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The California Institute for Energy Efficiency

Multiyear Research Plan 1992-1996

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CIEE is a branch of the University of California's Universitywide Energy Research Group,
administered by Lawrence Berkeley Laboratory

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Executive Summary

The mission of the California Institute for Energy Efficiency (CIEE) is to coordinate, plan, and implement a statewide program of medium- to long-term (five to fifteen years) applied research aimed at advancing the energy efficiency and productivity of all end-use sectors in California.

The focus of CIEE's multiyear research and development (R&D) program is to benefit California's ratepayers within the context of the state's energy, environmental, and economic needs and priorities. This context includes the current research efforts of CIEE's sponsors, of significant national R&D organizations, and of industry. CIEE's 1992-1996 Multiyear Research Plan guides the Institute's research development, research management, and technology transfer efforts. The Plan briefly describes CIEE's current R&D program and introduces potential R&D initiatives that are responsive to California's unmet energy efficiency needs.

In 1992, CIEE is planning, funding, and managing \$5 million in multiyear research, exploratory research, Director's discretionary research, and technology transfer activities. The Institute's 1992 effort includes \$3.6 million in multiyear research conducted in the Building Energy Efficiency, Air Quality Impacts of Energy Efficiency, and End-Use Resource Planning programs and \$1 million in exploratory and Director's discretionary research.

During the period 1992 to 1996, CIEE will continue to conduct energy efficiency R&D that will secure sustainable, affordable energy for California while improving the state's economy and environment.

Introduction

CIEE's Background and Mission

CIEE was established in 1988 by the University of California (UC) in cooperation with California's electric and gas utilities, the California Public Utilities Commission (CPUC), the California Energy Commission (CEC), and the U.S. Department of Energy's (DOE's) Lawrence Berkeley Laboratory (LBL). CIEE's mission is to coordinate, plan, and implement a statewide program of medium- to long-term (five to fifteen years) applied research aimed at advancing the energy efficiency and productivity of all end-use sectors in California. This research, conducted primarily at colleges, universities, and university-affiliated research laboratories statewide, is designed to complement the research efforts of CIEE's sponsors and of other significant public and private research organizations.

CIEE's R&D has the following goals:

1. To identify, develop, and demonstrate efficient end-use energy technologies and processes that:
 - Increase the security and sustainability of energy systems in California.
 - Help assure continued access to reliable, affordable energy services for all California end-users.
 - Enhance the productivity and competitiveness of California's agricultural, manufacturing, and service industries.
 - Contribute to improving the environment, including regional air and water quality and the quality of the indoor built environment, while remaining sensitive to global-warming issues.
2. To improve the data and analytical tools related to the end-use of energy so that utilities and the public sector can make sound planning decisions on the balanced development of demand- and supply-side energy resources in California.

CIEE emphasizes collaboration in its multisponsor structure, multicampus approach to research, and commitment to translating successful energy efficiency R&D into practical products and processes. CIEE incorporates sponsor input into the design and management of its R&D programs, primarily through policy guidance from the CIEE Research

Board, program guidance from CIEE's Planning Committee, and ongoing technical input from Project Advisory Committees (PACs)¹ as part of research management.

CIEE's R&D approach emphasizes sponsor input throughout all phases of multiyear research planning and project selection, research management, and transfer of promising research results.

Role of the 1992-1996 Multiyear Research Plan

The Multiyear Research Plan is an important collaborative document prepared annually by the CIEE Director, reviewed by the Planning Committee, and approved by the Research Board. California's energy, environmental, and economic goals provide the context for CIEE's research efforts and its Multiyear Research Plan. The Plan is a "road map" for project management, project development, and technology transfer efforts in support of CIEE's multiyear research objectives. Approval of the Research Plan authorizes CIEE to conduct the research activities specified for the period 1992 through 1996.

The Research Plan is updated annually with input from CIEE sponsors, DOE, the Electric Power Research Institute (EPRI), the Gas Research Institute (GRI), other national and state R&D organizations, industry, government, professional organizations, the CIEE Advisory Committee, the Universitywide Energy Research Group (UERG) Intercampus Advisory Committee (IAC), and other interested researchers. The Plan identifies and prioritizes overall directions for end-use research, program-level research objectives and strategies, and research activities to be pursued over a three- to five-year period. The Research Plan briefly describes the current R&D program and its projected development over the planning period. The Plan also identifies potential new R&D initiatives that are responsive to California's unmet energy efficiency needs.²

¹PACs comprise sponsor and occasionally other R&D organization representatives, who participate in research management by defining research directions and reviewing and disseminating research project results.

²CIEE's Annual Report describes the progress and accomplishments of CIEE's current multiyear, exploratory, Director's discretionary, and technology transfer activities.

Section 1: CIEE's Organizational, R&D, and Planning Structures

CIEE's Organizational Structure

CIEE is a research unit of UC administered by LBL, a DOE national laboratory operated by UC. CIEE is also a branch of UERG, UC's systemwide energy research unit.

CIEE's Director and staff manage the planning, research, development, contracting, oversight, evaluation, and dissemination activities that make up the Institute's R&D program. The CIEE Director reports to the Director of LBL through the Director of the Energy and Environment Division. Attachment A identifies the CIEE Director and staff; Figure 1-1 illustrates CIEE's organizational structure. (For a detailed discussion of CIEE's organizational chart and the responsibilities of CIEE's Director, Research Board, and Planning Committee, refer to the CIEE Management Plan.)

CIEE Research Board

The Research Board consists of voting and nonvoting members who guide the CIEE R&D program and approve funding for research efforts. Research Board members are appointed by LBL's Director. Voting members include senior management from each utility sponsor, a CPUC Commissioner, a CEC Commissioner, and a representative of the UC Office of the President. Other nonvoting members include CIEE's previous Acting Director and representatives of EPRI, GRI, and the California Utility Research Council (CURC). The CIEE Director is a nonvoting member of the Research Board. CIEE's Executive Committee comprises CIEE's Director and the Chairperson and Vice Chairperson of the Research Board. Attachment B lists current Research Board members.

CIEE Planning Committee

CIEE's Planning Committee consists of staff representatives from each organization on the Research Board. Planning Committee members are appointed by the CIEE Director. The Planning Committee provides program guidance and technical input to CIEE's Director and the Research Board. Attachment C lists current Planning Committee members.

