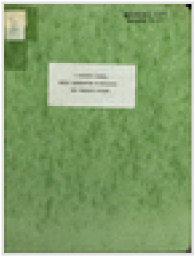

Research Agenda: Energy Conservation in Buildings and Community Systems for the Office of Building Energy Research and Development, the U.S. Department of Energy (1982)

Pages
71

Size
7 x 11

ISBN
0309329248

Committee on Energy Conservation in Buildings and Community Systems; Advisory Board on the Built Environment; National Research Council

943133 DE82019465

Research Agenda: Energy Conservation in Buildings and Community Systems 82 [redacted]

National Academy of Sciences, Washington, DC.
Corp. Source Codes: 019025000; 4415000
Sponsor: Department of Energy, Washington, DC.
Report No.: DOE-CS
1982 63p
Languages: English
NTIS Prices: PC A04/MF A01
Country of Publication: United States
Journal Announcement: GRAI8303; NSA0700
Contract No.: AC01-77CS20436

An agenda is presented on research needs in the field of energy conservation within buildings and communities to be supported by the federal government. The agenda is developed in a futures perspective, presenting material that would be relevant for research and development five or more years from the present. An overview is provided of agenda setting in general, pointing out some of the difficulties as well as possible approaches that any group might encounter while planning research for future, as yet unspecified, needs. A set of boundary conditions was created to help determine subject areas that should be a part of this agenda. Twenty-seven subjects are described as appropriate for areas of research. They are organized into six categories - broad classes of interest under which all related research can be grouped. A description of each category and area is provided, along with suggested topics of specific research projects. (ERA citation 07:054230)

Descriptors: *Buildings; *Communities; Energy conservation; Research programs; Occupants; Environment; Heat transfer; Control; Energy consumption; Information dissemination; Technology transfer
Identifiers: ERDA/320100; ERDA/291000; ERDA/320600; NTISDE
Section Headings: 10A (Energy Conversion (Non-propulsive)---Conversion Techniques); 97G (Energy--Policies, Regulations, and Studies)

A RESEARCH AGENDA:
ENERGY CONSERVATION IN BUILDINGS AND COMMUNITY SYSTEMS

FOR

THE OFFICE OF BUILDING ENERGY RESEARCH AND DEVELOPMENT
THE U.S. DEPARTMENT OF ENERGY

Advisory Board on the Built Environment
National Research Council
Washington, D.C.

National Academy Press
Washington, D.C., 1982

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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This report was prepared under Contract Number DE-AC01-77-CS20436 between the National Academy of Sciences and the U. S. Department of Energy.

For information regarding this document, write the Executive Director, Advisory Board on the Built Environment, National Research Council, 2101 Constitution Avenue, Washington, D.C. 20418.

Printed in the United States of America

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PREFACE

Background on Phase II: Energy Conservation in Buildings and Community Systems

This report presents the results of a study conducted by the Advisory Board on the Built Environment (ABBE) for the Office of Building Energy Research and Development (BERD) of the U.S. Department of Energy (DOE). The purpose of Phase I of the study, initiated in 1976, was to conduct an evaluation of the mid- and long-range research, development, and demonstration program of DOE's Division of Buildings and Community Systems (BCS). During the course of Phase II, the Division of Buildings and Community Systems was reorganized into the Office of Building Energy Research and Development.

After spending some time reviewing written documents and speaking with the staff of BCS, the committee for Phase I concluded that BCS had no clear objectives or overall plan that could be critiqued; therefore, the original assignment could not be carried out. In its Phase I report, completed in February 1979, the committee noted the difficulty of completing its original task, and offered to outline a coherent program for BCS. After considerable delay, due mainly to reorganization within BCS as well as to the change of Administration after the 1980 election, the committee's offer was accepted and Phase II began in April 1981.

The intent of Phase II of the study was to develop rather than critique a long-range research agenda for BERD. A new steering committee was appointed, headed by the chairman of the original parent committee, Richard C. Jordan. The work plan for Phase II evolved into three major activities. The first was a period of background research and information gathering in order to propose possible areas of interest and potential research to be included on the agenda. This work was carried out primarily by consultants to the project. An annotated bibliography of the sources consulted during this activity appears in Appendix A of this report.

The second activity was a two-day meeting of the steering committee to review the consultants' material, structure a preliminary agenda, and prepare for a workshop to be held in February 1982. Several possible structures were suggested, discussed, and examined for their potential success as an agenda of energy conservation research. The format and goals of the workshop also were determined. It was decided that each committee member would choose six experts in the energy conservation field to attend the February workshop and to serve on a panel chaired by that committee member.

The agenda was reviewed at the workshop on several levels. All participants were invited to respond to and critique the agenda as a whole, or any part thereof. Each panel was then assigned a specific portion of the agenda to review and comment upon in detail. The result was a revised agenda that included suggestions for several subject areas and topics that had not been included in the preliminary version. A draft final report was reviewed by a number of persons selected under the procedures of the National Research Council. This report presents a combination of the results of the February workshop and the comments from various reviewers.

ENERGY CONSERVATION AND THE BUILT ENVIRONMENT:
INTRODUCTION TO AN AGENDA FOR RESEARCH
TO BE SUPPORTED BY THE FEDERAL GOVERNMENT

The prevailing world energy situation points to a need to redirect our building technology fundamentally. In order to meet the growing energy challenges of the late 20th century it will be important to rethink the design criteria for buildings and community systems, to modify the technology that for the past 35 years has been used for producing buildings, and to utilize our built environment in new ways that are less dependent on fossil fuels. This transition to a more energy conserving built environment takes place amidst a global technological revolution in information and communication systems, the impacts of which will likely parallel those of the industrial revolution. How this context of rapid technological change will advance the purpose of fossil fuel conservation will be the basis for a third phase study in 1982-1983.

This research agenda, developed in 1981-1982, is oriented toward developing a technology and techniques that support an approach to building capable of closely matching the needs of human occupants to micro-climate conditions. All human activity within and around buildings takes place amidst a set of energy forces, the central generator of which is the sun. The work presented here is based on the perception that our built environment is dependent on purchased energy--the oil, gas, coal and other forms of energy that must be bought and paid for. This agenda recognizes that new and existing buildings and communities must be moved toward increased reliance on abundant sources of ambient, nonpurchased energy, and that energy conservation will facilitate this transition.

The implications of a research agenda developed along these lines extend well beyond energy. They are linked inextricably with an entire social, political, and economic context and encompass concerns that range from employment to environmental quality.

THE NATURE AND ROLE OF ENERGY CONSERVATION

The conservation of energy is a basic response manifested in virtually all aspects of nature. Its relation to buildings, communities and society is no less fundamental. Richard C. Jordan, chairman of the committee for this effort, has described this relation and our present predicament well:

> This profligate society, energy based and until the 1960s energy exporting, has paid little heed to energy conservation practices until very recently. This has been true not only in the United States but to a lesser degree in other developed areas of the world. In 1978 the United States consumed 29% of the world's energy; Europe, including communist Europe, 41%, and the Far East dominated by Japan, 18%. Thus developed societies still consume 88% of the world's energy.
>
> The American Institute of Architects estimates that energy conservation could reduce the requirements 20% to 50% in older buildings and, in new construction, between 50% and 80%. One of the major barriers to more rapid achievement has been the public view of energy conservation as representing austerity and deprivation; alternative energy sources and particularly solar energy have had much greater appeal and glamor. Yet enhanced conservation is a preliminary need if alternate energy resources are to economically phased in.
>
> The rubric "energy conservation" is many faceted and includes at least the retardation of heat losses through the use of more insulation and better construction; the substitution of low-cost energy resources such as solar and wind for nonrenewable energy resources, such as oil and gas; the development of storage techniques to conserve energy at times when it is most readily available; more efficient conversion of fuels such as gas and coal into heat and electrical energy; the use of improved cogeneration systems; the development and use of natural light guides in supplement of incandescent and fluorescent lighting; and computerized load management techniques for energy conservation. Although the US cannot "conserve" its way out of the energy dilemma, energy saved by conservation will probably always be cheaper than energy obtained from coal, oil, gas and nuclear, or from any of the promising future energy candidates such as solar, nuclear fusion and synthetics. Thus, it is in the national interest to maximize both the application of known energy conserving techniques and research on further energy conserving developments.*

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*Jordan, Richard C. "Research and Development Priorities for Energy Conservation in Buildings and Community Systems." <u>Technology in Society</u>, Vol. 3, 1981.

THE CHALLENGES OF AGENDA SETTING

One distinctive feature of the 20th century is the deliberate intervention of technology to control change for specified societal ends. The use of technology to solve critical problems and the use of research and development to drive such change are subject to misunderstanding due to our seeming inability to get ahead of the problems we perceive. This calls for an approach to agenda setting that is open ended, capable of adjusting to, if not altogether anticipating change. The research described in a research agenda will include solutions to problems that exist in the future as well as those present today.

Among the factors which have helped to shape this agenda is the conception that the built environment is an integral system, in which the behavior of each component affects the behavior of the whole, sometimes in unpredictable ways. This concept cannot be imparted fully to a research agenda, but is nonetheless critical in shaping a better understanding of the interconnected influences of climate, people, systems and operating procedures. Ultimately, the reason for conservation related research is to produce better knowledge on how to design, build and manage the components of the built environment. This must be done with recognition that the parts affect the whole.

ORGANIZATION OF THE RESEARCH AGENDA

As in any attempt to present complex information about complex subjects, the developers of this agenda grappled with the problems of taxonomy and classification. The following conventions were adopted because they are relatively simple and seem well-suited to the information:

- o <u>Categories</u>, of which there are six, are intended to be very broad collections of subject matter, within which various elements can be presented;
- o <u>Areas</u> are group related subjects of research interest that fall within categories but are still broadly based; and
- o <u>Topics</u> are illustrations of the kind of specific subjects to be explored within an area, but are not intended to be definitive.

