respond to the mean radiant temperature of the conditioned space.

II.L.2 (H,C)

Develop and test controls and actuators for movable insulation schemes.

II.L.3 (H,C)

Design and test damper control assemblies suitable for use with thermocirculation systems in Trombe walls and other natural convection systems.

M. Combination Assemblies

II.M.1 (H,C)

Develop schemes for combining glazing, absorbers or emitters, storage, reflectors, and insulation into assemblies which are economically advantageous and/or provide performance benefits over the non-integrated alternatives. Also consider the addition of necessary heat exchangers, hybrid components such as fans and pumps, and central systems.

II.M.2 (C)

Generate and evaluate designs for an assembly combining a direct catabatic evaporative chiller with a solar chimney.

II.M.3 (H)

Assess the state of the art of thermal diode technology. Consider the appropriateness of the operational characteristics and performance of currently available components and systems.

II.M.4 (H)

Generate and assess south aperture heating schemes which combine convective heater panels with direct gain panels and which regulate gains and losses through the direct gain glazing via movable insulation which is stored behind the convective heater panels.

II.M.5 (H,C)

Develop south aperture fold-down movable insulation combined with a reflector which can be used to enhance winter solar gains, and, in the partially lowered position, to enhance cooling by deflecting radiative losses toward the sky (i.e., it would shield the emitting aperture from radiation emanating from the vicinity of the horizon). Critical to the effort is combining such elements with glazing which is at least seasonally movable.

N. Miscellaneous

II.N.1 (H,C)

Evaluate existing trenching machines for laying earth-air exchange pipes and make recommendations for new capabilities which might need to be incorporated.

II.N.2 (H,C)

Develop portable microclimate survey equipment. Place emphasis on ground temperature data.

II.N.3 (H,C)

Generate schemes for variable volume ceilings.

II.N.4 (H,C)

Develop improved vermin control appropriate to passive applications (e.g., for protecting inlet/outlet in earth-air heat exchangers).

II.N.5 (H,C)

Develop backdraft dampers appropriate to a variety of passive applications.

II.N.6 (H,C)

Generate devices which provide security for large ventilation openings.

II.N.7 (H)

Generate schemes for using solar as a preheat for hot-air clothes dryers.

III. SYSTEMS DEVELOPMENT TASKS

A. Concept Generation Assessment

III.A.1 (H)

Investigate the possibilities for passive wall heating by thermosyphon from flat plate liquid collectors.

III.A.2 (H)

Generate and assess concepts for using east wall (with moving insulation) for early morning direct gain heating.

III.A.3 (H)

Generate and assess concepts for space heating using remote collection with storage floor.

III.A.4 (H)

Develop structural schemes for shaded roof aperture systems, integrating insulation, reflectors, storage, structure, etc. The goal is to provide a standard roofing system which can be purchased and easily erected as a substitute for standard, flat, built-up roofs. Emphasis should be on:

- details of manufacture and deployment;
- ease of maintenance and operation;
- safety and durability.

A full range of systems will be investigated, including:

- direct heating;
- indirect heating with roof storage;
- isolated heating with roof storage;
- combinations including clear water storage (direct and indirect).

Both factory and site-built systems will be designed; design parameters will include thermal performance and daylighting.

III.A.5 (H)

Generate and assess passive solar mobile home concepts. Emphasis should be placed on direct gain systems with water floor storage, using south aperture for single widths and shaded roof aperture for the north section in double-wide mobile homes. The generation of other innovative mobile home schemes should be encouraged.

III.A.6 (H,C)

Generate and assess schemes for mobile home passive solar retrofit. Emphasis should be placed on add-ons for south walls, including habitable spaces with south or south-sloping apertures. The generation of other innovative schemes should be encouraged.

III.A.7 (H,C)

Generate and assess concepts for urban-scale solar applications.

III.A.8 (H,C)

Generate concepts for integrating photovoltaics with passive solar heating and cooling systems.

III.A.9 (H,C)

Investigate the relative merits of plants, ozone generators, and heat exchangers (between outgoing and incoming air) as sources of oxygen for occupied buildings. Compare on the basis of performance (oxygen level, ion level, impurity content) and cost (back-up energy required).

III.A.10 (H,C)

Generate and assess schemes for transferring heat between zones in single and multiple depth N-S zone configurations.

III.A.11 (H,C)

Generate schemes for passive preheating and pre-cooling of ventilation air.

III.A.12 (H)

Assess the energy implications of retrofit use of convection driven, window-mounted air heaters.

III.A.13 (C)

Generate and assess schemes for enhancing natural convection or using fans to augment evaporative cooling in shaded roof systems.

III.A.14 (C)

Generate and test conceptual and engineering designs for radiative cooling systems if feasibility is established in test bed applications.

III.A.15 (C)

Generate schemes for roof storage systems which are modularly expandable in two directions and which are suitable for commercial applications (e.g., warehouses, workrooms, etc.). Low-powered hybrid configurations may be appropriate.

III.A.16 (C)

Generate and assess configurations for utilizing stack effect for cooling purposes in high-rise buildings and assess thermal potential. Functional space utilization impacts of the systems will be considered as a function of building type and geometry.

III.A.17 (C)

Generate and assess schemes for using nocturnal outside air for cooling in the building envelope or a storage mass. The cooled components would be used for cooling the space during daylight hours.

III.A.18 (C)

Investigate the potential in hot climates for using conduction to the ground for direct cooling.

III.A.19 (C)

Assess the environmental implications of widespread use of evaporative cooling and compare to the effects resulting from utilization of competing technologies.

III.A.20 (C)

Assess the energy applications of shaded and unshaded skylights (with and without both moving insulation and reflectors) which are used both for heating and illumination.

III.A.21 (C)

Develop ways to enhance ventilation cooling with vegetation and special landscaping. Investigate methods of pre-cooling induced or natural ventilation.