CIEE Advisory Committee

LBL's Director appoints the CIEE Advisory Committee, made up of the Director of the Energy and Environment Division (currently the Advisory Committee's Chairperson), the Director of UERG, and a representative of the UC Office of the President. The Advisory Committee participates in setting CIEE's goals to ensure adherence to broader LBL and UC operating practices. It also participates in evaluating the effectiveness of

CIEE's research program. Attachment D lists current CIEE Advisory Committee members.

UERG Intercampus Advisory Committee

The UERG IAC is appointed by the UC President and consists of representatives from the UC campuses and national laboratories. CIEE keeps the IAC informed of the overall goals and objectives of its R&D program.³ Attachment E lists current members of this committee.

CIEE's R&D Structure

CIEE's R&D approach emphasizes sponsor input throughout three phases: multiyear planning and project selection, using a systems approach to developing new energy-efficient end-use technologies;⁴ research management; and transfer of promising research results.⁵ CIEE's R&D program is designed to respond to California's specific energy, environmental, and economic objectives and needs and to complement the research efforts of sponsors, DOE, EPRI, GRI, and other public- and private-sector organizations. Attachment F analyzes California's past, present, and future energy use and the R&D, building-standard, and demand-side management (DSM) opportunities for tapping the state's energy efficiency potential.

In 1992, CIEE is planning, funding, and managing \$5 million in energy efficiency research.⁶ The following criteria are used to plan, develop, and select multiyear, exploratory, and Director's discretionary research projects:

- The potential for significant energy, environmental, and economic benefits for California ratepayers and consumers.
- Technical and engineering feasibility.
- The potential for making an original scientific or technical R&D contribution or for significantly enhancing R&D efforts conducted by other research organizations.
- The likelihood that promising results will be used by CIEE sponsors, other research organizations, the building industry, equipment manufacturers, and other industry professionals.
- Compatibility with and/or continuation of existing CIEE programs.

³IAC reviews CIEE as part of its annual review of UERG, as described further in the CIEE Management Plan.

⁴For example, while manufacturers of a new residential cooling technology might be interested in optimizing its technical and cost-performance characteristics, CIEE, in the Alternatives to Compressor Cooling in Transition Climates project, would use a systems approach to evaluate the best combinations of building envelope properties, building thermal mass, building and window shading, building controls, and end-use cooling and dehumidification equipment.

⁵In planning its multiyear research program, CIEE considers the following to be potential "R&D products": system design specifications; components and integrated systems; performance data for applied components and systems; commissioning procedures; performance monitoring and other techniques that enhance long-term operating performance; technology transfer activities to encourage adoption by industry and utilities; and technology performance data and analytical tools for industry, resource planners, and policymakers.

⁶CIEE seeks cofunding from organizations that have a special interest in planning, managing, and using the research results of particular research projects.

CIEE's 1992 R&D effort comprises multiyear research, exploratory research, Director's discretionary research, and technology transfer activities. Multiyear research is conducted in the Building Energy Efficiency, Air Quality Impacts of Energy Efficiency, and End-Use Resource Planning programs. Figure 1-2 depicts CIEE's programmatic structure; Figures 1-3 and 1-4 illustrate CIEE's program, topic, project, subproject, and "scoping" components in more detail.

Multiyear Research

CIEE's multiyear research is based on an analysis of California's past, present, and future energy use and on an evaluation of opportunities for tapping California's energy efficiency potential by supporting building standards, R&D, and DSM programs (details are presented in Attachment F).

Programs

CIEE plans, funds, and manages multiyear research in three programs:

Building Energy Efficiency (BEE)

The BEE program focuses on energy-efficient end-use technologies that can reduce the cost of providing energy services in buildings while maintaining healthy, safe, and productive indoor environments.

Air Quality Impacts of Energy Efficiency (AQI)

The AQI program focuses on new energy-efficient end-use technologies that result in air quality benefits, improved energy efficiency, and/or reduced emissions.

End-Use Resource Planning (ERP)

The ERP program focuses on developing data and models for use in integrated resource planning and on developing new techniques and technologies for measuring and monitoring the load shapes, energy savings, and persistence of savings from energy-efficient end-use measures.

Topics

Research subjects that are important to CIEE's sponsors are referred to as *topics*. Topics are generally agreed upon during the Multiyear Research Plan review and approval process, although topics can be introduced by the Research Board or CIEE throughout the year (refer to Section 6). In the period 1992 to 1996, CIEE will develop, fund, and manage future phases of existing multiyear research projects within the following topics.

In the BEE program:

- Integrated Lighting Systems
- HVAC Distribution Systems
- Commercial Cooling Systems
- Residential Cooling Systems

- Building Commissioning, Operations, and Maintenance
- Improved Building HVAC Controls

In the AQI program:

- Alternative Transportation Systems
- Gas Combustion Systems
- Emission Reduction Strategies

In the ERP program:

- Technology Performance Analysis
- Advanced Forecasting Methods

CIEE will also initiate new projects and conduct scoping activities within topics that interest its sponsors. In Sections 2, 3, and 4, multiyear projects and projects under development are grouped by topic.

Focused Multiyear Research Projects

Focused R&D projects, which generally last three years, receive most of CIEE's funds. CIEE typically allocates \$300,000 to \$500,000 per year to each multiyear project. Based on the Director's recommendations and technical input from the Planning Committee, the Research Board approved funding for eight projects in the BEE, AQI, and ERP programs during 1990. In 1991, the Research Board approved funding for three additional projects and for continuing phases of ongoing multiyear projects according to the procedures outlined in Section 6.