The character of categories, areas and the topical illustrations is a direct result of the suggestions and recommendations that came from the people involved in generating and reviewing the agenda. While clearly not suitable as a plan for organizing a research program or as a method for describing energy use in the built environment, this research agenda is organized to convey a set of recommendations relating to research substance. No attempt has been made to set priorities between research categories or areas. As national goals and aspirations shift, as administrations bring changed political philosophies, and as agency management sets its own priorities based on internal strategies, priorities will also change. This agenda provides a wide range of alternatives for setting program choices and current priorities.

BOUNDARIES SURROUNDING THE AGENDA

The process of building an agenda requires the inclusion of some research areas and the exclusion of others. As a result of limitations imposed on this project by its sponsors and as a result of disciplines imposed by the committee itself, the following conditions were established to help determine which research areas would be included in the final agenda:

- The research area should be concerned with the built environment, not with an issue so fundamental that it is no longer recognizable with regard to its applicability (e.g., research on the fundamental properties of matter), or so far on the development end of the scale as to be an actual design problem.

- The research area generally should address issues that are national in scope rather than those of only local or even regional interest, with some obvious exceptions.

- A distinction should be made between research areas of broad public concern and interest, justifying public investment at the federal level, and those most appropriately pursued by private investment (although judgment is often needed for research that might appropriately be started on public funds and then continued through development by private investment).

- The research areas should be concerned with the demand side of the energy equation, not the supply side. This suggests that research related to new types of solar collectors or wind turbine generators, for example, are outside the scope of this agenda.

- The problem or opportunity addressed should be perceived as one that will still be of major concern at least five years from the present, not solved or changed to a new and different problem or opportunity.

- The research area should be considered fruitful and worthy of continued exploration; that is, more than marginal gains in knowledge are left to be developed.

It became clear to the committee and others associated with these efforts that the boundaries are not always easily fixed; reasonable people can and will disagree over whether, for example, a research area strays from the demand side of the energy equation into the supply side. There are gray areas--some forms of solar collectors must be integrated directly with ways of designing and constructing buildings and therefore become an integral part of the built environment and the energy conservation measures taken.

The committee recognizes that these relationships exist and that not all people will be satisfied with the items included in or left out of this agenda. However, the committee has agreed that the areas included on the agenda generally meet the boundary conditions.

A FINAL WORD ABOUT THE AGENDA

No agenda, regardless of the quality of people or the amount of time available for its development, can profess to have captured the complete range of potential for innovation and constructive change. Unquestionably, major developments have occurred in this field that were not and probably could not have been charted on an agenda of research to be undertaken or supported by the federal government. Rather, they were the product of efforts by individuals and organizations whose attentions were directed by a general climate of enthusiasm and support for energy related research. Often these developments came as a result of experiments and forays that were not supported by federal dollars directly but could not have occurred in a context that did not have federal support. The very network of energy enthusiasts and frontier-oriented experimenters has been fostered, but not always directly funded by the federal commitments in these areas.

The point to be made is that advances, breakthroughs and fundamental changes in the energy area are not likely to occur as the result of either federal spending or private spending alone, and will perhaps bear little or no relation directly to an agenda for technical research rooted in the scientific method. Design professionals from abroad who learn of American progress in the energy area are repeatedly amazed by this country's apparent freedom to test, experiment, build and evaluate, even when results are disappointing and produce no immediate benefit. They recognize what we too often fail to see: That it is this very climate of apparently undirected and unplanned inquiry that sometimes yields the most exciting, lasting, and productive results. The American building community, unconcentrated and comprised mostly of hundreds of thousands of small-scale businesses, has a long tradition of operating well in relatively unbridled circumstances.

With regard to energy, the importance of the federal role in fostering a general attitude and eagerness to learn cannot be overstated; the proceeds of federal dollars spent in this area extend well beyond the scientists, professionals, and researchers immediately involved in the work, in ways that cannot be charted on an agenda for research. It is anticipated that this climate of apparently undirected inquiry can be made even more productive through adoption of the information and computer-based society we are now embarked on. This country would do well to continue to encourage, by all means available, this intellectual and technical climate, for it holds what might be described as the greatest promise for the future.

Category 1: OCCUPANT & USER INTERACTIONS WITH BUILDINGS AND COMMUNITIES

It is the satisfaction of human needs for comfort and for meeting the functional patterns of buildings and communities that places demands on fossil fuel. In the absence of human users there are few building functions or community operations that would require any energy. User interactions with buildings and communities, therefore, drive the agenda for any well structured program. Understanding and controlling the interactions of buildings and communities with the natural environment (Category 2) may have physical science considerations of materials' degradation or may be studied from the perspective of the meteorologist, but any energy conservation agenda is derived primarily from conditions of human needs and satisfactions. Similarly, understanding and improving the interactions of the mechanical and electrical systems of buildings and communities (Categories 3, 4 and 5) must be related to an understanding of user requirements.

The following areas are a linked set of research questions; they are mutually dependent. To explore the efficiency and quality balances of a building's use, one must understand how to define and measure the well-being of its occupants. To achieve the well-being of users there must be some means of controlling the conditions of the environment in which users are located. One means of achieving the controlling fit between the built environment and the users is to provide for adaptation of the solutions to changing conditions. All of this must be achieved within a framework of market conditions, user requirements, and regulations which tend to advance or restrict the nature of the solutions. The diffusion of new or improved technologies is impacted by market conditions, the regulatory climate and legislative action.

The six areas of research which follow from this analysis are:

1.1 Energy Efficiency, Cost-benefits and the Quality of Life

1.2 Well-being Related to Comfort, Safety and Health

1.3 User Controls of the Built Environment Conditions

1.4 Adaptation of Solutions to Changing Conditions

1.5 Market Conditions and User Requirements

1.6 The Regulatory Process and Energy Conservation

1. OCCUPANT AND USER INTERACTIONS WITH BUILDINGS AND COMMUNITIES

1.1 ENERGY EFFICIENCY, COST BENEFITS AND THE QUALITY OF LIFE

Efficiency can be measured in terms of the effectiveness of the solutions compared to the associated costs of those solutions. It also can be measured in terms of the ratio of the useful energy delivered by a solution to the energy supplied for the solution. These concepts are understood more readily as they are applied to machines, but there is also a conceptual basis for using "efficiency" as a means of understanding the appropriate use of energy to make a building or community responsive to the functional requirements and comfort needs of the users.

Cost-benefit analysis has become a recognized method of evaluating the trade-offs between levels of human satisfactions and the associated costs of meeting those performance levels. While this report is concerned primarily with research driven by questions of science and technology, the economic consequences of alternatives should be considered in terms of the costs and benefits. Energy conservation programs always will be faced with these trade-offs, but this seems especially important to understand as the increasing cost of fossil fuels tempts owners and providers of energy using systems to reduce the level of performance to save money.

Solutions to providing buildings and communities with energy using systems are a total response to human requirements (e.g., a setting for health care, or education, or work, or living our private lives.) How efficiently the solution serves the requirement for which it was intended can be measured in terms of the productivity of workers in an office, or in health care services delivered. Or efficiency could be concerned with the "appropriate" use of spaces (for example, an educational program that could be housed effectively in 10,000 sq. ft., but is utilizing more than 20,000 sq. ft., is placing a demand on energy support systems that is inefficient.) On still another level, energy efficiency can be measured with respect to the operation of equipment proposed for the solution in terms of the second law of thermodynamics.

Examples of research topics in this area are:

1.1.1 Develop better models of the interactions of energy costs and the benefits to users of buildings and communities in order to assess the threshold conditions needed (this contrasts with most existing models designed to determine maximum energy allowances based on price alone).

1.1.2 Develop an understanding of how to define and measure appropriate energy requirements in terms of efficient use. Users will vary in preferences, needs and requirements, and responsiveness to energy alternatives, thus extending the complexity of the analytic methods needed.

1.1.3 Develop measures on the relationship between density of community design solutions and how density relates to the quality of alternatives to the solution. Variables such as cultural backgrounds and perceptions of the users will influence measurement of the quality of the solutions.

1.1.4 Develop analytical methods for evaluating the trade-offs between density of urban design solutions and solar access rights.

1.2 WELL-BEING RELATED TO COMFORT, SAFETY AND HEALTH

The concept of "well-being" is meant to encompass a large number of the actual or occupant perceived attributes of buildings and communities. Not all of these attributes are related exclusively to the conditions provided by energy using systems, so that a clear understanding of all of the factors that contribute to the performance of spaces (e.g., safety conditions) needs to be achieved in order to better understand the impacts that energy conservation programs will have. The common design standards for ventilation, lighting, temperature and humidity control already have been tested in energy conservation programs and consequently are now being questioned. If safety issues are added to the parameters of comfort and health more complex questions of these interactions arise. For example, there is reason to be concerned about the incidence and spread of fire in spaces that have been tightly sealed to reduce air infiltration problems.

Ensuring the health, safety, and welfare of citizens is a fundamental role of government. Consequently, it follows that government should support the research required to understand, evaluate, design and test these conditions under various energy conserving alternatives. There are added concerns related to understanding the long-term liabilities which energy efficient solutions might contribute to the degradation of health, comfort or safety attributes. Most of the research areas identified in Categories 3, 4 and 5 will produce effective or usable solutions directly in proportion to how well they satisfy the conditions of human well-being.

Typical research topics would include:

1.2.1 Develop methods of analysis of comfort oriented psychometric data; that is, the perception of comfort or well-being by the users of the space that extends the limits of instruments customarily used in environmental systems.

1.2.2 Develop methods of analysis that contribute to a better understanding of building safety impacts of conservation programs.

- o As a subset of 1.2.2, research is required to better evaluate the impact of energy conservation alternatives on individuals with physical or mental limitations, especially the elderly.

1.2.3 Develop performance criteria and measures of testing ventilation to integrate new knowledge on the interdependence of air quality, fire safety, and energy requirements.