III.A.22 (H,C)

Develop schemes for integrating earth-air heating exchanters with conventional air handling equipment.

III.A.23 (H,C)

Survey indigenous passive architecture as a basis for generating ideas.

III.A.24 (C)

Explore new techniques to keep direct sunlight off the building envelope in summer. Examples include use of window boxes, trellises, and balconies. Update the landscaping textbooks to provide innovative use of vegetation of all kinds particularly directed to keeping buildings and surrounding areas cool in summer.

B. System Specification

III.B.1 (H)

Develop specifications for passive and hybrid convective preheaters for ventilation air. Systems specifications should include integration of the passive/hybrid components with the conventional HVAC equipment.

III.B.2 (H)

Engineer movable insulation systems for glazing assemblies and storage systems exposed to the occupied space.

III.B.3 (H,C)

Select several promising functional applications for passive or hybrid solar heating and cooling office buildings, motels, etc. Select and specify configurations which are appropriate to these applications and which respect basic passive solar heating and/or cooling design principles (e.g., double-loaded corridor office spaces with corridor running east-west). Energy management issues will be included as appropriate in the specifications.

III.B.4 (H,C)

Develop specifications for combining stack effect/natural convective systems with outside air ventilation and with isolated thermal storage systems. Integration with the conventional HVAC equipment will also be considered.

III.B.5 (C)

Develop specifications for improved evaporative cooling systems of special significance and ease of maintenance, operational efficiency, and low cost.

III.B.6 (C)

Define the engineering specifications for a variety of roof storage systems and associated movable insulation schcmes. Consider snow load requirements for systems to be used in colder climates.

III.B.7 (C)

Perform engineering specifications for radiative cooling systems. Certify proposed passive cooling system designs for seismic, fire, lighting, and other structural resistance as required by building codes. Determine cost availability, and possible detrimental effects of all materials to be used in passive cooling systems.

C. System Analysis

III.C.1 (H)

Develop algorithms which characterize solar absorption in clear water containers with and without absorbing additives.

III.C.2 (H)

Investigate two-dimensional heat flow characteristics in vented storage walls, direct-gain storage systems, and in slab-on-grade construction. If necessary, develop descriptive algorithms for those heat transfer situations.

III.C.3 (H,C)

Continue development of network analysis computer codes to account for the following range of passive solar heating system characteristics:

- direct, indirect, isolated, and combinations;
- south, roof, and shaded roof apertures;
- water (clear and opaque), masonry, and PCM storage.

III.C.4 (H,C)

Modify existing public domain building energy analysis programs to provide simulation capabilities which include passive heating and cooling systems and which focus on commercial building types. In addition to developing models which describe the passive collection and storage elements and the associated inter- and intra-zone energy distribution systems, extension and/or improvements will be made to existing heat transfer algorithms which limit the programs to conventional building types. The resulting code will be validated, documented, and made available to the design and engineering communities.

III.C.5 (H,C)

Investigate applicability of passive heating and cooling techniques to high occupancy situations.

III.C.6 (H,C)

Identify the uncommon features of passive systems which affect occupant comfort; quantify and assess the need for control systems which respond to these comfort-influencing parameters.

III.C.7 (H,C)

Carry out studies, using detailed hour-by-hour computer codes, to compare the practicality of various active and passive systems as a function of degree of control over the thermal environment in the functional space.

III.C.8 (H,C)

Perform a state-of-the-art investigation of closed-cycle environments (e.g., sumbarines, spaceships, etc.) to identify techniques for generating oxygen and purifying air. Human comfort studies and performance criteria related to these systems should also be identified.

III.C.9 (H,C)

Determine the characteristics, requirements, and costs of conventional cooling systems when they are coupled to passive heating and cooling systems to provide heating and cooling in various climates.

III.C.10 (H,C)

Use appropriate thermal balance and/or response-factor energy analysis programs to predict temperatures in the vicinities of the north and south walls and the ceiling and floor in multizone configurations as a function of:

- number of N-S divisions;
- number of E-W divisions;
- number of floors;
- north-south extent of space;
- east-west extent of space;
- ceiling height;
- nature of wall(s) which separate N-S spaces;
- nature of south aperture collection (direct, indirect, insolated);

- COP for energy distribution (infinity for totally passive distribution, finite if fans used);
- climate.

Validate with test data wherever possible.

III.C.11 (H,C)

Perform a systematic examination of the health, safety, and comfort issues which arise in buildings characterized by low infiltration and ventilation rates. The influence of the building materials, auxiliary HVAC system, and functional utilization of both residential and commercial structures should be identified.

III.C.12 (H,C)

Integrate phase-change materials storage into hourly computer analysis programs. Utilize the code to optimize the phase-change temperature and heat transfer criteria for phase-change storage systems.

III.C.13 (H,C)

Develop computer codes to simulate ground effects on system performance. Consider the following range of buildings:

- mounted on stilts;
- with crawlspace;
- with basement;
- slab-on-grade;
- slab-on-grade with N berm;
- slab-on-grade with N, E, and W berms;
- slab-on-grade with N, E, W berms and roof direct;
- buried to roofline;
- buried completely.

Use computer codes to assess relative merits of the various configurations in both heating and cooling situations.

III.C.14 (H,C)

Assess the suitability of the techniques used in existing public domain building energy analysis computer programs for passive systems simulation. Both residential-oriented thermal balance programs and multi-zone codes which emphasize commercial building types will be examined. Particular attention will be paid to identifying the limitations of current techniques for analysis of (1) thermally massive building elements and (2) radiative and convective heat transfers within the functional space.

III.C.15 (H,C)

Perform a systematic study of the solar add-on costs associated with the various passive system configurations. Surveys will be made of the incremental costs incurred in existing passive buildings and detailed estimates of costs expected for other configurations will be obtained. These data should reflect differences in regional construction costs as well as alternative construction methods.