The following multiyear projects are underway:

In the BEE program:

- Integrated Envelope and Lighting Technology to Reduce Electric Demand (topic: Integrated Lighting Systems), BEE.ILS.1
- Efficient Systems for Thermal Distribution (topic: HVAC Distribution Systems), BEE.HDS.1
- Thermal Energy Storage (topic: Commercial Cooling Systems), BEE.CCS.1
- Impact of Shade Trees and White Surfaces on Building Peak Loads and Cooling Energy Savings (topic: Residential Cooling Systems), BEE.RCS.1
- Alternatives to Compressor Cooling in Transition Climates (topic: Residential Cooling Systems), BEE.RCS.2

In the AQI program:

- Assessment of Natural Gas and Electric Vehicles (topic: Alternative Transportation Systems), AQI.ATS.1

- Formation of Nitrogen Oxides in Industrial Gas Burners (topic: Gas Combustion Systems), AQI.GCS.1
- Energy-Efficient, Low-NO_x and -CO Burners for Residential, Small Industrial, and Commercial Gas Appliances (topic: Gas Combustion Systems), AQI.GCS.2
- Analysis of Energy Efficiency and Air Quality (topic: Emission Reduction Strategies), AQI.ERS.1

In the ERP program:

- California Utility Database on Monitored Performance of Efficient End-Use Technologies (topic: Technology Performance Analysis), ERP.TPA.1
- Integrated Estimation of Load Shapes and End-Use Energy Intensities in Commercial and Residential Buildings (topic: Advanced Forecasting Methods), ERP.AFM.1

Additional information about the goals, objectives, and status of these projects is given in Sections 2, 3, and 4. The process CIEE uses to manage these projects and initiate new projects is described in Section 6.

Scoping Activities

Scoping activities examine the opportunities for supporting research that addresses California's energy efficiency needs. Scoping is also undertaken to identify an appropriate research role for CIEE in a given topic and to assess the relative benefits of alternate research directions. CIEE may subsequently develop and fund one or more research projects within a topic.

In 1992, CIEE is initiating scoping activities in five of the following eight topics and plans to expand scoping in the HVAC Distribution Systems, Residential Cooling Systems, Building Commissioning, Operations, and Maintenance, and Advanced Forecasting Methods topics (emphasizing performance measurement of building energy systems) in 1992 or 1993.

In the BEE program:

- Integrated Lighting Systems (emphasizing integrated lighting controls in existing commercial buildings)
- HVAC Distribution Systems (emphasizing residential ventilation impacts of improved duct distribution systems)
- Commercial Cooling Systems (emphasizing performance improvement for conventional chiller systems)
- Residential Cooling Systems (emphasizing the performance of compressor-based cooling systems near peak-load conditions)

- Building Commissioning, Operations, and Maintenance (emphasizing the operation and commissioning of building control systems)
- Improved Building HVAC Controls

In the ERP program:

- Technology Performance Analysis (emphasizing technology performance measurement)
- Advanced Forecasting Methods

The results of these activities may lead to the initiation of one or more multiyear research projects in 1992 or future years. Additional scoping studies may be initiated to explore energy efficiency opportunities identified during the implementation of existing projects. Section 6 describes this process.

Exploratory Research

Each year approximately ten (one-year) exploratory research projects are conducted with approximately \$500,000 to \$600,000 in funding. In 1991, ten exploratory projects received \$597,000 in funding. In 1990, eleven exploratory projects received \$525,000. Exploratory research projects are selected through a competitive process involving the solicitation and review of proposals, as described in Section 6. CIEE funds projects following Research Board approval of the Director's recommendations. Successful exploratory research projects may develop into multiyear research projects. Table 1-1 lists the current exploratory research projects; brief descriptions of these projects appear in Section 5. Information on the institutions and researchers conducting exploratory research appears in Attachment G. Attachment H contains the 1991 Solicitation of Exploratory Projects.

Director's Discretionary Research

Each year approximately \$100,000 in funding is approved by the Research Board to support R&D on promising energy-efficient end-use technologies or processes identified by the Director. The Research Board allocated \$100,000 to Director's discretionary research in 1992. Each Director's discretionary research project receives approximately \$25,000 in seed money for R&D. Projects that yield promising results may develop into exploratory, technology transfer, or multiyear research projects. The currently active Director's discretionary projects are described briefly in Attachment J.

Technology Transfer Activities

The principal objective of CIEE's technology transfer effort is to communicate the objectives, scope, and interim and final results of its R&D projects to potential users. The CIEE Research Board allocated \$200,000 to technology transfer activities in 1992.

The CIEE Director approves technology transfer activities on a continuing basis as needed to support CIEE's multiyear, exploratory, and Director's discretionary research. The principal technology transfer mechanisms are general information dissemination (including the *CIEE Research News*), an Annual Report, technical reports, workshops, and PAC activities. An annual R&D conference is another mechanism for disseminating the results of R&D projects to CIEE sponsors, industry, government, and other research organizations. In addition, a technology transfer component is built into each multiyear and exploratory research project.

CIEE's R&D Funding

Funding for CIEE's R&D program comprises contributions from California's electric and gas utilities. The California legislature designated that Petroleum Violation Escrow Account funds, administered by the CEC, be made available to CIEE in 1992. Table 1-2 summarizes the funding currently available from these sources.

Table 1-3 summarizes CIEE's expected allocation of available resources by year for 1992-1996 multiyear research, exploratory research, Director's discretionary research, and technology transfer activities.

CIEE's preliminary estimates show that sufficient resources are available in 1992 to fund future phases of existing multiyear focused research projects, the exploratory research program, the Director's discretionary research program, scoping activities within several new topics as discussed in Sections 2, 3, and 4, and technology transfer activities.

CIEE's R&D Planning

CIEE focuses on the development of new energy-efficient technologies and processes that are important to California because of state priorities, special climatic conditions, and other factors characteristic of California. CIEE plans its R&D program to complement the research efforts of its sponsors and other significant public and private research organizations and to address California-specific research needs that may not be adequately covered by national R&D agendas. Section 6 describes CIEE's program development and implementation strategies in detail.

CIEE conducts programmatic planning with support from the Planning Committee and guidance from the Research Board. The principal goal of CIEE's multiyear planning

process is to facilitate agreement between CIEE sponsors and staff on the objectives and funding of CIEE's R&D program given California's specific energy efficiency R&D needs and existing R&D programs. CIEE's cooperative planning process involves:

- Reviewing California's energy-efficient end-use technology needs in the context of future energy, environmental, and economic constraints and of current scientific/technical advances that create opportunities in energy efficiency R&D.
- Soliciting comments from its sponsors and other experts regarding the applicability of CIEE's R&D program to California's energy efficiency needs.
- Evaluating the progress and accomplishments of existing multiyear and exploratory projects.
- Assessing the potential benefits of initiating additional multiyear research projects.
- Identifying the potential benefits of scoping new topics.
- Reviewing and refining the goals of the exploratory research program.
- Preparing and distributing the Multiyear Research Plan for Research Board, Planning Committee, and other expert audience review and comment.
- Obtaining Research Board approval to proceed with 1992 research activities as described in the Multiyear Research Plan.