1. OCCUPANT AND USER INTERACTIONS WITH BUILDINGS AND COMMUNITIES

1.3 USER CONTROLS OF THE BUILT ENVIRONMENT CONDITIONS

In addition to control devices used to operate mechanical and electrical systems, there are control measures based on having sufficient information to know how to correct one's own sensory environment. There also are clear differences in the controls that individuals use to modify the indoor environment of their living or working spaces to achieve a level of well-being, and the controls that a group of users require to avoid abuses by any individual member of the group. The delivery of healthy, safe and comfortable settings for human activities by an appropriate use of energy usually is achieved when the system's controls are exercised by those most directly affected. As is true of any good systems design, it is also important for the control mechanisms to be linked to feedback loops used in maintaining the operating characteristics of the system within predetermined boundaries.

Among the topics which could be explored within this area are:

1.3.1 Determine the requirements of special population sectors (for example, the elderly and the very young) that would suggest customized control measures being made available to them. The susceptability of these two groups to hypothermia could be an example of special requirements.

1.3.2 Develop a better understanding of the deprivation which people may experience if they have little or no control over their own access to outside views, as a result of rooms without windows.

1.3.3 Develop better methods for determining the perceived satisfactions of users to the quality of light, the amount of fresh air, or the temperature gradients of a room.

1.3.4 Develop methods of evaluating the total efficiency of buildings and communities in relation to the mix of individual, group and automatic control methods.

1.4 ADAPTATION OF SOLUTIONS TO CHANGING CONDITIONS

If solutions to building or community designs are to be capable of adapting to the changing conditions of use, there must be some means to achieve this adaptation. Adaptation can provide a quick response to the changing conditions of the daily cycle of use, night and day conditions, or climatic changes. When adaptive responses are built into design solutions there is less need to predict the required performance characteristics of the energy using systems. In addition the control systems can be made more responsive to the desires of the occupants. There is also an adaptive requirement for buildings and communities over long periods of time as characteristics of users change (for example, the population of a community grows older, or new users take over, or a school building becomes a local government office). The general concepts of "loose-fit, long life, and life-cycle costing" each become important to the development of adaptive solutions.

The following topics are among those to be considered in this area:

1.4.1 Identify conceptual models for heating, ventilating and air conditioning systems that are adaptive to changing conditions of building and community use. Both short-term cycle and long-term cycle models are required.

1.4.2 Identify the life style changes which have been made by many persons in response to the increasing costs of fossil fuels. The results of these analyses would provide indicators of the adaptive means humans use to respond to the changing en- ergy picture, and could provide guidance to policy makers for further studies.

1.4.3 Conduct studies of changing working/living arrangements to better understand how technological changes such as computer terminals in home offices may cause a societal adaptation to a major new form of working/living arrangements.

1.5 MARKET CONDITIONS AND USER REQUIREMENTS

There is a general argument that suggests that more than enough knowledge and sufficient methods are available to conserve a great deal of energy, but market resistance to new conditions and new methods has become the major obstacle to improved energy efficiency. Governments need to know more about how to overcome the natural resistance to change in order to advance the diffusion of new technologies. This appears to be true particularly in the area of energy conservation since it is the user's requirements that drive energy demand. Many believe that a great deal of energy can be conserved within an economic framework that is more soundly formulated than the accounting concept of "payback." Evidence demonstrating new economic propositions should be assembled and, if the evidence is clear, other reasons for resistance to sound decision making should be studied.

Research topics associated with this area include:

1.5.1 Develop a better understanding of how cultural patterns and personal values influence choices of new technologies and techniques. While the private sector has done a great amount of market research in order to sell products and services, it appears that not much is known about market acceptance of conservation programs that are <u>not</u> tied to products.

1.5.2 Develop a better understanding of the institutional factors that appear to offer the best means of accelerating diffusion of new technologies. This includes an analysis of resistance of organizations which are employed in designing, manufacturing, assembling, regulating, financing, and managing the built environment.

1.6 THE REGULATORY PROCESS AND ENERGY CONSERVATION

Among the barriers and, under some circumstances, incentives to the introduction of new energy conserving innovations into the marketplace are regulations at various levels of government. The regulations are incorporated in building codes, zoning ordinances and tax provisions. Recently there has been a series of steps taken to reduce the regulatory climate at the federal level with the belief that free market forces are sufficient to induce energy conservation decisions. The regulations which remain at the state level (based in most states on ASHRAE 90-75R) are prescriptive in nature with special provisions for evaluating alternative design solutions based on the comparative method. There is a lack of understanding about how, and in what ways, these regulations may encourage or discourage innovations in the marketplace.

This understanding also is lacking with regard to speoial tax provisions designed to encourage private investment in energy saving measures. For example, quick development of energy saving short cuts may occur simply as a means to utilize the investment tax credit. In the short-term this will create a favorable, highly visible impression that the building industry is concerned with saving energy. However, many investments may be made on products that will eventually erode from disrepair and non-use because they produce no lasting energy conscious design solutions. Such questionable benefits achieved in the short-term may have a highly negative impact upon the long-term objectives set forth in this research agenda if consumers see "energy conservation" as a risky venture.

The policy related research topics included in this area are:

1.6.1 Develop evaluation methods for total building or community performance (providing for well-being with appropriate levels of energy use) in order to measure the impact of various regulations in terms of their costs and benefits.

1.6.2 Develop test methods related to performance criteria in order to provide free market conditions for the introduction of innovative energy conserving concepts. Most test methods are tied to prescriptive specifications for existing solutions and consequently do not allow free competition for new concepts.

1.6.3 Facilitate the rapid development of computer-based design and engineering methods that will provide the potential for code and zoning requirements that are also written in computer usable formats.

The exterior walls (or skin) of a building are a mediating element between the conditions of the natural environment--air, water, earth, light--and the internal building conditions required for various human activities. The energy using mechanical systems make up for the deficiencies; the construction of the building determines at what rate that deficiency will have to be made up. There are various components of the natural environment useful for the operation of the building--heat, air movement, air quality, humidity and precipitation, and light. All of these may be excessive on either side of the building skin, requiring a transfer from one side to the other. This transfer may be achieved either directly through the skin or indirectly through mechanical plants, along with the make-up quantities of heat, heat removal (cooling), light, humidification, dehumidification, air purification, air movement and air replacement.

Moreover, geographical differences in natural environmental conditions require completely different responses in building forms (with technological and social constraints taken into consideration). For example, the various climatic conditions in different parts of the world produce different requirements for buildings and cities. The cities in the Southwest and in Alaska, for example, are, or should be, quite dissimilar.

Not only does the natural environment affect the design of cities and regions, but they, in turn, affect the environment. Large urban areas with their massive heat retaining materials, reduced vegetation and accelerated water runoff modify the natural environment significantly. For example, the temperature and wind patterns (both diurnal and prevailing) around New York City have changed sharply in the last few decades. The coal combustion and high stacks have changed the air quality of the Northeast and introduced the damaging effects of acid rains. The water consumption patterns in Phoenix and Tucson have lowered the water table by many feet, creating both structural problems and problems related to sustainable growth.

The act of building transforms not only the direct site of the building, but also requires the relocation of various parts of the natural environment from around the world to the building site in the form of building materials and components. This modification of the natural environment has far-reaching consequences in terms of desertification, deforestation, abandoned quarries and mines, flooded plains and modified shore lines. These modifications may also be changes leading to new and desirable stabilities, as in the clearing of farm land, the planting of orchards or the controlling of flooding. In addition to the existence of the changes outlined, achieving them has required the expenditure of large amounts of energy for the extraction, transformation and transportation of these materials. Excluding the human energy that has gone into the production and placement of building materials, the countless millennia of solar energy that have produced our fossil fuels and the cosmic forces that have created the diversified minerals in the earth's crust, the purchased energy to produce and install the materials used by the construction industry amounts to over 10 percent of our national energy use. This has been termed the embodied energy in buildings.

These interactions between the built and natural environments and their energy consequences can be grouped and discussed in four main areas:

2.1 Interaction between Man and the Natural Environment as Moderated by the Built Environment

2.2 Building Form Responses to the Natural Environment

2.3 Changes in the Natural Environment Resulting from Building Energy Uses

2. INTERACTION BETWEEN THE BUILT AND NATURAL ENVIRONMENTS

2.1 INTERACTIONS BETWEEN MAN AND THE NATURAL ENVIRONMENT AS MODERATED BY THE BUILT ENVIRONMENT

Approximate calculations of building energy flow are used routinely as a basis for building design. However, those currently in use are of limited utility. Those which are simple enough to be useful in the early design stages of a project tend to be rather limited in scope. They are one-dimensional (for example, all heat transfers are assumed to be of one dimension), steady state or quasi-steady state, and consider a limited, linearized temperature and solar load interaction with the natural environment. Some analytical programs that extend consideration to a wider range of variable inputs also are one-dimensional, at best quasi-static, and not responsive to the dynamic nature of energy flows. An additional shortcoming is that they have limited use as design tools because the required input is so extensive that a design must be fully specified before these programs can be applied. An energy study of several design trade-offs can require prohibitive time and expense.

Perhaps the most serious fault of both types of analysis is that they presume a uniform and static (or quasi-static) interior condition independent of changing needs for conditioning the interior space due to variations in occupancy, activity or interaction with the external environment. They do not explicitly address the basic function of the built environment; that is, to moderate the natural environment to meet human needs. The objective of this research area is to provide a sound, scientific basis for modeling the built environment--a filter or moderator between the natural environment and the needs of the individual for a comfortable, productive environment. This will require an order-of-magnitude improvement in our ability to model energy flows between man and the environment.

There are at least four aspects to the modeling process, all of which must be capable of varying over time:

- Describing the radiative, convective, and conductive environment required for human activity and modeling the interaction between the individual and the interior space;
- Modeling the interaction between the interior and exterior surfaces of the building, and modeling the interaction between the various control and equipment components that make up the building service system;
- Modeling the interaction between the building's external surfaces and fenestration and its site specific environment; and
- Modeling the site specific environment as a function of surrounding buildings, vegetation, landscape, topography and climatic conditions.

2. INTERACTION BETWEEN THE BUILT AND NATURAL ENVIRONMENTS

Many elements of the basic model exist but have not been applied in an integrated way; other elements are yet to be developed.