III.C.16 (H,C)

Identify special control logic and control actuator requirements suitable for passive solar energy systems. Investigate the potential of "smart controller" (e.g., microprocessors) for the operation of passive solar systems. Identify sensors and data inputs (e.g., weather predictions) which would be meaningful in establishing control strategies.

III.C.17 (H,C)

Perform system studies to establish the energy implications of building proportions--i.e., relative magnitude of north-south, east-west, and vertical extent.

III.C.18 (H,C)

Investigate and tabulate the add-on cost characteristics of the various passive solar energy systems by reviewing existing passive solar energy system installations and costs, using standard cost-estimating procedures for buildings.

III.C.19 (H,C)

Identify parameters which characterize the thermal performance of large mass (e.g., masonry) construction and passive system configurations. These parameters should be part of simplified methods for predicting the thermal performance of buildings which utilize passive system configurations.

III.C.20 (C)

Investigate the potentials of dehumidifers, heat pumps, and solar dessicant dryers for extending the climatic range and occupancy level of passive cooling by handling part of the latent load.

III.C.21 (C)

Determine the characteristics, requirements, and cost of conventional cooling systems when they are coupled to passive heating and cooling systems to provide heating and cooling in various climates.

III.C.22 (C)

Incorporate measured atmospheric infrared emission parameters into a load-calculating computer program.

III.C.23 (C)

Investigate evaporative and/or nocturnal outside air cooling in conjunction with rock bed or other storage systems.

III.C.24 (C)

Determine the ability of natural ventilation to handle high-occupancy situations. Compare in terms of level of comfort and cost to conventional cooling.

III.C.25 (C)

Develop models for determining performance of systems using combined effects, such as wind and induced ventilation.

D. Data and Instrumentation Requirements

III.D.1 (H,C)

Based on the systems analysis tasks, identify a broad range of factors and/or parameters which characterize the thermal performance of the full scope of passive solar heating and cooling systems. The parameters should allow comparative evaluation between different systems and absolute evaluation of a particular system. Define the thermal parameters which must be measured to evaluate system performance and which will provide for engineering proof-of-concept; measurement frequency and accuracy must also be determined.

An identification should be made of the most crucial performance factors which would be appropriate to a very broad-based program to gather statistically significant data from many passive solar heating and cooling demonstration projects. Define standardized methods for reporting passive solar heating and cooling system performance. In addition to including meaningful and measurable system performance parameters and variables, data on mechanical design, livability, operating characteristics, and maintenance requirements must be documented.

III.D.2 (H,C)

Select an instrumentation package appropriate to basic performance measurement and in-depth experimental studies of passive solar systems.

III.D.3 (H,C)

Set standards for sub-metering on solar energy projects to ensure adequate measurement of the use of auxiliary units.

III.D.4 (H,C)

A multi-level instrumentation package (i.e., a basic package with options) should be identified and developed for use in a broad-based, extensive passive solar systems monitoring program. The basic package should provide for a minimum set of measurements to include:

- comfort achieved;
- weather conditions;
- auxiliary energy used.

The options should allow expansion of the system to approximately 40 or more channels to allow for detailed performance evaluations and for computer code validations.

III.D.7 (H,C)

Investigate methods of compressing systems data by pre-processing. This will reduce the quantity of data which must be stored and provide a condensed output that will be more easily understood.

E. Performance Data Acquisition

III.E.1 (H,C)

Continue and expand as appropriate existing small-scale passive heating and cooling system testing efforts.

III.E.2 (H,C)

Expand present test cell program as necessary to validate analytic models.

III.E.3 (H,C)

Design a systems testing program employing side-by-side, controlled, full-scale test cell experiments involving a range of passive solar systems to be located at several sites representing distinct climatic conditions. Emphasis should be on rigorous system-to-system and climate-to-climate comparisons, while keeping costs down and allowing for a broad range of experiments by devising test cells with highly interchangeable parts. Over the full range of sites the potential should exist for experiments involving:

- direct, indirect, isolated, and combination heating through south apertures (with or without sunspace add-on), roof apertures, and shaded roof apertures;
- direct, indirect, and isolated cooling to sky, atmosphere, and ground;
- water, masonry, and PCM storage;
- conventional construction.

Consideration should be given to appropriate control strategies, simulation of occupancy, and the use of the data to validate all significant passive solar computer codes. A scheme for assessing the results in terms of comfort and back-up energy should be devised.

III.E.4 (H,C)

Assess the merits of side-by-side systems testing programs. If judgement is favorable, select institutions for test sites. Emphasis should be on universities with strong technical programs and design-profession education programs.

III.E.5 (H,C)

Undertake expansion and/or continuation of preliminary full-scale testing of passive systems as appropriate.

F. System Studies

III.F.1 (H)

Investigate the impact of body heat and other internal heat sources on heating requirements in well-insulated, low-infiltration buildings.

III.F.2 (H)

Investigate the effect of distribution of thermal mass in direct gain systems. Identify the importance of locations, color, coverings, etc. on the effectiveness of thermal storage in direct gain systems.

III.F.3 (H,C)

Sensitivity studies will be undertaken to quantify the effects in building performance of (1) passive system design parameters; (2) building design, use, and operation parameters; and (3) auxiliary heating/cooling system controls and control strategies. These studies will be utilized in assessing the applicability of passive design concepts to various combinations of building design and end uses.

III.F.4 (H,C)

Assess the trade-offs between illumination and summer load for various direct gain apertures.

III.F.5 (H,C)

Institute study of north windows trade-off between summer ventilation and winter heat losses. Establish design guidelines for percent windows on north wall. Carry out similar studies for east and west windows.

III.F.6 (H,C)

Use building energy analysis computer programs with passive systems simulation capabilities to study the thermal performance of residential and commercial buildings. The studies should emphasize (1) the impact of varying climatic conditions on system design; (2) design optimization; (3) definition of control strategies; (4) interaction of auxiliary HVAC systems with the passive system; and (5) definition of energy distribution systems which improve thermal performance and comfort conditions in multi-zone structures.