Table 1 - 1

CIEE Exploratory Projects

1991 Exploratory Projects

- E.91.01 Optimizing the Use of EMCS Technologies to Reduce Peak Loads and Energy Consumption in Non-Residential Buildings
- E.91.02 In-Field Investigation of Weatherization Instrumentation, Co-Heating, and Cost-Effectiveness Protocol for Mobile Homes in California
- E.91.03 Preparation of High-Strength, Low-Density Polymeric Insulation Material with Environmentally Sound Foaming Agent
- E.91.04 Improved Energy Efficiency for HVAC Systems via Advanced Process Control
- E.91.05 Reducing Environmental Impact and Energy Use Through Water Recycling and By-Product Recovery in Food Processing
- E.91.06 Comfort-Based Control Logics for Natural and Low-Energy Cooling Systems in California Residences
- E.91.07 Design of a Phase-II Study of Sick Building Syndrome
- E.91.08 Assessment of Peak Power Reduction Potential of Radiant Cooling Systems
- E.91.09 Spectrally Selective Glazings for Residential Retrofits
- E.91.10 Indoor Ozone Concentrations: Quantification of Mechanisms of Outdoor Concentration Attenuation

Currently Active 1990 Exploratory Projects

- E.90.1 Low Heat Loss, Non-CFC-Based Appliance and Building Insulation
- E.90.2 An Assessment of Residential Evaporative Cooling Technologies in California
- E.90.3 High-Albedo Materials for Reducing Building Cooling Energy Use
- E.90.7 Integrated Estimation of Commercial Load Shapes and Energy Use Intensities

Table 1-2**CIEE Funding
(1992 - 1996)**

Source of Funding	1992	1993	1994 (Dollars in thousands)	1995	1996
Sponsors					
LADWP	300	300	300	300	300
PG&E	1500	1500	1500	1500	1500
SDG&E	350	350	350	350	350
SCE	1000	1000	1000	1000	1000
SCG	600	600	600	600	600
SMUD	115	115	115	115	115
Subtotal	3865	3865	3865	3865	3865
Planned Carryover from 1991					
PVEA*	1000	—	—	—	—
LBL Cost Sharing	73				
Total Funding	5716	3865	3865	3865	3865

*Petroleum Violation Escrow Account funds administered by the CEC.

Table 1-3

**CIEE Five-Year Funding Plan
Expected Allocation of Available Funding Resources
(1992 - 1996)**

Program	1992	1993	1994	1995	1996
(Dollars in thousands)					
Multiyear Research					
Building Energy Efficiency	1750	1010	1010	1010	1010
Air Quality Impacts of Energy Efficiency	1125	685	685	685	685
End-Use Resource Planning	700	350	350	350	350
Subtotal	3575	2045	2045	2045	2045
Exploratory Projects	660	600	600	600	600
Director's Discretionary Funds	190	100	100	100	100
Contracting Services	110	110	110	110	110
Subtotal	4535	2855	2855	2855	2855
Technology Transfer	265	200	200	200	200
CIEE Operations*	916	810	810	810	810
Total Projected Allocation	5716	3865	3865	3865	3865

*Estimated expenditures include staffing, travel, and other overhead costs required to plan, develop, and manage R&D and technology transfer program.