Examples of required research in this area include:

2.1.1 Develop two- and three-dimensional heat transfer analyses which will provide realistic distribution of temperatures over the various interior surfaces of the space and yet be manageable in terms of computation time and capacity. Variations in surface temperatures have a definite effect on occupant comfort.

2.1.2 Analytically describe advanced room climate control strategies which integrate sensing of air temperature, radiant temperature, air motion and humidity (operative temperature sensors).

2.1.3 Determine the appropriate basis for dynamic analysis (time interval) for modeling human response, system response to control, and building response, and determine means of integrated inputs for variable time reference models.

2.1.4 Develop efficient means of linking models in a way that is truly flexible and adaptable to innovative building system design strategy analysis. On a collective basis the building energy budgets determined by such models become the national budget for the operation of buildings.

2. INTERACTION BETWEEN THE BUILT AND NATURAL ENVIRONMENTS

2.2 BUILDING FORM RESPONSES TO THE NATURAL ENVIRONMENT

Changes in building form responding to differences in the natural environmental conditions result in modifications of energy demand. The shift to a greater awareness of regionalism in architectural design is a spontaneous manifestation of this tendency. Nevertheless, the factual basis is not well developed or understood.

The following are typical of the problems requiring investigation:

2.2.1 As a continuation of studies on windows, solar gain and daylighting, investigate and develop models noting interaction between heat gain or loss, light gain, and air transfer, as affected by temperature, solar angle and other local environmental conditions.

2.2.2 Develop cost/benefit studies on various devices that affect sun control, light control and insulation such as Rolladen, exterior Venetian blinds and others.

2.2.3 Develop studies comparing building forms whose internal conditions are provided largely through the exterior skin, with buildings with large interior areas whose internal conditions (light, air, temperature, humidity) are provided basically through mechanical systems.

2.2.4 Develop models of analysis for built form at the community level, in order to assess alternative patterns of interaction with the natural environment.

2.3 CHANGES IN THE NATURAL ENVIRONMENT RESULTING FROM BUILDING ENERGY USES

This topic is a complex but central issue of energy conservation. By reorganizing the natural environment in communities, cities and regions, human activities can take place. As this process continues, the resources of wide areas (air, water, land) are modified to serve these concentrations. At some point, the intensive use can exceed recoverable conditions and can cause the degradation of the conditions necessary to sustain life in the concentrated area. The control of demand for energy use by the building patterns of communities can have serious ramifications for the natural environment.

For example, New York has created a heat sink of such magnitude that diurnal wind change no longer operates, making it necessary to use mechanical cooling where natural seabreeze cooling formerly occurred.

Some examples of topics to be considered within this area are:

2.3.1 Study energy requirements as they potentially degrade the natural environment.

2.3.2 Study energy requirements for transforming the natural environment to provide infrastructure for cities. (Energy cost of water supply, waste disposal, electric generation and transmission, road network, and other transportation facilities.)

2.3.3 Examine alternative size and density patterns for communities where energy benefits of compaction, reduced transportation, and so forth are maximized in relation to energy required to provide satisfactory conditions.

The underlying scientific basis for much of the technology for energy utilization in buildings and communities comes in large measure from fundamental and empirical research of basic energy processes--heat and mass transfer, energy storage principles, and thermodynamic cycles. The central goal in this research category is to create an enhanced scientific understanding of basic energy processes that can lead to a broadened energy technology base that in turn can lead to more energy efficient buildings.

Advances in basic scientific knowledge in this field could potentially have far-reaching effects in fostering conservation. An improved understanding of thermodynamic cycles of heat and mass transfer, for example, could lead to dehumidification processes or alternatives to heat pumps that, when applied, could save enormous amounts of energy.

While the rewards of this basic scientific research could be large, the risks are also very high. There is no way of knowing now which scientific areas could lead to breakthroughs, and even less certainty as to whether a breakthrough could lead to proprietary products for a group that sponsored such basic research. Privately funded basic scientific research of this type has been, and presumably will be, a rare exception.

Research areas identified within this category are:

3.1 Models of Heat Transfer

3.2 Heat Exchange Technology

3.3 Thermodynamic Processes

3.4 Energy Storage

3.5 Cogeneration in Buildings

3.1 MODELS OF HEAT TRANSFER

A better understanding is required of dynamic, and three-dimensional heat transfer processes in buildings and their component energy using systems. Especially needed is an improved understanding of building systems where dynamic behavior is significantly different from predictions that would result from steady state analysis (for example, passive solar designs, buildings of high mass, and ground contact systems). Finite-element and finite-difference models generally are suited to many of these tasks. Advances in computers makes their use increasingly feasible; however, useful models and analyses are needed.

Development of certain specific three-dimensional, dynamic design analysis programs would be helpful including those involving earth contact building systems, wind sensitive analyses, and analyses of envelope heat transfer sensitive to variation in solar insolation and outside temperature. These programs should be translated into design tools for architects, engineers and builders. Also important will be validation of new dynamic analysis design tools, and standardized test methods for real building and building component monitoring and evaluation.

The following illustrations are examples of projects in this area:

3.1.1 Develop validated algorithms for describing earth contact conditions. Most energy analysis computer programs available today do not include this very important feature in their calculations. A model that includes this condition would have increased usefulness.

3.1.2 Develop and validate dynamic simulation models for predicting energy use in small buildings. Many times a discrepancy does exist when comparing actual data obtained from occupied buildings with the predicted values obtained from existing models.

3.1.3 Improve techniques to model, measure, analyze and test relative and absolute heat flow and air infiltration through building components and envelopes. The vast majority of calculation methods in use today do not address the important differences between varying components such as ceilings and walls.

3.1.4 Examine natural ventilation and convection phenomena in buildings as they relate to and affect the basic principles of heat transfer.

3.2 HEAT EXCHANGE TECHNOLOGY

Heat exchange capabilities of fluids and solid surfaces are understood on an empirical basis, but substantial room for new knowledge may exist, especially in the areas of basic chemistry and physics and in control of heat transfer. Basic research could be productive regarding particle or molecular heat exchange between fluids and solid surfaces (for example, to determine if variations in working fluids, heat exchange coatings, or heat exchange materials could substantially improve performance, especially in temperature ranges applicable to buildings).

A knowledge of modeling and analytical methods exists for empirical consideration of heat exchange performance. However, further research on buildings is required to provide the data to support these models. Other potential beneficial research includes materials research relating to performance and the utilization of materials for heat exchange, and the development and validation of standardized test methods in the technology of heat exchange.

Possible research topics in this area include:

3.2.1 Analyze the effects of various physical stimulants on changing the heat transfer characteristics of glazings. For example, electric current is known to have an impact on glazing.

3.2.2 Improve techniques for measuring, analyzing, and testing in the area of phase change heat exchange technology.

3.2.3 Improve measurement techniques for surface coefficients. The coefficient figures currently in use in many energy calculation techniques could be greatly improved through more accurate measurements in the field.

3.2.4 Conduct research to measure and modify heat gain characteristics of glazing by external devices. Field results on the use of overhangs, horizontal and vertical louvers, and other devices have not been documented sufficiently for use as feedback to improve the design and efficiency of such devices. The practical application and durability of these devices also should be examined.

3.3 THERMODYNAMIC PROCESSES

Thermodynamic principles are well known but the potential for substantial improvement exists in application in the built environment, especially regarding development of alternative thermodynamic cycles, new refrigerants, and chemical or solar assisted devices. While the development work should be in the private sector, public sector support for initial concept development could be important.

Specific research topics to be addressed in this area are:

3.3.1 Evaluate the properties of nonazeotropic refrigerant mixtures as a working fluid for vapor compression cycle heat pumps. (Two fluids are currently being considered; this could be expanded to three.)

3.3.2 Evaluate the properties of nonazeotropic refrigerant mixtures for absorption heat pumps.

3.3.3 Conduct tests to determine the applicability of variable speed AC motors for variable speed compressor drives.

3.3.4 Evaluate Brayton, Stirling and other cycles for more efficient heating and cooling devices.

3.3.5 Evaluate properties of new desiccants and vapor permeable membranes.

3.3.6 Conduct basic research on absorption/desorption dynamics.

3.3.7 Conduct research on ground heat and mass transfer (dynamics of soil moisture, freezing and thawing properties of different soils).

3.4 ENERGY STORAGE

The application of energy storage techniques in buildings could reduce energy consumption and lower peak energy demands as well as facilitate the use of alternative or renewable energy sources. Buildings, during their yearly operational cycle, often have periods when they have to dissipate excess thermal energy. Alternatively, buildings may have periods when they cannot use all the energy available to them. This may occur in the evening with low electric demand. The advantages of being able to store excess heat gained in the summer for heating in the winter are obvious, as are the advantages of storing electricity during off-peak periods for meeting peak period requirements--energy that would otherwise be wasted could be used.

The basic scientific principles that underlie the broad range of thermal, chemical, biological and mechanical energy storage are known, but much work needs to be done to refine and apply these principles in an energy and cost efficient manner in buildings.

Some promising research opportunities in this area include:

3.4.1 Develop concepts for new or improved energy storage processes and materials. Investigations could focus on improving phase-change materials, developing thermochemical processes, producing new chemicals for high-density energy storage, improving battery and other forms of electrical energy storage, improving biological energy conversions and storage processes, developing methods for energy storage and retrieval from ground water aquifers or abandoned mineshafts, and integrating energy storage into building architecture.

3.4.2 Develop modeling techniques for long-term storage of thermal energy. These models must accommodate such problems as stratification, time lags and thermal losses. Because of varying earth characteristics, ground storage presents some special modeling problems that need to be resolved.

3.4.3 Develop methods of design and synthesis to size and integrate energy storage technologies effectively and reliably with other building systems.