III.F.7 (H,C)

Perform sensitivity studies on an assortment of generic active, hybrid, and passive solar systems with respect to ambient temperature, wind speed and direction, humidity, and solar radiation at a variety of locations. Characterize variations in system response from year to year. Compare variation from one system type to the next.

III.F.8 (H,C)

Evaluate yearly heating and cooling demand for south aperture "heating systems" (with and without sunspaces) as a function of aperture size, aperture orientation (relative to south), shading or movable insulation with various control strategies, climate, mass, and night ventilation.

III.F.9 (H,C)

Define and evaluate control strategies (and hardware necessary to implement the strategies) for passive systems using a common storage for both heating and cooling.

III.F.10 (C)

Investigate the relative merits of spray cooling vs. flooding of storage roof systems, in terms of thermal performance in various climates, operating cost, and initial capital cost.

III.F.11 (C)

Define and evaluate control strategies for combining ventilation (air movement) with storage roof systems.

III.F.12 (C)

Study the regional applicability of cooling systems based on both selective and non-selective emitting systems.

G. Design Tools

III.G.1 (H,C)

Identify design tool user groups and assess their needs.

III.G.2 (H,C)

Integrate thermal balance and/or network analysis routines into user-oriented computer programs appropriate for the building design community.

III.G.3 (H,C)

Develop and validate simplified techniques for analyzing and predicting the performance of passive solar buildings. Handbook tables and graphs, hand calculation methods, hand-held calculator programs, and simplified computer programs are included. Supporting documentation is required for all design tools developed under this task.

III.G.4 (H,C)

Use output from analytical tools developed in the program to periodically expand and update residential-scale passive solar design handbooks. Participation by the design community in generating these handbooks is critical.

III.G.5 (H,C)

Use output from multi-zone computer simulation studies to develop and periodically expand and update a commercial-scale passive solar concept manual. Participation by the design community in generating concepts and techniques is critical.

III.G.6 (H,C)

Develop design methods which account for the trade-offs between conservation, passive solar, and active solar.

III.G.7 (H,C)

Prepare atlas showing regions of applicability for various passive systems, with estimates of system contribution.

III.G.8 (H,C)

Develop design nomographs for earth-air heat exchangers.

H. Performance Criteria

III.H.1 (H,C)

Based on validated analysis techniques developed for each passive heating and cooling system, identify and document an initial set of functional criteria relating to the thermal performance of the system. The criteria will appropriately account for climatic effects and for the full range of system design parameters which affect performance.

III.H.2 (H,C)

Based on the initial criteria and a broad-based experimental program, develop definitive performance criteria which are technically valid in actual building situations. The criteria should include a methodology for assessing compliance based on design information and a procedure for measuring post-construction compliance.

I. Market Field Tests

III.I.1 (H,C)

Perform an assessment of the technical readiness of individual passive solar heating and cooling systems in order to determine their potential marketability. The assessment will include examination of (1) the availability of appropriate design tools, (2) suitability of existing designer and user experience, and (3) adequacy of the existing economic data base.

III.I.2 (H,C)

Initiate a program to test the marketability of specific passive systems in both new and retrofit applications to different building types. The testing will serve as the final step in the proof-of-concept process; it will examine the climatic adaptability of the developed designs, it will test the design tools both with respect to usability and technical viability, and it will provide a broad-based test of the validity of initial performance criteria. These building programs will be initiated for residential and commercial buildings and/or specific passive system types. Relevant information will be thoroughly documented for each building constructed in the program; this will include:

- pre-construction parameters: design, performance estimate;
- construction costs;
- post-occupancy evaluation: performance, comfort.

III.I.3 (H,C)

The results of the market field testing programs will be used to perform a technological and economic feasibility analysis to determine cost-effectiveness based upon system type, application, climatic region, and geographic location. The analysis will provide a basis for commercialization activities and will be used to encourage designers, developers, and builders to employ the developed passive solar approaches for heating and cooling. Secondary uses include: (1) broadening awareness and understanding of passive solar within the residential and commercial design and construction community and the general public; (2) development of passive solar designs appropriate to the marketplace; (3) identification of barriers to commercialization; and (4) acquisition of cost, performance, market, and attitudinal data.

HEATING SYSTEMS	DEVELOPMENT TASKS: Concept Generation and Assessment	System Specification	System Analysis Thermal, Economic, etc. Human Comfort	Data and Instrumentation Requirements	Performance Data Acquisition	System Studies Parametric Sensitivity	Design Tools	Performance Criteria	Market Field Tests	Important Associated Tasks
Single Zone										
• South Aperture										
1. Direct-Gain Wall	◒	○	○	○	○	○	○	80	79-81	I.A.1-2
2. Storage Wall (With and Without Vents)	◒	◒	◒	○	◒	◒	◒	80	79-81	I.A.1-2
3. Isolated storage Wall (With Vents and/or Movable Insulation)	○	○	○	○	○	○	80	80	80-82	I.A.1-2, I.F.
4. Collection Wall w/Storage Floor, etc.	80	80	80	○	○	80-81	80-81	81	80-83	I.A.1-2, I.F.4-5
5. Collection Sunspace w/Storage Floor, etc.	80	80	80	○	○	80-81	80-81	81	80-83	I.A.1-2, I.F.4-5
6. Combinations of 1 through 5	80-83	80-83	80-83	81	80-83	80-83	82-83	83	81-84	I.A.1-2, I.F.4-5
• Shaded Roof Aperture										
7. Shaded Direct-Gain Roof	○	○	○	○	○	80-82	81-82	82	80-83	I.A.1-2
8. Shaded Storage Roof	○	○	○	○	○	80-82	81-82	82	80-85	I.A.1-2
• Roof Aperture										
9. Direct-Gain Roof[†]	○	○	○	○	○	○	80-81	81	†	I.A.4, I.A.5
10. Storage Roof	○	○	○	○	○	80-81	80-82	81	80-85	
11. Collection Roof w/Storage Floor, Ceiling, or Wall*	80-82	80-82	81-82	81	81-83	81-82	81-82	82	81-83	I.F.4, I.F.5
12. Combinations of 7 through 11	81-84	81-84	81-84	82	81-84	81-84	83-84	84	82-85	I.F.4, I.F.5
• Remote Aperture										
13. Remote Collection w/Storage Floor	○	○	○	○	○	80	80-81	81	80-83	I.F.4, I.F.5
14. Remote Collection w/Isolated Storage (e.g., Solar Pond)	80	80	80-81	81	81-83	81	81-82	82	81-83	I.F.4, I.F.5
15. Ground Preheat	○	○	○	80-81	80-84	81-84	82-84	84	81-85	I.F.4, II.J.1-2
Multi-Zone										
• Single-Story	80-81	80-81	80-82	80-81	80-83	81-82	82-83	83	81-84	I.F.3, I.F.4
• Multi-Story	○	○	○	81	81-85	80-84	82-95	84	83-86	I.F.3, I.F.4
• Community & Urban Systems	○	80-85	81-85	81-82	82-86	82-86	83-86	85	84-87	I.E.1