Figure 1-1
CIEE Organization Chart

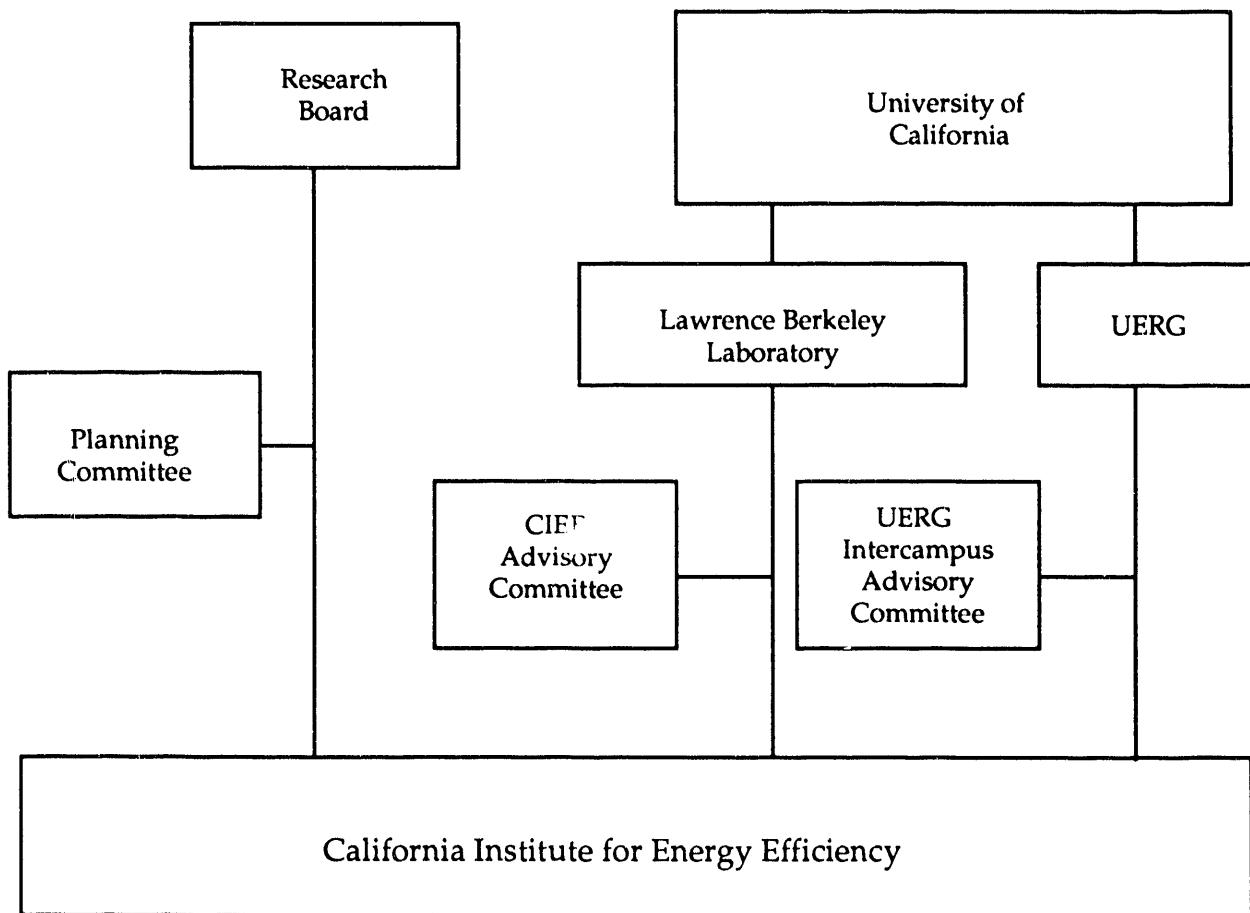


Figure 1-2

CIEE's R&D Program Structure

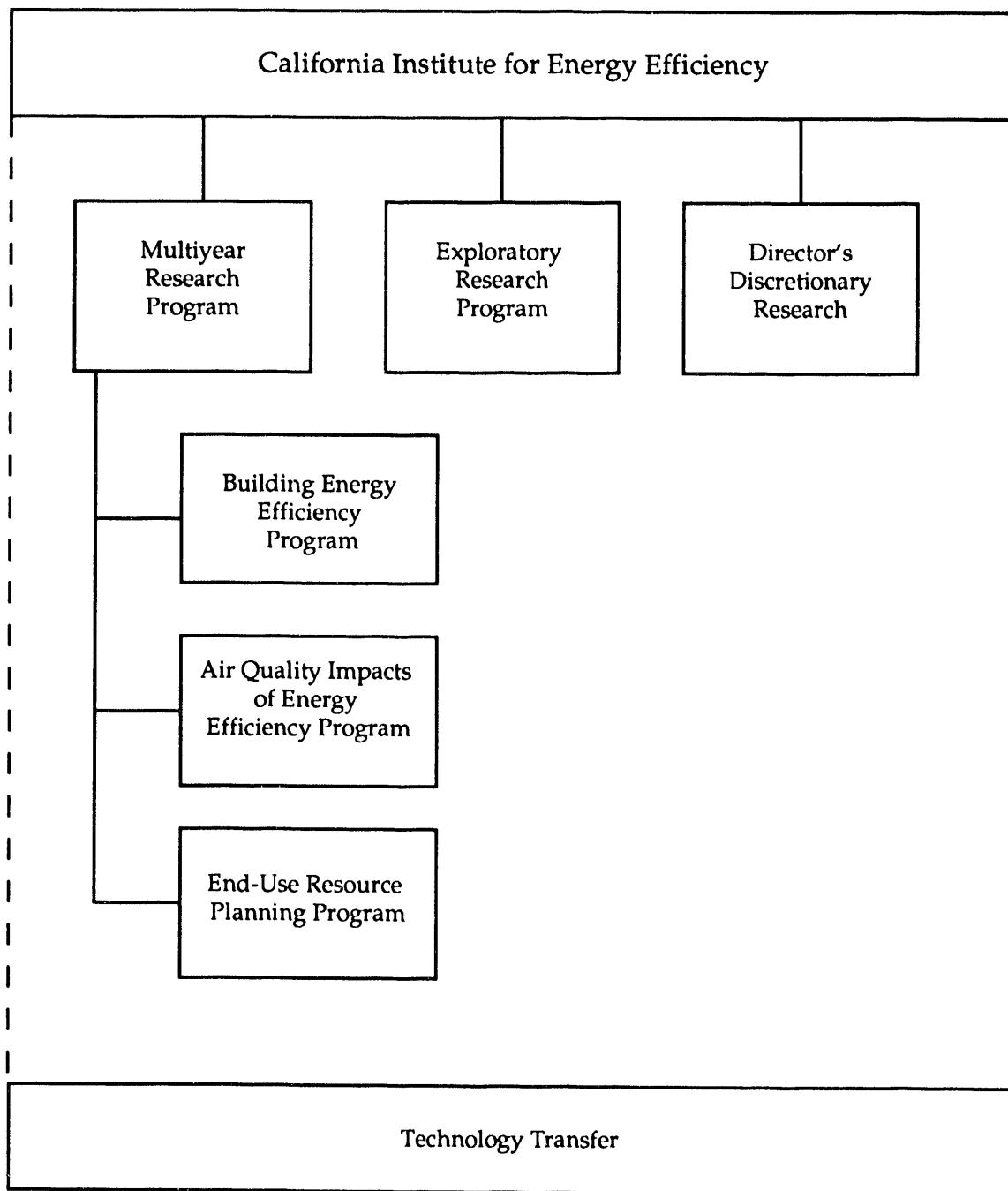