3.5 COGENERATION IN BUILDINGS

Cogeneration in buildings is the combined production of useful thermal energy and electricity in one process. Though theoretically advantageous, cogeneration systems in buildings, especially small buildings, have only recently started to achieve success. While cogeneration systems have been in place for years at the community and industrial levels, perhaps the most promising avenue for advancement is cogeneration systems for small buildings and residences. Research could provide an understanding of alternative thermodynamic processes and new materials and systems that could facilitate this technology in overcoming the problems of high initial cost and low durability.

Typical research topics may include:

3.5.1 Develop methods of testing for long-term wearing characteristics of cogeneration systems.

3.5.2 Perform exploratory research on new thermodynamic cycles and new materials for cogeneration systems.

- o Under 3.5.2, perform modeling and analyses of new alternative thermodynamic cycles.

3.5.3 Evaluate possible use of community or sub-community cogeneration.

Most buildings and community systems that exist today have been designed based on fairly simple and straightforward empirical relationships, as discussed under Category 3. Heating and cooling systems and their component parts, for example, are designed and specified primarily on the basis of expected peak-load energy conditions. The operation of components and systems is seldom considered on a dynamic and interrelated basis. If dynamic interrelationships can be considered successfully, the potential exists for significantly increasing conservation of energy. This will require development of more sensitive and sophisticated means for analyzing energy use in buildings and communities. Needed are variables that are dynamic in nature, that are sensitive to geometry and configuration, that are sensitive to microconditions rather than only macro or average conditions, and that consider partial loads and interrelationships between systems. While several of the available mainframe computer programs do attempt this kind of modeling, more work is needed to improve and expand their capabilities.

The research areas within this category are directed toward gaining a working understanding of design variables and their interrelationships that until now, have been ignored or have been treated on only an intuitive basis. The motivation is that it has been demonstrated repeatedly in passive solar and other types of buildings that the use or control of design attributes such as siting, mass, color, orientation and sizing can bring dramatic energy savings, while at the same time produce a built environment that better meets the needs and desires of people. However, adequate quantitive means do not exist for reliably and effectively utilizing all design and operational options. Research in this category needs to produce a better understanding and definition of the range of system variables that is now pertinent, to quantify interrelationships between factors, and to develop analytical models. Research is also needed to develop design methods and tools that can take advantage of this new level of knowledge, but can do so without making the design process inordinately complex, time consuming or expensive.

The areas that have been structured under this category are:

4.1 Whole Building Energy Processes

4.2 Energy Control Strategies

4.3 Embodied Energy: Buildings and Communities

Category 4: ENERGY USE AND CONTROL IN BUILDINGS AND COMMUNITIES

4.4. Intermittent and Localized Energy Systems

4.5 Moisture Control

4.6 Illumination of Buildings and Communities

4.7 Characteristics of Building Envelope Systems

4.8 Retrofit of Existing Buildings

4: ENERGY USE AND CONTROL IN BUILDINGS AND COMMUNITIES

4.1 WHOLE BUILDING ENERGY PROCESSES

Human activity in buildings occurs amidst a backdrop of complex energy forces. While the common sources of building energy are purchased such as oil, gas and electricity, environmental factors such as sun and wind, and the "hidden" sources of energy such as heat from equipment have a significant effect on energy performance.

Improvements can be made in understanding the joint dynamic workings of the whole building's energy producing and using systems. These improvements can be made for all building types and systems. A better understanding of whole building energy processes can lead to improved energy efficient design.

Currently there is little verifiable data on actual energy use in buildings. Any data base should be able to utilize the dynamic status of buildings. A better understanding is needed where steady state performance poorly represents dynamic behavior, as in passive solar design features. Analytical tools that are sensitive to the performance differences caused by dynamic processes are needed both for highly accurate research analyses and for simplified forms of analyses.

Examples of research topics:

4.1.1 Undertake research to determine how best to gather, classify, access and use data on total building energy use.

4.1.2 Develop a better understanding of natural convection phenomena in rooms and interior spaces. Further knowledge needs to be developed on multi-rcom transient analysis of buildings. Models should be developed to test the effects of one room's influence on another room.

4.1.3 Develop simple, low-cost, front end design tools for whole building energy analysis. Criteria for these should be developed based on user analysis for format requirements and other needs.

- o As a subset of 4.1.3, develop simple, interactive dynamic analysis models to be used as tools for predesign energy use analysis. Existing complex computer simulation programs can be condensed into useful tools.

4.1.4 Develop methods and techniques for integrating energy intensive appliances with other building systems.

4.1.5 Examine the impact of "hidden" sources of energy on whole building energy performance for various building types. "Hidden" energy in a building is energy that is typically not accounted for in standard calculations, such as the heat produced by large computers or by treatment processes of community waste.

4.2 ENERGY CONTROL STRATEGIES

Energy controls for buildings are concerned with coordinating the functions of the energy consuming and producing systems in a building with each other and with the demands of the external and internal building environment so that energy is used in as efficient a manner as possible. Work in this area has resulted in the development of a whole range of software and hardware technology for controlling energy use in buildings. Future research needs to be directed towards developing techniques and systems to monitor, measure and interpret the energy related variables impacting a building in the dynamic mode and then use this data to adjust the energy systems in that building so that they minimize energy consumption.

Typical research topics include:

4.2.1 Perform modeling of multi-variable energy control strategies to develop an understanding of how these control strategies would be integrated, how the strategies would respond to varying operating and environmental conditions, and how the occupants would interface and respond to them.

4.2.2 Based on the model work proposed in 4.2.1, undertake development of optimum control algorithms and energy system configurations. These energy control strategies could be combined with energy load strategies that may be developed under 5.2, "Community Energy Processes, Use, and Systems." Private sector developments should pick up concepts and implement than in the market place.

4.2.3 Develop testing and evaluation methodologies for static and dynamic control performances of buildings and systems.

4.2.4 Develop field validation methods for control strategy models.

4.3 EMBODIED ENERGY: BUILDINGS AND COMMUNITIES

As new buildings and communities become increasingly energy efficient from an operating point of view, the energy expended prior to their operational phase, defined here as embodied energy, takes on greater significance. In a contemporary office building, for example, the embodied energy can readily approach 1 million BTU per square foot of floor area. If the useful life of the building is 20 years, then it will have required 50,000 BTU per square foot to create the building. Among other things, this suggests that increasing attention be paid to reuse of existing buildings.

This area is concerned with the embodied energy in buildings and communities, the energy consequences of alernative building choices and the long-range implications of these activities. Some studies have been conducted that identify in great detail the purchased energy that is required by the construction industry for the entire economy, for various building sectors, for individual buildings and for the materials and assemblies used in building. This embodied energy accounts for all energy required to produce an end product, from the extraction of raw materials to all steps in the manufacturing processes, and includes prorated energy costs for transportation, plants and equipment, and facilities for administration and marketing. The data show that over ten percent of total U.S. purchased energy is used by the construction industry.

There is also a need to assure that information available concerning embodied resources is integrated with design methods and decision making at various levels in the building and community development processes. To the degree that the value of embodied resources is not reflected in the first costs of building and development, it is important to recognize that appreciable returns on research and development efforts related to embodied resources may not soon be realized by individual builders and developers. This suggests an appropriate area of federal expenditure, as the return to society generally will be great.

Among the topics that could be explored in this area:

4.3.1 The available data on embodied energy in buildings is based on Commerce Bureau of Economic Analysis data from 1967. More recent data from 1972 are available. Updating the information to this later data base will make it dynamic, and will identify directions of change in the building industry.

4.3.2 Parallel to the modeling of the total energy use required for the operation of buildings, a study is required to determine the amount and kinds of energy needed to provide new buildings and replacements.

4.3.3 Expand the conceptual base of basic scientific developments that would lead to reductions in the amount of embodied energy used to produce buildings and community systems while maintaining their desired performance characteristics.

4.3.4 Develop interactive models that would project alternative embodied resources for various building construction types and land use planning approaches.

4.3.5 Assess the resources embodied in various forms of physical development at the community and urban scales.

4.3.6 Explore alternative methods (including existing practices) for resource valuation. Define what these new methods might provide in the way of analytical tools.

4.4 INTERMITTENT AND DISTRIBUTED ENERGY SYSTEMS

Substantial gains in energy efficiency may occur if heating, cooling, lighting, and other forms of space conditioning are supplied only when and where needed, and only in amounts necessary for the purpose at hand. Current building systems are seldom designed to take advantage of this concept, except in terms of very gross environmental adjustments.

At both the building and community levels research would be beneficial that presses our ability to provide distributed, decentralized systems that are designed to operate only intermittently and at levels suited to the requirements of the moment. This approach is an integral part of making buildings and community systems responsive to their locations and the demands of use placed upon them.

It is commonly held that increased user control over energy systems is to be avoided; environmental conditioning systems in all but the smallest of buildings routinely are designed on the assumption that occupants should have less, rather than more, involvement in determining ambient conditions. Great promise exists in an alternative approach, which would require positive actions or decisions of users in determining environmental conditions. The concept of intermittent and highly localized energy systems is closely linked with research into user practices and environmental responses, as well as the overall energy economy of building operation. The pursuit of this area would conceivably lead to systems that would not provide ventilating air until users decided it was needed, heating and cooling would be supplied only upon demand by users. As an example, subway escalators that run only when people are present, a common approach in European cities, can be designed to operate only on active demand. (see the associated ideas of Section 1.3)

Among the topics that would be researched in this area are:

4.4.1 Develop models of building energy performance that would be capable of assessing the performance of demand based, distributed energy systems.

4.4.2 Develop design estimating methods and other design oriented tools that would assist in applying this approach to various generic buildings and community systems.

4.4.3 Develop design strategies that combine large-zone, constant condition heating, cooling and ventilating systems with smaller, spot-zoned devices and systems.

4.5 MOISTURE CONTROL

The concept of moisture control used here includes the problems of moisture in building components as well as the interrelated concerns of humidity control for human comfort and health. Moisture problems, especially in structural components and insulation, can lead to problems of materials' deterioration as well as reduced energy performance.