[†] Emphasis will be on limited collection area for day lighting applications.

*Includes active collection and passive discharge to functional space.

● - Completed
◒ - Completed for selected versions
○ - Under way
79 - To be initiated

COOLING SYSTEMS	DEVELOPMENT TASKS: Concept Generation and Assessment	System Specification	System Analysis: • Thermal, Economic • Human Comfort	Data & Instrumentation Requirements	Performance Data Acquisition	System Studies Parametric Sensitivity	Design Tools	Performance Criteria	Market Field Tests	IMPORTANT ASSOCIATED TASKS
Single Zone										
o Sky and/or Atmospheric Sink[a]										
1. Storage Roof[b,c]	O	O	O	O	O	80-81	80-82	82	80-85	I.B.1-3, I.C.3, I.F.4, II.A.10, II.A.11, II.B.4-8
2. Storage Wall[b,c,d]	80-82	80-82	81-82	81	81-83	81-83	82-83	82	81-84	I.C.3, I.F.4
3. Low-Mass Cooling Roof[b,c,d]	80-82	80-82	81-82	81	81-83	81-83	82-83	83	82-83	I.B.1-3, I.C.3, I.F.4, II.A.10, II.A.11, II.B.4-8
4. Low-Mass Cooling Wall[b,c,d]	80-82	80-82	81-82	81	81-83	81-83	82-83	83	82-83	I.B.1-3, I.C.3, I.F.4, II.A.10, II.A.11, II.B.4-8
5. North-Facing Shaded Storage Roof	O	O	81-82	81	O	81-83	82-83	82	81-83	I.C.3, I.F.4
6. South-Facing Shaded Storage Roof	O	80-81	81-82	80	80-83	81-83	82-83	82	81-85	I.C.3, I.F.4
7. Vegetation Shielding of Structure	80-82	81-83	82-83	82	82-84	82-84	83-84	84	83-85	I.F.1, I.F.4, I.F.5, I.C.4-6
8. Remote Cooling Ponds[d,e]	80-82	80-82	81-82	81	81-83	81-83	82-83	83	82-83	I.B.1-3, I.C.3, I.F.4, II.A.10, II.A.11, II.B.4-8, II.G.1, II.G.3
o Atmospheric Sink[f]										
9. Direct Ventilation of Space	80-81	80-82	81-82	81	81-83	81-83	82-83	82	81-84	I.C.3, I.C.5-8
10. Evaporative Cooling via Low-Mass Heat Exchangers	80-82	80-82	81-82	81	81-83	81-83	82-83	82	81-84	I.C.4-6, I.F.4, I.F.5
11. Evaporatively and/or Night Air-Charged Storage[b]	80-82	80-82	81-82	81	81-83	81-83	82-83	82	81-84	I.C.4-6, I.F.4, I.F.5
12. Convective Cooling of Bldg. Surfaces Protected by Solar Shading Devices	80-82	81-83	82-83	82	82-84	82-84	83-84	84	83-85	I.F.1, I.F.4, I.F.5, I.A.3
13. Dessicant Dehumidification	80-82	81-84	82-84	82	82-84	82-84	83-84	83	83-85	I.F.6, II.K.3-6

- CONTINUED -

COOLING SYSTEMS	DEVELOPMENT TASKS: Concept Generation and Assessment	System Specification	System Analysis • Thermal, Economic • Human Comfort	Data & Instrumentation Requirements	Performance Data Acquisition	System Studies Parametric Sensitivity	Design Tools	Performance Criteria	Market Field Tests	IMPORTANT ASSOCIATED TASKS
• Ground Sink										
14. Indirect	80-81	80-81	80-82	80	81-83	81-83	82-83	82	81-85	I.D.1, I.D.3, I.D.4
15. Isolated[d]	O	O	80-82	81	81-84	81-84	82-84	83	82-85	I.D.1, I.D.3, I.D.4, I.F.4, II.G.1, II.G.2
• Water Sink										
16. Structure to Water-Body Heat Exchange[d]	80-82	80-82	81-82	81	81-83	81-83	82-83	83	82-83	I.B.1-3, I.G.3, I.F.4, II.A.10, II.A.11, II.B.4-8, II.G.1, II.G.3
18. Thermal Wells[d]	80-82	81-82	81-83	81	81-84	81-84	82-84	83	82-84	I.B.1-3, I.C.3, I.F.4, II.A.10, II.A.11, II.B.4-8, II.G.1, II.G.3
Multi-Zone										
• Single Story	80-82	80-82	80-83	81	80-83	81-84	82-84	83	81-85	I.C.3, I.F.4, II.H.4, II.H.6
• Multi-Story	O	80-84	80-84	81	81-85	81-84	82-85	84	83-86	I.C.3, I.F.4, I.F.5, II.H.4, II.H.6
• Community & Urban Systems	80-84	81-85	81-85	81-82	82-86	82-86	83-86	84	83-87	Unidentified

[a]Radiation to the sky will normally be present, as well as convective transfer to (or from) the atmosphere. In all system studies, evaporation should also be considered for exchanging discharge to the atmosphere (consider flooding or spraying, as appropriate).