Figure 1-3
Multiyear Research Structure

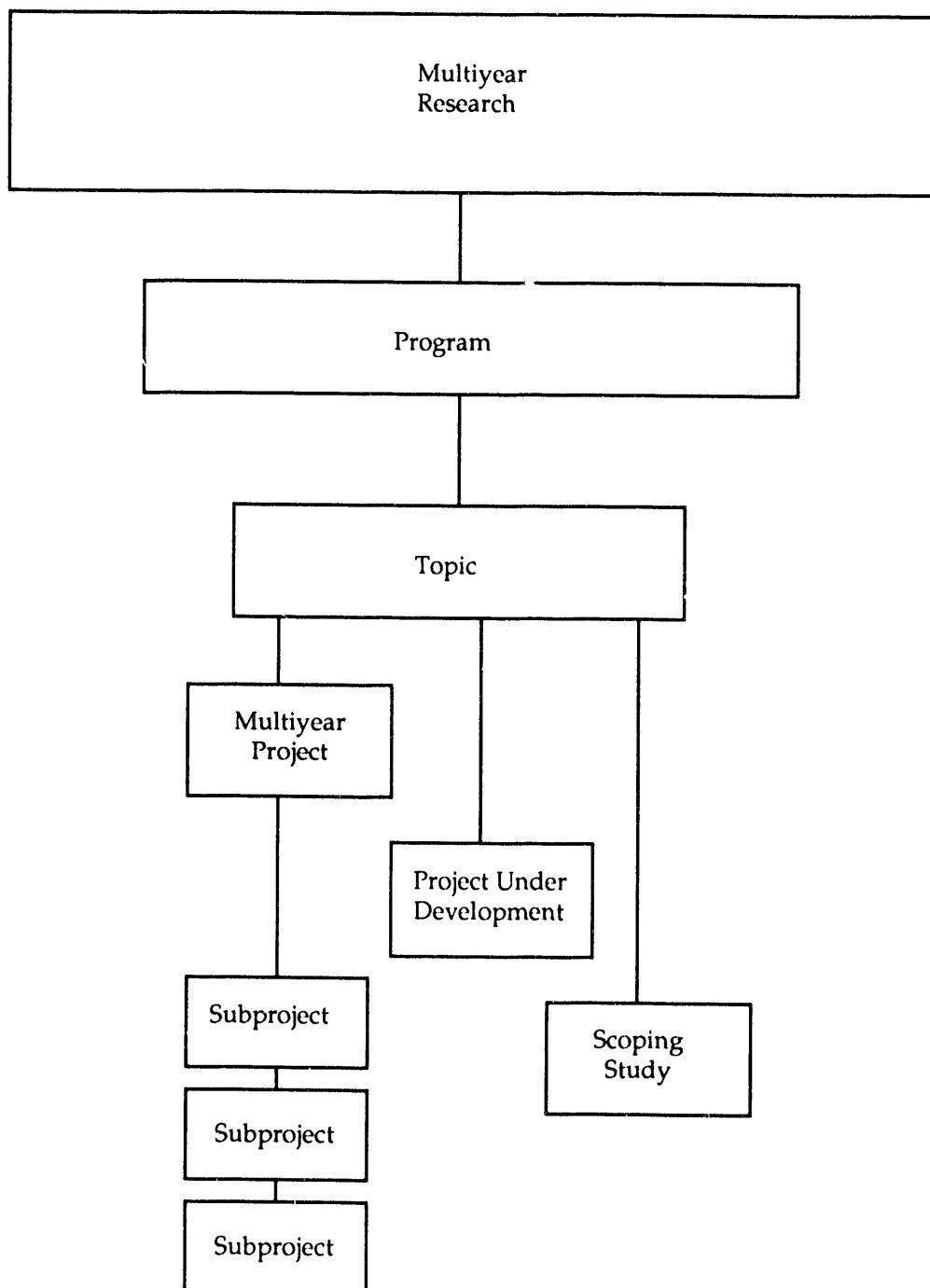
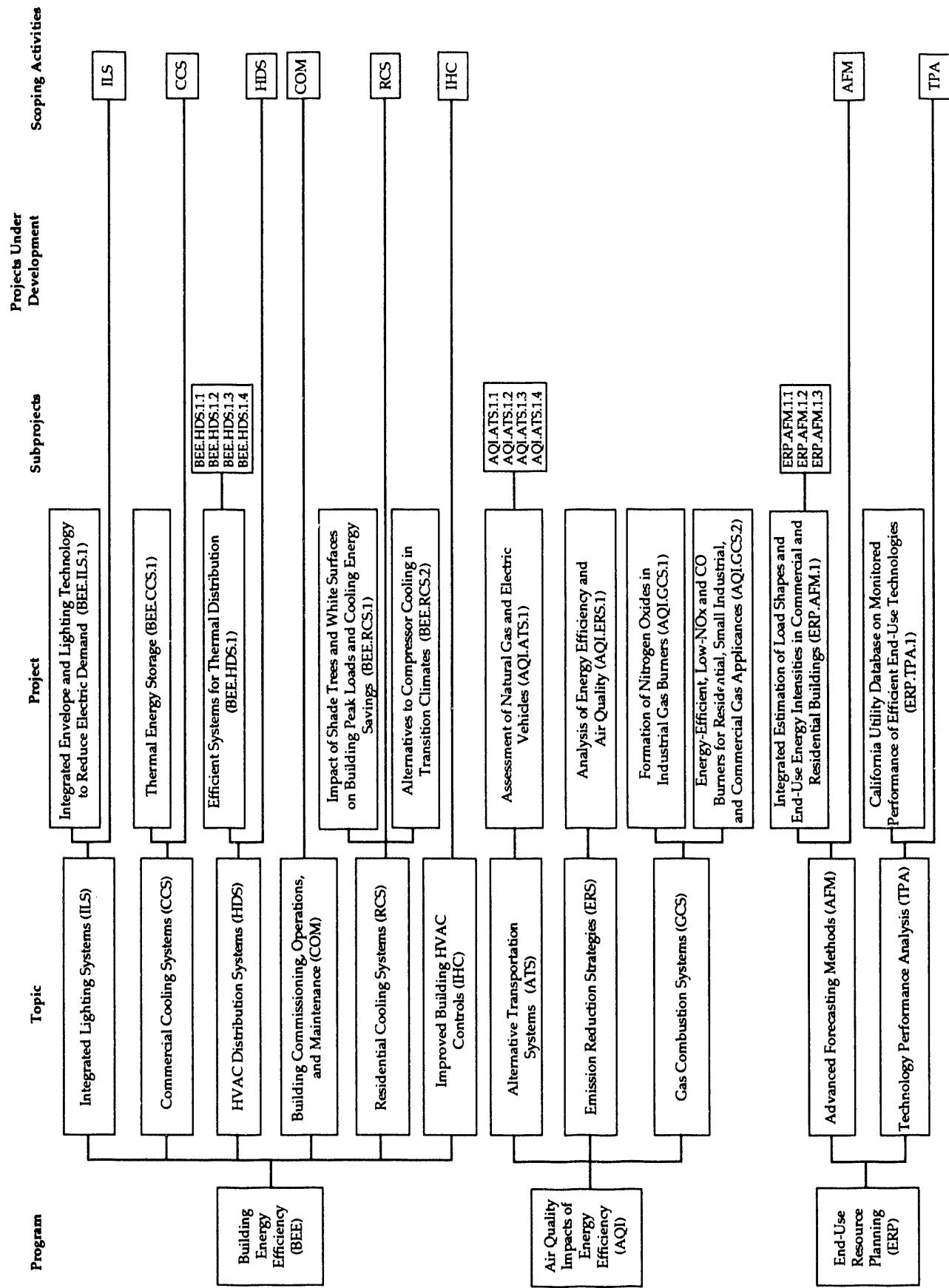