A better understanding is needed about the impact of natural transport of moisture through building materials, especially insulation and structural components. Recognizing that moisture in buildings is a key problem, research should be undertaken to learn more about the effects of moisture on new materials and the relationship of moisture to human comfort issues.

Human comfort is affected by humidity conditions. Alternatives to conventional systems of humidity control such as rechargeable desiccants can be identified and may have the potential for significant energy savings.

Examples of research topics in this area are:

4.5.1 Develop a better understanding of the energy requirements for recharging desiccant materials.

4.5.2 Develop models that reveal more about moisture transport through building materials.

4.5.3 Develop better information for building designers about moisture transport and humidity controls under specific climate conditions. Materials and methods should be developed to assist designers with this area of concern.

4.5.4 Develop methods to measure, test and evaluate the effectiveness of vapor retardants.

4.5.5 Develop an analytical model for the effective dissipation of the moisture generated in buildings in relation to climatic, construction, design and occupancy factors, air infiltration and ventilation, and building site.

4.5.6 Prepare and publish guidelines for the control and management of moisture in buildings in a format suitable for designers, builders, and managers.

4.6 ILLUMINATION IN BUILDINGS AND COMMUNITIES

Design of the luminous environment is crucial to energy questions in the built environment. At virtually all levels in buildings and communities lighting is a major requirement, linked to safety, health, productivity, and the very functioning of environments.

An abundant form of solar energy reaches us as light, yet this is a frequently overlooked and certainly underused resource. In buildings there is a basic need to better integrate sunlighting systems with other kinds of lighting. In larger contexts--for roads, sidewalks, public spaces and commercial facilities--there is a need to achieve this same integration and to apply the "task-oriented" approach that has achieved some currency in contemporary buildings.

The relationships between required illumination levels and the technology of lighting need to be investigated. Research also is needed to improve methods of lighting control and assessment of available daylighting resources.

Among the research topics in this area are:

4.6.1 Develop correlations between data on available insolation (now generally known for most areas of the country) and possible illumination levels.

4.6.2 Develop instrumentation, sensors and measurement devices for evaluation of physical models of buildings and groups of buildings.

4.6.3 Explore the potential of alternative technologies for producing and transmitting light for possible application in buildings and communites.

4.6.4 Develop information on the reflective properties of various building materials, glazings and coatings.

4.6.5 Develop new methods for use by designers in integrating natural lighting with other lighting systems, and for relating these systems to overall building energy performance.

- o As a subset of 4.6.5, develop generic design strategies for deep penetration of sunlight to interior spaces and controls for such strategies.

4.7 CHARACTERISTICS OF BUILDING ENVELOPE SYSTEMS

Among the scientific and technological factors limiting improvement of the energy efficiency of buildings is a lack of detailed knowledge about how they respond to external and internal changes in environmental and use conditions on a continuing basis. A better understanding is needed of the characteristics of building envelope systems, especially their dynamic behavior. This information will lead to more accurate predictions of how buildings will perform under different conditions and will aid in development of improved control strategies (Section 4.2).

Potentially fruitful research topics include:

4.7.1 Develop laboratory and field testing procedures for building envelope systems to establish and document basic properties and dynamic modes of behavior which currently are inadequately understood.

4.7.2 Develop dynamic analytical methods for building materials, composites and envelope systems to define what constitutes good and bad dynamic performance.

4.7.3 Investigate the development of new building materials, composites and systems for building envelopes that have good dynamic response characteristics.

4.7.4 Develop test methods to carry out the measurements required in some of the preceeding suggested research topics in this area.

4.8 RETROFIT OF EXISTING BUILDINGS

More than one-third of the energy expended in this country is consumed by existing residential and commercial buildings, and it is estimated that 40 percent of this energy is wasted. The potential for energy savings through retrofitting existing buildings is tremendous, especially when one considers that 80 percent of the buildings that will be in use in the year 2000 are in existence today.

The process of retrofitting a building involves diagnosing the problems and areas of opportunities, designing, evaluating and implementing the solutions, and evaluating the results. While research has been undertaken on all parts of this process, especially for residential buildings, efforts are still needed to improve the diagnostic techniques and hardware. Improvement of these techniques and hardware, particularly at the commercial building scale, will assist designers and engineers in making retrofit decisions with a reasonable degree of confidence.

While it generally is recognized that the nontechnical barriers to retrofitting existing buildings are significant (for example, financial, regulatory and educational barriers), specific technical research is needed to provide the necessary techniques and tools.

Some examples of research in this area are:

4.8.1 Develop and validate simpler and more accurate diagnostic tools. Existing modeling techniques are generally inadequate for creating a framework for consideration of retrofit options.

4.8.2 Develop better test methods to assess the in-place energy performance of buildings and their components.

- o As a subset of this activity, perform analyses on the thermal characteristics of materials under exposed conditions over many years.

4.8.3 Develop a uniformly consistent data base of building energy performance based on field experience rather than laboratory results.

4.8.4 Conduct evaluations of the in-place performance of retrofit measures in order to minimize the differences between predicted and actual energy performance.

This category addresses fossil fuel and energy conservation issues at the community or urban level. One important aspect of this subject is hardware systems, characteristically owned and operated by local governments or utilities, and are often referred to as the infrastructure (for example, the systems for supplying energy and water, and removing waste from a total community as contrasted to a single building). In many communities the infrastructure systems were put in place more than seventy years ago. As a result the energy efficiency of these systems is impaired by the lack of maintenance or repairs--clearly a governmental responsibility. Even in newer communities the same basic hardware systems, developed 100 years ago, still are being installed.

Aside from pure hardware issues, this category also addresses the more general issue of energy flow into and within communities, and the related issues of consumption, conservation, and possible planning strategies. The opportunity for innovation in this category is enormous, but may be constrained by the many political and institutional barriers that can slow down or block the introduction of major new ideas into ongoing local government operations.

The research areas included in this category are:

5.1 Water and Waste Water Systems

5.2 Urban Solid Waste Systems

5.3 Community Energy Processes, Use and Systems

5: COMMUNITY INFRASTRUCTURE AND ENERGY CONSERVATION

5.1 WATER AND WASTE WATER SYSTEMS

The processing and delivery of potable water and the removal and treatment of wastewater and sewage are services that require large amounts of energy. New technologies and methods with respect to water conservation, heat reclamation and low energy use need to be examined. There is a need for basic research particularly where chemical or biological processes can substitute for current energy intensive processes. Alternative methods for water and wastewater treatment, use and reuse, distribution, and disposal need to be assessed with regard to energy conservation at both the community and building level. For example, energy use for pumping is increasing because groundwater supplies are being diminished and are not being replenished.

The following are examples of research topics that can be considered in this area:

5.1.1 Conduct research to develop new materials to ease the flow of water through pipes to reduce the energy used for pumping (for example, special interior pipe surfaces to reduce friction).

5.1.2 Develop new concepts which would encourage conservation of water use in buildings and the energy used to heat that water.

5.1.3 Develop methods for heat recovery from waste water.

5.1.4 Analyze the feasibility of injecting low-grade heat into main water conduits serving municipalities. This heat typically would come from electrical generating power plants.

5.1.5 Conduct research on waste treatment processes to facilitate underground disposal.

5.1.6 Model and develop storm water management systems to reduce runoff, replenish ground water supplies and reduce stream pollution in new building developments.

5.2 URBAN SOLID WASTE SYSTEMS

The relationships between municipal solid waste and energy production need to be examined with regard to improved processing techniques, environmental effects and energy production technologies. Better technologies for handling, separating and processing municipal waste need to be developed. For example, new urban waste energy systems may use biological enzymes to produce gases from waste materials. Research to better understand this process and others is needed. In addition, improved techniques for processing urban waste need to be examined especially with regard to the interface of such systems with the existing urban infrastructure of waste disposal, and systems for treatment at the source. Other beneficial research includes the development of improved methods for the design of economical urban and individual waste systems, followed by the development of methods to measure and test the environmental effects of urban waste systems on the community.

Examples of possible research include:

5.2.1 Develop methods of reducing the volume and/or mass of urban solid waste. This could ultimately lead to a much reduced energy load in handling and processing this waste.

5.2.2 Develop methods of waste treatment at the source of its generation. The current technique of removing waste to a central processing point is extremely energy intensive. By treating the waste at the source (i.e. at the building rather than community level) much energy can be saved by eliminating the vast amounts of energy used to transport the waste.

5.2.3 Conduct research into nonpolluting disposal systems.

5.3 COMMUNITY ENERGY PROCESSES, USE AND SYSTEMS

The physical organization and relationships of the buildings and other facilities in a community to each other, to the people who use them, and to systems that supply their energy and other resource requirements may have important influences on the amount of energy consumed. Currently, most urban planning is done with little consideration for these potential impacts. This is not surprising because the flow of energy within communities and regions and the interrelating impacts are not very well understood.

This research area proposes improving the base of knowledge on the flow of energy within communities and regional areas and utilizing this information to improve existing strategies, and to develop new strategies, for dealing with these flows.

Possible research topics include:

5.3.1 Develop the socio-economic rationale to explain how human living patterns and technology work together to impact energy consumption.

5.3.2 Clearly map patterns of energy flow within communities--the supply, distribution, storage and use--and characterize and quantify the community factors that influence energy use.

5.3.3 Examine how new energy technologies and applications may affect the physical form and spatial/functional layout of buildings and community facilities.

- o As a subset of this topic, develop prototype community layout schemes that consider the quality and temperature of energy flowing into and out of buildings as well as other more traditional functional relationships.

5.3.4 Develop strategies and methods for minimizing waste in community energy flows.

5.3.5 Develop design techniques for testing and evaluating strategies for designing and managing community energy flows.

Other subjects that could be addressed in this research area are solar zoning and community design, the improvement of micro-climate with vegetation, and other space planning techniques.

Category 6: RESEARCH INFORMATION DISSEMINATION AND TECHNOLOGY TRANSFER

The ability to introduce innovative concepts and methods into the processes of designing, producing, and managing the built environment has a direct relationship to the success of any conservation effort. While Category 1 which concerns user interactions is the driving force behind this agenda, Category 6 must be the final culmination of any efforts of the previous five. Unless successful research and development efforts are communicated directly to the planners and implementors of the built environment, the results of research may remain unused.