[b]Thermal mass can also serve as storage in the heating mode.

[c]If used for both heating and cooling, glazing must be at least seasonally movable.

[d]Hybrid system requiring fan or pump.

[e]For large bodies of water this is equivalent to water sink cooling.

[f]Wherever heat exchange via air movement is involved, all applicable mechanisms for moving the air should be considered, e.g., wind (with and without scoops and towers), anabatic convection (including solar chimneys, Trombe walls, greenhouses, and natural cooling towers), catabatic convection, fans, etc.

O Underway

APPENDIX C:

TECHNOLOGY UTILIZATION TASKS

Presented in this appendix are utilization tasks. They have been generated from a review of current passive solar issues and problems within the utilization process. The task emphasis is on near-term activities. Special consideration was given to the results of the Reston meeting and subsequent commercialization meetings in defining and giving priority to the tasks. Many of these critical near-term utilization tasks will provide information and data for defining more specific long-term tasks and will help establish a detailed comprehensive utilization plan.

TABLE III-1

Technology Utilization Task Classifications

I. COMMERCIALIZATION READINESS ASSESSMENT	A. Technical Readiness B. Market/Economic Readiness C. Environmental Readiness D. Institutional Readiness E. Benefits Analysis F. Commercialization Planning
II. TECHNOLOGY TRANSFER	A. Data Management B. Education and Training C. Information Dissemination
III. STIMULATION OF TECHNOLOGY DELIVERY CAPABILITY	A. Solar Access B. Building Codes and Standards C. Performance Criteria D. Incentives
IV. STIMULATION OF MARKET DEMAND	A. Consumer Education B. Utility Programs C. Solar Energy in Federal Facilities D. Solar Energy in State/Local Bldgs. E. National, Regional, and State Design/Build Competitions F. Policy Studies G. Incentives

I. COMMERCIALIZATION READINESS ASSESSMENT

A. Technical Readiness

I.A.1

Maintain a continuously updated technical readiness assessment for all passive systems, to be used in identifying systems for intensified commercialization activities. The near-term emphasis will be on initiating a detailed assessment of passive space-cooling systems, to complement the existing space heating assessment.

B. Market/Economic Readiness

I.B.1

For systems judged technically ready or close to technically ready, identify prime markets in terms of

- building construction rate;
- compatibility of climate and passive system;
- competing technologies;
- receptivity of community to innovative building designs;
- characteristics of local construction business and attitudes of building community.

I.B.2

Evaluate community attitudes toward passive solar installations, impact on land values, and influences on future development of neighborhoods.

I.B.3

Evaluate consumer attitudes to passive solar energy systems including devices that require intervention by the resident (moving insulating panels at night, etc.). Compare consumer attitudes in this area with consumer reaction to other energy conservation measures.

I.B.4

Interview occupants of passive solar buildings to assess the life-style and comfort factors of different passive approaches. Both technical (quantifiable) and non-technical (qualitative) issues should be addressed. Testimonials resulting from this activity could be useful in promotions of passive solar.

C. Environmental Readiness

I.C.1

Assess the environmental readiness of all passive systems deemed technically ready and marketable.

I.C.2

Use microclimate studies to assess environmental acceptability of evaporative cooling in densely-built, large-scale developments.

I.C.3

Assess the water resource impact of evaporative cooling in arid climates.

D. Institutional Readiness

I.D.1

Synthesize information on the building industry experience. Identify factors that have slowed or prevented building technology innovations as well as factors that have accelerated the adoption of such innovations. Draw parallels and distinctions between past building technology innovations and passive solar and identify likely problem areas.

I.D.2

Assess lender attitudes which could impact funding of passive solar projects.

E. Benefits Analysis

I.E.1

Perform benefits analysis for all passive systems deemed technically ready and marketable. Disaggregate according to economic and climactic conditions prevalent in those parts of the U.S. where building construction rates are high. Base benefits analysis on passive systems sized to maximize net present worth. System emphasis will be as follows:

Short-term:	Storage wall, direct-gain wall, and combinations of the two.
Mid-term:	Roof and shaded roof aperture heating systems.
Long-term:	Passive hot-water and cooling.

F. Commercialization Planning

I.F.1

Refine and update commercialization planning on the basis of technical, market/economic, environmental, and institutional readiness assessments and benefits analyses. The near-term planning will emphasize space heating; in the future, the emphasis will shift to space cooling and passive hot water.

II. TECHNOLOGY TRANSFER

A. Data Management

II.A.1

Expand data base for passive program: nationally through the information center and regionally through the RSEC's.

B. Education and Training

II.B.1

Organize lectures and seminars for the financial community stressing:

- performance and reliability of passive solar;
- benefits of considering projected energy expenditures in determining allowable mortgage.

II.B.2

Organize lectures, seminars, university curricula, and conferences for building designers (architects and engineers) emphasizing:

- basic principles;
- design decision-making;
- detailed thermal analysis.

Among other things, these activities should provide support to and be coordinated with other parts of the program, such as the design/build competition.

II.B.3

Organize lectures, seminars, and conferences for builders, developers, and related professional organizations. Among other things, these activities should provide support to and be coordinated with other parts of the program, such as the marketable design development.

II.B.4

Organize lectures, seminars, and conferences for planners and government officials, emphasizing the integration of solar considerations into more general land management and planning methods.

II.B.5

Develop and fund trade-school courses for installers and craftspeople.

II.B.6

Organize lectures and seminars for realtors. Emphasize the importance of a variety of energy issues, such as solar exposure, orientation, window placement, overhangs, vegetation, insulation, etc.