Figure 1-4 CIEE Multiyear Research



Section 2: CIEE's Building Energy Efficiency (BEE) Program

The purpose of CIEE's BEE program is to conduct research into the efficient end-use of energy in California's buildings and develop new technologies to improve that efficiency. This R&D is intended to benefit the California utility ratepayer by decreasing the cost of energy services or increasing the value of the services offered. The research will directly and indirectly enhance CIEE's mission by:

- Increasing the security and sustainability of energy systems
- Increasing the affordability of energy services
- Enhancing the productivity and competitiveness of the state's building industry
- Contributing to the improvement of environmental quality inside buildings
- Creating new energy services that benefit the ratepayer

In keeping with this overall purpose, CIEE's decision criteria (listed in Section 1) and a set of program goals provide a framework for assessing research proposals and the progress of existing projects. CIEE projects funded within the BEE program must demonstrably advance one or more of these goals:

- Improving building technologies and their application
- Improving the efficiency of existing buildings
- Assessing and improving building standards and practices
- Improving load-shape characteristics
- Providing a high-quality indoor environment

CIEE collaborated with the Planning Committee and Research Board in selecting the following topics for emphasis within the BEE program: Integrated Lighting Systems; HVAC Distribution Systems; Commercial Cooling Systems; Residential Cooling Systems; Building Commissioning, Operations, and Maintenance; and Improved Building HVAC Controls. A discussion follows of four multiyear projects initiated in 1990, one new multiyear project initiated in 1991, scoping activities already initiated in 1991 within three topics, and scoping activities to be conducted in 1992 and 1993 within three topics. Anticipated funding allocations by topic are shown in Table 2-1. Attachment I provides summary descriptions of current BEE multiyear projects, including project/subproject objectives, accomplishments of prior phases (if applicable), current phase activities, anticipated current phase products, project/subproject benefits and impacts, future directions, principal investigator and research organization, and funding.

Procedures for funding future phases of multiyear BEE projects and developing potential new BEE projects are described in Section 6. CIEE will base its future funding of existing projects on the results of previous phases and collaborative efforts to obtain cofunding support for future phases.

Topic:
Integrated Lighting Systems (ILS)

In commercial buildings in California, the two largest components of peak electric demand are lighting loads and cooling loads associated with solar and lighting heat gains. Direct electricity consumption by lighting accounts for approximately 40% of all electricity used in commercial buildings; cooling requirements (partially composed of lighting heat loads) account for approximately 20% of the commercial building electric total. This topic addresses issues surrounding the integration of energy-efficient lighting methods with other systems in commercial buildings. An ongoing project is investigating the potential for integrating envelope and lighting systems to reduce electric demand.

In 1992, CIEE plans to conduct scoping activities in this topic on the effective use of daylighting, lighting controls, and other related envelope technologies to minimize both electric lighting demand and cooling requirements caused by various lighting options in existing commercial office buildings.

Project: BEE.ILS.1

Integrated Envelope and Lighting Technology to Reduce Electric Demand

The long-term objective of this multiyear research project, led by LBL, is to accelerate the development and market penetration of integrated wall/lighting systems in new commercial buildings and new lighting systems in existing buildings. These systems could reduce net energy and power consumption significantly while improving occupant comfort and productivity.

The project's first-phase (1990-1992) tasks, conducted by LBL and the University of California at Los Angeles (UCLA), include the potential impact and establishment of performance targets for lighting and envelope systems, review of promising technologies, identification of opportunities for and obstacles to integration of envelope/lighting systems, and development of a monitoring plan for post-occupancy building performance evaluations. Additional tasks consist of initial planning for short-term demonstration projects and identification of opportunities for mid- and long-term demonstration projects.

Proposed second-phase (1992-1993) objectives are to continue the design and development of integrated envelope and lighting configurations based on available component technology. These configurations will include architectural solutions (light shelves, for example) and new hardware (such as improved photocell controls). Methods that encourage market adoption of cost-effective technologies will also be developed. Design, construction, and field tests are proposed for the second and third phases of the project. Future phases are anticipated to emphasize control technologies and include both new and existing buildings.

First-phase (1990-1992) CIEE funding for this project was \$425,000. The second phase (1992-1993) is under development pending the results of the first phase, with funding levels to be established.

Topic:
HVAC Distribution Systems (HDS)

Improving the efficiency with which heating, ventilating, and air conditioning (HVAC) services are delivered within buildings will significantly improve overall building energy efficiency and reduce commercial and residential building energy demand. This topic includes the characterization and optimization of air distribution and other systems.

Results of the first phase's research on residential air distribution systems have indicated that a substantial portion of home ventilation is inadvertently caused by duct systems. Since this kind of ventilation is very energy intensive, CIEE intends to scope the issue of residential ventilation within this research topic.

Project: BEE.HDS.1
Efficient Systems for Thermal Distribution

Improving the efficiency of thermal distribution in residential and commercial buildings could significantly reduce energy demand and costs. The goal of this project, conducted at LBL and the University of California at Berkeley (UCB) and Santa Barbara (UCSB), is to evaluate promising technologies and methods for improving thermal distribution efficiency.

The project's first-phase (1990-1991) accomplishments included:

- Completion of a 31-house field study to characterize residential air distribution performance and development of a simulation tool that can accurately account for the distribution-system inefficiencies and interactions with houses.
- Measurement of the ventilation and thermal comfort performance of two localized thermal distribution systems for office buildings within a controlled environment chamber, development of an experimental plan and site selection for field monitoring of these systems, and completion of a preliminary simulation-based analysis of the energy implications of various localized thermal distribution options.
- Measurement and visualization of the room air motion associated with a commercially available diffuser developed for cold-air distribution (CoAD) for office buildings, and development and testing of a two-dimensional air-flow simulation code for spaces cooled with various diffusers and temperatures, including direct cold-air injection.