The building industry is diffuse and fragmented; its participants have diverse backgrounds and needs, and mostly limited resources. The building industry is characterized by low levels of capital and decentralized sources of funding. Because of these factors, traditional communication theory may not be well-suited to the needs of the industry. A research effort should be devoted to the development of the science and theory of communication between the research and application areas within the industry. It also seems appropriate to have all government sponsored research linked to effective dissemination of results to those who could benefit from such information.

Support for effective knowledge dissemination and the utilization of existing research can produce major benefits to the building community in general. Such support often can be as effective and produce as highly visible results as allocating resources toward new areas of research.

Research areas related to this category are:

6.1 Communications Methods and Requirements

6.2 Design Integration Methods and Requirements

6: RESEARCH INFORMATION DISSEMINATION AND TECHNOLOGY TRANSFER

6.1 COMMUNICATIONS METHODS AND REQUIREMENTS.

With rapid changes in the technology and methods of communicating, there is a major opportunity to explore ways to facilitate the flow of information among the various participants and organizations involved in designing, making, managing, and using the built environment. The inadequate flow of knowledge, user requirements, tools of analysis and synthesis, and data among disciplines, research areas, research institutions, and professionals can easily freeze the state-of-the-art of any development. In the development of energy conservation methods and products for buildings and communities there is a clear need for integration of the design activities in order to achieve wider use of nontraditional means. Transdisciplinary concepts often are developed more easily if the effort to understand users' needs and the satisfactions of their well-being is tied to new methods of communications such as computer-based systems. The existing institutional constraints are removed more easily when an entirely new medium beyond the written words of specifications, regulations, and methods of analysis and synthesis is introduced. The use of simulation in computer-based methods is an example of one way to overcome the traditional fragmentation of design results into decisions made by each of the existing professional disciplines.

Communications-based research topics in this area include:

6.1.1 Develop evaluation methods and design synthesis tools that are derived from computer-based concepts. This work can be done by the federal agencies who are responsible for in-house design and construction programs as a means of improving their own operations. The conceptual basis for these new tools then can be assimilated by the private sector companies who provide software support for professional firms in the private sector, as long as the communications links between federal agencies and the private sector are kept open.

6.1.2 Develop means of interrelating the traditional disciplines of HVAC design, lighting design, architectural design and interior space design in a manner which is transdisciplinary. The use of computers would seem to offer the technological base for this development. The financial risk of achieving successful development (as compared to the initial costs of software) is likely to be so high as to preclude private sector initiatives at this time.

6.1.3 Develop a better understanding of how mass media can be used to communicate with users their options for energy conservation in their private and organizational settings.

6.2 DESIGN INTEGRATION METHODS AND REQUIREMENTS

In all systems that are designed and produced by human effort the questions and problems that lie at the interface between the components of the system are always the most interesting and the most challenging. When a community is designed conceptually it may be the work of a planner, an urban designer and a developer. However, as the community actually begins to take shape, and as it grows over time a host of other professionals, organizations and institutions that interact in satisfying needs such as transportation, utilities, buildings, communication systems, waste management and public safety become involved. The institutional designs for providing the residents of the community with health care, educational programs, recreation, work and living spaces are even more complex. The interactions of the "hardware" performance capabilities installed in the community and the "software" performance requirements for effective institutions are seldom studied.

While the problems and opportunities are ones of local government, the methods and tools of analysis can be utilized by all governments, and, as a result, seem to represent a logical program for federal support. Once such tools of analysis and synthesis have been created, the first few applications (or demonstrations) of their use also would seem to be a logical program for federal support. When the methods of analysis and synthesis have been tested and proved to be effective they can pass into the literature and practice of local governments and their professional consultants.

Research and development topics in this area include:

6.2.1 Develop tools of analysis at the level of total communities in order to enable local governments to make trade-offs between alternative hardware systems performance and desired institutional programs.

6.2.2 Study ways of introducing energy conserving methods that move across traditional boundaries of community organization (for example, the trade-offs between transportation and communications in educational programs or work settings).

- As a subset of this topic also explore the means of gaining the cooperation of traditional craft-based union groups to allow the introduction of innovations that lie at the interface between existing ways of designing or building.

APPENDIX A: ANNOTATED BIBLIOGRAPHY

Achenbach, P. R. (ed.) The National Program Plan for the Thermal Performance of Building Envelope Systems and Materials. Oak Ridge National Laboratory, Oak Ridge, Tennessee, Draft Report, September 1981, 133 pp.

Comprehensive and detailed identification and description of research needs related to building envelopes. The majority of research needs identified focus on the years until 1986.

AIA Research Corporation. Energy: A Challenge to Community Growth (unfunded research proposal to the U.S. Energy Research and Development Administration). Washington, D.C., March 1976, 80 pp.

An outline of a framework within which the energy using elements of community infrastructure may be seen and examined, with discussion of opportunities for successful intervention.

American Physical Society. Efficient Use of Energy: A Physics Perspective. Philadelphia, Pennsylvania, January 1975, 210 pp.

The results of a summer study on the technical aspects of efficient energy use, concentrating on needs and opportunities in buildings, transportation and community systems. Represents views of physicists concerned with making existing systems more efficient.

Association of Energy Engineers, Directory of Technical Magazines and Directories. AEE Energy Books, Atlanta, Georgia, 1981.

A comprehensive listing of magazines and directories in the energy field with statistics about cost, renumeration for authors, circulation.

Battelle Columbus Laboratories, Energy Information Resources. American Society for Information Science, Washington, D.C., 1975, 207 pp.

Describes a wide variety of energy information resources and their fields of coverage. Conservation related research for buildings and community systems is not described in great detail.

Booz, Allen & Hamilton, Inc., An Assessment of Passive and Hybrid Solar Energy Systems. For U.S. Department of Energy, Washington, D.C., Draft Report, February 1981.

Assesses the readiness of passive and hybrid solar systems for more widespread use in buildings. Identifies problem areas that require further research. Concluded that only residential passive heating systems are ready now for wide use.

Commoner, Barry. The Politics of Energy. Alfred A. Knopf, New York, NY, 1979, 101 pp.

A highly opinionated but nonetheless technical assessment of needs for different approaches to building and developing communities, including extensive critiques of past and present federal policies in these areas.

Comptroller General of the United States, Greater Energy Efficiency can be Achieved through Land Use Management. General Accounting Office, (EMD-82-1). December 21, 1981.

Another useful reference pertinant to improved planning techniques.

Energy, Mines and Resources Canada, Energy Conservation in Office Buildings: Review of Canadian and U.S. Studies, Surveys, Programs, and Publications. Energy, Mines and Resources Canada, Conservation and Renewable Energy Branch, Ottawa, Ontario. Publication #2f, 1979, 1900 pp.

While not related directly to identification of energy research needs, this comprehensive directory indicates the state-of-the-art in recent research and application in this area of building energy conservation.

Energy Research and Development Administration. Buildings Conservation Program Approval Document, Executive Summary. Washington, D.C., 1975, 40 pp.

A further refined and developed version of several predecessor documents, containing a comprehensive rationale for the ERDA programs related to buildings and community systems and many explicit research objectives.

Federal Energy Administration. Five Year Program Planning Document for End Use Energy Conservation, Research, Development and Demonstration. PB240406, Washington, D.C., June 1974, 238 pp.

The first comprehensive federal plan related to energy conservation, encompassing the efforts and views of 16 federal agencies. It sets forth research and development priorities, many as yet unfulfilled.

Ford Foundation/Resources for the Future. Energy the Next Twenty Years. Ballinger Publishing Company, Cambridge, Mass., 1979.

Nineteen experts criticize recent government energy policies in a major policy study supported by the Ford Foundation. Research needs are discussed.

Holloman, J. Herbert et al. Energy Research and Development. Ballinger Publishing Company, Cambridge, Mass., 1975.

Collected papers prepared for the energy policy project of the Ford Foundation. The need for building energy research is discussed along with general suggested directions and priorities. Specific research recommendations are not extensively covered.

National Academy of Engineering. U.S. Energy Prospects: An Engineering Viewpoint. Washington, D.C., 1974, 141 pp.

A comprehensive report on the recommendations of the NAE Task Force on Energy, which was influential in shaping early federal energy conservation efforts. Extensive discussion of research and development needs and priorities.

National Advisory Council on Research in Energy Conservation. Energy Conservation Research: A Key to Resolving the National Energy Dilemma. Washington, D.C., December 1975, 50 pp.

A report of findings from a year-long study concerned with the needs and opportunities for energy conservation research, giving special emphasis to buildings.

Oak Ridge National Laboratory. Assessment of Building Diagnostics, Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 1981, 108 pp.

This assessment addresses the building diagnostic requirements for in-situ or field measurements on energy consumption in conditioned spaces and on heat gain and loss in residential and non-residential buildings. The diagnostics program plan that is included contains the following elements:

1. Envelope Thermal Performance Evaluation Techniques
2. Efficiency and COP of HVAC Systems
3. Large Scale No-Visit Surveys
4. Whole Building Periodic Audits
5. Electronics Technology Transfer
6. Energy Performance Monitoring in Buildings
7. Interior Environmental Monitoring
8. Research and Development
9. Information Dissemination

Organization for Economic Cooperation and Development. Energy Research and Development. Organization for Economic Cooperation and Development, Paris, 1975.

Discusses broad fields of energy research required. Notably it states on page 89 that "it must also be borne in mind that science and technology probably contribute less in this field (buildings) than in the production of energy."

Press, Jacques Cattell (ed). Energy Research Programs. R. R. Bowker Company, New York, N.Y., 1980.

Massive compilation of private and public organizations involved in various aspects of energy research. Provides brief indications of the areas of research in which listed organizations are active.

Public Affairs Clearinghouse. Energy: A Guide to Organizations and Information Resources in the United States. Second Edition, Public Affairs Clearinghouse, Claremont, California, 1978, 221 pp.