II.B.7

Fund the preparation of articles for architectural, engineering, and planning professional journals.

C. Information Dissemination

II.C.1

Expand information dissemination program nationally through the information center and regionally through the RSEC's. Prepare literature, films, slide presentations, and other information packages suitable for use by universities, trade schools, and professional groups and organizations. Materials should be made available for designers, builders, developers, planners, government officials, craftspeople, installers, realtors, and lenders.

II.C.2

Provide technical and design specification documentation to the building community.

II.C.3

Generate and periodically update a catalog of available passive solar products.

IV. STIMULATION OF TECHNOLOGY DELIVERY CAPABILITY

A. Solar Access

III.A.1

Based on the results of the land use surveys and the land use planning tools developed in the technical areas, develop planning guidelines and provide planning assistance to municipal officials, and developers.

III.A.2

Initiate development of model solar access regulations which recognize regional, local, and site-specific characteristics.

III.A.3

Initiate development of model urban planning legislation.

III.A.4

Provision of assistance to state and local governments in tailoring model code to the locale and in defining and implementing necessary legislation.

B. Building Codes and Standards

III.B.1

Provide information and guidelines to state and local officials for implementation of conservation codes which are not detrimental to the solar alternative.

III.B.2

Develop guidelines for recommended modifications to state codes which inhibit passive solar implementation.

III.B.3

Assistant to code officials:

- Prepare and distribute information describing passive systems and their elements to code officials.
- Provide guidelines for evaluating the effectiveness of passive solar elements and distribute to code officials.
- Provide assistance to state and local code officials in evaluation of passive system compatibility with existing codes.

C. <u>Performance Criteria</u>

III.C.1

Expand on the results of Technology Development task III.H.1 to establish detailed thermal and lighting criteria for a range of fully-developed passive solar systems, in a range of climates.

D. <u>Incentives</u>

III.D.1

Based on studies of building construction industry (task I.D.1), identify those parts of the industry where substantial national benefits could be derived from financial incentives such as tax credits and government loans and grants.

III.D.2

Use prime-market studies (task I.B.1) to identify target communities for concentrated second-generation market field tests.

III.D.3

Encourage FHA and local building authorities to make passive solar add-ons eligible as part of basic home mortgages.

III.D.4

Encourage FHA and local building authorities to use passive solar in low-cost public housing.

IV. STIMULATION OF MARKET DEMAND

A. <u>Consumer Education</u>

IV.A.1

Organize lectures, with slide-shows and films, for presentation at consumer and civic group meetings. Emphasis should be on simple principles and the elements of good design: solar exposure, orientation, window placement, overhangs, vegetation placement, etc.; but some more detailed lectures emphasizing philosophical and technical issues should also be available.

IV.A.2

Supply public and institutional libraries with literature and films on passive solar.

IV.A.3

Develop lectures, textbooks, films, slide-shows, and mobile and science class demonstrations for public school education. Fund field trips to passive solar facilities.

IV.A.4

Generate posters and television commercials on passive solar.

IV.A.5

Assist in preparation of articles for various popular periodicals.

IV.A.6

Encourage dissemination of information through product manufacturer advertising.

B. Utility Programs

IV.B.1

Use results of system studies (see Technology Development Tasks) to encourage utilities to promote passive solar where beneficial to their load profile.

C. Solar Energy in Federal Facilities

IV.C.1

Select high-visibility federal building projects to demonstrate a range of functional applications and building system types.

D. Solar Energy in State/Local Buildings

IV.D.1

Encourage and support building and community demonstrations with high visibility. Share the design and solar add-on cost of several state and local buildings, a substantial portion of which will be schools. Use projects as focus for educational programs:

- Provide accommodations for field trips to passive solar facilities.
- Provide literature on passive solar facilities.

E. National, Regional, and State Design/Build Competitions

IV.E.1

Use prime-market studies (Task I.B.1) to identify regions, states, and cities for design/build competitions.

IV.E.2

Hold passive solar design competitions, the primary purposes of which will be to:

- reward designers (who might not otherwise find an appropriate forum) for innovative ideas;
- increase public and building community awareness;
- build the most promising designs.

F. Policy Studies

IV.F.1

Study and evaluate the impact of conventional fuel subsidies on the life cycle cost comparisons of passive and conventional heating systems.

IV.F.2

In conjunction with other federal and state agencies and with representatives of the conventional fuel industry, develop scenarios for phased reduction of subsidies.

G. Incentives

IV.G.1

Establish a definitional and procedural framework for federal income tax credits which is easily administered and which simultaneously promotes design integrity in response to local climate conditions.

IV.G.2

Establish a definitional and procedural framework for low-interest loans which is easily administered and which simultaneously promotes design integrity in response to local climate conditions.

IV.G.3

Define criteria for accelerated depreciation eligibility.

IV.G.4

Establish a definitional and procedural framework for loan guarantees which is easily administered and which simultaneously promotes design integrity in response to local climate conditions.

IV.G.5

Integrate passive solar financing options into local solar loan programs.

IV.G.6

Encourage state adoption of alternative mortgage instrument programs for solar financing.

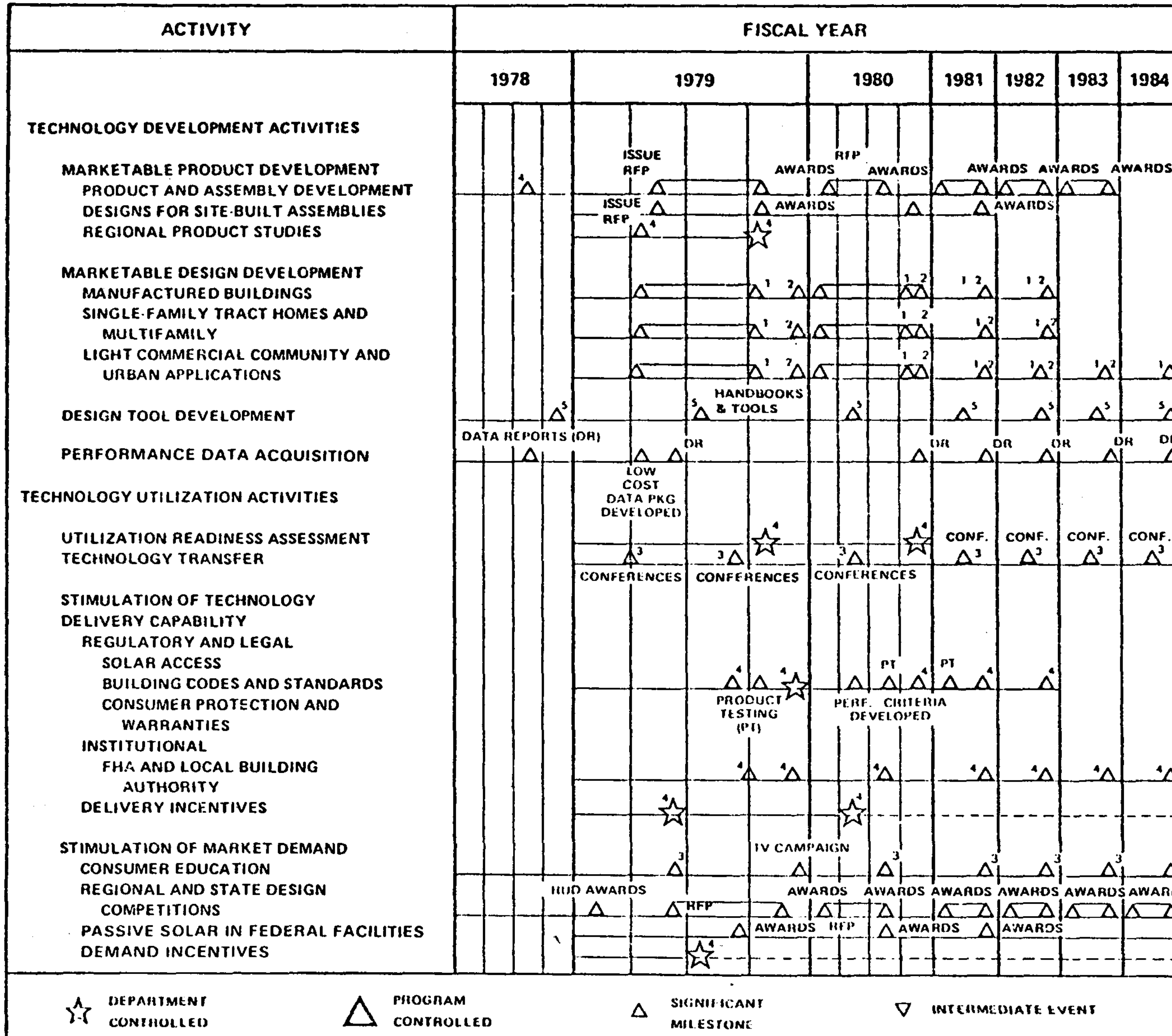
IV.G.7

Encourage state income tax credits which promote design integrity in response to local climate conditions.

IV.G.8

Encourage adoption of property tax exemptions for passive solar add-on cost.

APPENDIX D: TECHNOLOGY UTILIZATION TASK SCHEDULES



NOTES:
1. DESIGN PHASE COMPLETED
2. BUILD PHASE INITIATED
3. INFORMATION PACKAGES
4. REPORT
5. HANDBOOKS AND DESIGN TOOLS

APPENDIX E:

PROJECTED PASSIVE SOLAR SPACE-HEATING ENERGY IMPACT

Residential and Light Commercial
Passive Solar Costs and Energy Impacts
Without Tax Credits

EXPECTED MARKET PENETRATION	1985	1990	2000
New Construction			
New Energy Market (quads)	.134	.134	.134
Energy Penetration (quads in that year)	.0034	.012	.028
Percent of New Energy Market Penetrated	2.5%	8.9%	20.8%
Percent Penetration of New Units	6.0%	19.0%	41.0%
Retrofit Construction			
Total Retrofit Energy Market (quads)	9.52	9.94	10.5
Energy Penetration Retrofit (quads)	.0042	.0120	.0196
Percent of Retrofit Energy Market Penetrated	.04%	.12%	.18%
Percent Penetration of Retrofit Units of Total	.17%	.47%	.73%
Total Annual Energy Displaced (quads),† New and Retrofit	.0202	.107	.5

†Total annual energy displaced, in quads, by passive heating systems installed between 1978 and the year designated.

The Draft Domestic Policy Review projects higher combined energy savings for Passive Heating and Cooling.

APPENDIX E (cont'd)

Residential and Light Commercial
Passive Solar Costs and Energy Impacts
With Tax Credits

EXPECTED MARKET PENETRATION	1985	1990	2000
New Construction			
New Energy Market (quads)	.134	.134	.134
Energy Penetration (quads in that year)	.0084	.020	.032
Percent of New Energy Market Penetrated	6.2%	14.9%	23.7%
Percent Penetration of New Units	12.0%	30%	48%
Retrofit Construction			
Total Retrofit Energy Market (quads)	9.52	9.94	10.5
Energy Penetration Retrofit (quads)	.0101	.022	.017
Percent of Retrofit Energy Market Penetrated	.11%	.23%	.16%
Percent Penetration of Retrofit Units of Total Stock	.41%	.88%	.62%
Total Annual Energy Displaced (quads),† New and Retrofit	.0502	.222	.64

†Total annual energy displaced, in quads, by passive heating systems installed between 1978 and the year designated.

The Draft Domestic Policy Review projects higher combined energy savings for Passive Heating and Cooling.

*U.S. GOVERNMENT PRINTING OFFICE : 1979 0-281-128/633