Chapters 8-10 deal with organizations involved in the interrelated areas of energy conservation, environmental quality and consumer protection.

Schurr, Sam H., et al., Energy in America's Future: The Choices Before Us. published for Resources for the Future by John Hopkins University Press, Baltimore, 1979.

Solar Energy Research Institute. A New Prosperity: Building a Sustainable Energy Future. Brick House Publishing, Andover, Mass., 1981, 450 pp.

Perhaps the most comprehensive assessment ever completed on the potential for energy conservation and renewable energy resources, with a major section on buildings and communities. Originally prepared for the House Science and Technology Committee and Energy and Commerce Committee. Contains a range of recommendations on research and development priorities.

Steadman, Philip. Energy, Environment and Building: A Report to the Academy of Natural Sciences of Philadelphia. Cambridge University Press, New York, N.Y., 1975, 287 pp.

A thorough examination of the needs and opportunities for energy conservation in buildings, emphasizing new technologies for the use of renewable energy sources and for saving energy. One of the first major assessments of development potential for buildings.

Sullivan, Thomas F. P. (ed). Energy R & D, Present and Future. Proceedings of the First Annual Energy R & D conference, Government Institutes, Inc., Washington D.C., 1974.

Provides a variety of papers related to energy R & D. Papers are related to conservation in buildings and community systems.

U.S. Department of Energy, and Brookhaven National Laboratory. Building Energy Controls Assessment. Second draft.

Prepared as a guide for planning efforts by the Department of Energy in building energy controls. This assessment identifies both current and emergency issues in the controls field, many of which could be addressed by research.

U.S. Department of Energy, Buildings Division. Numerous internal planning and budgeting memoranda and unpublished reports from contractors and national laboratories concerned with ongoing research activities.

U.S. Department of Energy, Technical Information Center. Information Resources in the USA on New and Renewable Energy. U.S. Government Printing Office, Washington, D.C., June 1981, 80 pp.

This comprehensive directory prepared for a United Nations conference details who performs research,, how the results are distributed, and lists libraries, offices, data bases, and directories.

U.S. Department of Energy. Passive Commercial Buildings SubProgram Multiyear Plan. Final Draft, U.S. Department of Energy, December 8, 1980.

Identifies five-year objectives, strategies, proposed activities and schedules for a DOE program in commercial buildings.

U.S. Department of Energy. Preliminary Plan for Fiscal Year 1982 Programs Related to Passive and Hybrid Solar Heat Technologies. Washington, D.C., August 1981, 280 pp.

A comprehensive and unimplemented plan for development of solar heating and cooling technologies for buildings, with extensive discussion of research needs and recommended funding priorities.

World Energy Engineering Conference. Energy Utilization. in Proceedings, AEE Energy Books, Atlanta, Georgia, 1051 pp.

A collection of state-of-the-art applications for improving plant and building energy efficiency and applying alternative energy resources by 60 energy experts.

APPENDIX B: BIOGRAPHICAL SKETCHES OF COMMITTEE MEMBERS

COMMITTEE ON ENERGY CONSERVATION IN BUILDINGS AND COMMUNITY SYSTEMS

Chairman:

RICHARD C. JORDAN, Professor and Associate Dean, University of Minnesota, Minneapolis, Minnesota. Dr. Jordan is currently an Associate Dean of the Institute of Technology. He was also Head of the Department of Mechanical Engineering, and Head of the School of Mechanical and Aerospace Engineering. He has served on numerous national and international committees and boards, and has published extensively in the fields of mechanical engineering, particle technology, solar energy utilization, education, heat and mass transfer, air pollution and air filtration, and environmental control. He is a Fellow of the American Society of Mechanical Engineers, a Fellow, Presidential Member, and past president of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, and a member of various other professional societies and councils. Dr. Jordan is a registered professional engineer and holds a Bachelor of aerospace engineering, an M.S. in mechanical engineering, and a PhD in engineering from the University of Minnesota.

Members:

MICHAEL G. GRIFFITH, Director, Research and Development, Owens-Corning Fiberglas Corporation, Technical Center, Granville, Ohio. Dr. Griffith is the director of research and development for all the corporation's technical activities. He has previously directed labs dealing with insulation technology and exploratory research. Dr. Griffith has also held various research and development positions with the DuPont Company, specializing in textile fibers. Previous to a year of postdoctoral research at the University of Minnesota, he received his B.S. in chemical engineering from Northwestern University, and his PhD in physical-organic chemistry from Louisiana State University.

JEROLD W. JONES, Associate Professor of Mechanical Engineering, University of Texas, Austin, Texas. Dr. Jones is an Associate Professor and Coordinator of Conservation Studies at the Center for Energy Studies.

He has also served as a consultant to Congress, federal and state agencies, professional organizations, and private companies on building energy requirements, energy conservation, and energy management. He has published technical articles and reports in these subject areas as well as in heat transfer and gas dynamics. Dr. Jones is a member of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, has been a member of several of their national committees, and served as a local chapter officer. He holds a B.S. in mechanical engineering from the University of Utah, an M.S. from Stanford University, and a PhD from the University of Utah.

PRESTON E. McNALL JR., Chief, Building Physics Division, Center for Building Technology, National Bureau of Standards, Washington D.C. Dr. McNall directs the efforts of a division involved in the development and implementation of design standards, and evaluation, test and measurement methods for building thermal envelope systems, and passive solar heating and cooling systems. He is also responsible for the development of similar criteria for building illumination and acoustical performance, and has directed research on standards in mechanical, thermal, plumbing, and electrical engineering. Dr. McNall is the author of numerous technical papers published in the ASHRAE Journal, ASHRAE Transactions, Building Research and Practice, and other publications. He is a member of the American Society of Mechanical Engineers, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, and has served as a member and chairman of many ASHRAE national committees. Dr. McNall was a professor at Kansas State University, and Head of their Mechanical Engineering Department. He is a registered professional engineer, and holds a B.S. in mechanical engineering from the University of Wisconsin, and an M.S. and PhD in mechanical engineering from Purdue University.

GERSHON MECKLER, Partner and Director of Engineering Design, Haines, Lundberg, Waehler, New York, New York. Mr. Meckler's work has focused on energy integrated design and cost analysis, and he has been issued more than 30 patents relating to building energy conservation and systems. He has served as a consulting engineer to the Owens-Corning Fiberglas/U.S. Steel Consortium for the General Services Administration's prototype building systems project and has been responsible for the design of the solar energy heating and cooling system for the U.S. National Fish Health Research Laboratory, the environmental system incorporating cogeneration for the Science Museum of Virginia, and the solar energy cooling and dehumidification system for the D.C. Veterans Hospital. Mr. Meckler currently is chairman of the Energy Conservation Committee of the Council on Tall Buildings and Urban Habitat, and the Solar Heating and Cooling Technical Committee of the International Solar Energy Society. He is a registered professional engineer and received a B.S. in engineering physics from the Pennsylvania State University.

RICHARD G. STEIN, FAIA, Principal, The Stein Partnership, New York, New York. Mr. Stein is an architect in private practice whose firm has become known for their architectural work, their planning studies, and their pioneering work in the energy field. His concern for building performance, satisfaction of clients' programmatic needs and economy both in construction and in operation has led to a deep interest in the relationship between buildings and energy use. Mr. Stein has been the recipient of many government and privately funded research grants to study energy use by the entire building industry. He is the author of the book Architecture and Energy, as well as numerous other articles and interviews in Science magazine, Newsweek, the AIA Journal, the Architectural Forum, Architectural Digest and others. His firm has received design awards and citations for schools, treatment centers, parks and recreation facilities. Mr. Stein is an adjunct professor at Cooper Union School of Architecture, a fellow of the American Institute of Architects and past president of the New York Chapter of the AIA, and served for two years as the Chairman of the New York State Board for Architecture. He holds a B.Arch from New York University, and a Masters degree from Harvard University.

JOHN ZEISEL, principal, Zeisel Research, Cambridge, Massachusetts. Dr. Zeisel is a sociologist focusing on communicating research information to designers and meeting special user needs. His areas of specialization include programming and evaluation of building projects, sociological research in design decision making, and making information useful in innovative design. His experience covers a broad range of building types, including offices, housing, hospitals and schools. Dr. Zeisel was a Loeb Fellow in Advanced Environmental Studies at Harvard University, and taught in the architecture department there as well as at Yale and McGill Universities. He is a member of the Environmental Design Research Association, the American Sociological Association, the American Institute of Architects Urban Design Committee, the American Association of Housing Educators, and serves on the Editorial Boards of Environment and Behavior and Housing and Society. He is the author of numerous articles and reports including Inquiry by Design: Tools for Environment-Behavior Research, a text used in architecture, sociology and psychology courses at colleges and universities throughout the United States and Canada. Dr. Zeisel holds a B.A. in chinese studies and a PhD in Sociology from Columbia University.

APPENDIX C: PARTICIPANTS IN ABBE WORKSHOP ON ENERGY CONSERVATION IN BUILDINGS AND COMMUNITY SYSTEMS
February 9 - 11, 1982

COMMITTEE CHAIRMAN: Richard C. Jordan, Professor and Associate Dean, Institute of Technology, University of Minnesota

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- Thomas Vonier, President
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<u>ABBE STAFF</u>

- John P. Eberhard, Executive Director, ABBE, Washington DC
- Joan D. Finch, Program Manager
- Delorse M. Thompson, Secretary

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- John Cable, Director, Building Systems Division, Department of Energy, Washington, DC
- Maxine Savitz, Deputy Assistant Secretary for Conservation, Office of Conservation and Solar Energy, Department of Energy, Washington, DC

<u>GUESTS</u>

- Mary Ann Eichenberger, The American Institute of Architects, Washington, DC
- James Frazier, Board on Toxicology & Environmental Health Hazards, National Academy of Sciences, Washington, DC
- Jerome Rothenburg, Program Manager, Building Technology Division, Department of Housing and Urban Development, Washington, DC