- Completion of a feasibility study of the use of drag-reducing additives in hydronic heating and cooling systems in commercial buildings. This includes review of the characteristics of drag-reducing additives and analysis of the corresponding hardware and operational characteristics of typical hydronic distribution systems.

Current-phase objectives include:

- Laboratory testing of an internal-access sealing technology for residential air-distribution systems, evaluating the savings potential of various residential distribution system options by means of the simulation tool and monitoring results, extending modeling and monitoring capabilities to houses with zone conditioning, and developing a detailed retrofit protocol.
- Performing additional experimentation on the performance of Localized Thermal Distribution (LTD) systems in a controlled environment chamber and in actual office installations, developing design and operating recommendations for LTD systems, and developing improved energy-modeling capabilities for LTD systems.
- Assessing the relevance and importance of CoAD to California commercial buildings by industry surveys and computer simulations, analyzing the experimental data that has been collected on an actual diffuser, and further developing the simulation model for predicting occupant comfort in zones cooled with CoAD.
- Experimentally examining the performance of drag-reducing additives for hydronic distribution systems, including the dynamic response to degradation and reconstitution of the additives, and heat-transfer measurements to determine the effect of drag reduction on the thermal performance of heat exchangers.

Future-phase objectives include:

- Completing development and field testing of internal access sealing technology, developing and testing high-performance air-distribution systems for new construction, developing and testing alternative thermal distribution systems for residences, and transferring research results into new-construction standards, utility DSM programs, and building codes.
- Extending single-family thermal distribution expertise to small commercial buildings.
- Developing an applications and engineering guide for LTD systems, providing information on the changes needed to incorporate the systems into building codes and standards, and conducting an LTD and CoAD technology transfer workshop.
- Completing the experimental and design work needed to support widespread dissemination of drag-reducing additives for commercial-building hydronic systems and the development of specific design recommendations based on the drag-reduction research conducted.

- Evaluating the actual performance of the various thermal distribution systems installed or being contemplated for installation in commercial buildings as well as the design processes and energy-analysis tools for these systems.

CIEE's first-phase (1990-1991) funding for this project was \$425,000; its second-phase (1991-1992) funding was \$603,000. Selected tasks of the first and second phases of this program were also cofunded by DOE. The third phase (1992-1993) is under development, with CIEE funding and sponsor cofunding levels to be established.

Topic:
Commercial Cooling Systems (CCS)

Electric demand for air conditioning in commercial buildings contributes significantly to California utility peak loads. This topic includes alternative methods for cooling commercial buildings. An ongoing project is investigating the potential for commissioning procedures to improve performance of thermal energy storage (TES) systems. This project is evaluating TES field performance and assessing operational characteristics of conventional cooling systems.

In 1991, CIEE initiated scoping activities in this topic to emphasize the evaluation of opportunities for improving the performance of conventional commercial cooling systems (including chillers). This effort was prompted in part by opportunities identified through the evaluation of field performance and operation of conventional chillers, performed in conjunction with current TES research. The resulting research agenda will be based on CIEE's evaluation of its sponsors' needs as well as a review of existing technology and current research programs. CIEE plans to complete scoping activities in 1992, with research to be initiated in 1993.

Project: BEE.CCS.1
Thermal Energy Storage

Several field performance evaluations have shown that cold storage systems, installed by large commercial customers in cooperation with California utilities, are not reducing peak electric loads as well as anticipated.

The overall objective of this multiphase project, led by San Diego State University's Energy Engineering Institute, is to develop diagnostics, acceptance, and start-up verification procedures for commercial TES systems to enhance their field performance and reliability. Start-up verification is a major component of building commissioning.

The project's first-phase (1990-1991) accomplishments included:

- Organization of a workshop fostering the exchange of information on TES problems and solutions among various TES industry groups.
- Development of case studies examining existing TES facilities.
- Preliminary work on diagnostic, acceptance, and start-up verification procedures (including performance tests).
- Preliminary analysis of TES and conventional cooling system field data.

Second-phase (1992-1993) objectives include:

- Additional analysis of TES and conventional cooling system field data.
- Completion of prototype diagnostic, acceptance, and start-up verification procedures (including performance tests).
- Validation of performance tests and other commissioning procedures through field tests and associated case studies.

First-phase (1990-1991) CIEE funding was \$245,000. Second-phase (1992-1993) CIEE funding is anticipated to be \$100,000 to \$150,000, based on the number of field verification sites and associated cofunding of site costs by utilities. Future efforts will be determined in the context of scoping activities for the CCS topic area.

**Topic:
Residential Cooling Systems (RCS)**

The high cost of supplying electricity to meet the cooling requirements of California's residential sector could be significantly reduced if the effectiveness of residential cooling systems were improved, particularly during periods of peak demand. This topic examines a variety of methods for reducing residential cooling loads.

In 1990, CIEE initiated research on the potential impact of shade trees and white surfaces as a strategy to reduce cooling load. In 1991, CIEE developed a new multiyear research program directed at developing alternatives to compressor-based cooling systems in California's transition climates. The techniques developed in this program may also assist CIEE sponsors in downsizing compressor-based cooling systems in other California climate zones.

The results of a CIEE-funded exploratory project (see Section 5) funded in 1990, An Assessment of Residential Evaporative Cooling Technologies in California, indicated that evaporative cooling may potentially be a cost-effective energy efficiency strategy in residential and small commercial buildings. CIEE will factor the results of this effort into the Alternatives to Compressor Cooling in Transition Climates project and coordinate with its sponsors in deciding whether further follow-on efforts are appropriate.

In 1992, CIEE intends to conduct scoping activities in this topic. The results of the first phase of the Peak Power and Cooling Energy Savings of Shade Trees and White Surfaces project, along with discussions with several utilities, have indicated that residential, compressor-based cooling systems' performance near peak-load conditions is not well understood. Since various energy-saving strategies may be accentuating peak-demand problems, CIEE intends to evaluate research needs and opportunities for mitigating these impacts and implementing the most cost-effective strategies.

Project: BEE.RCS.1

Peak Power and Cooling Energy Savings of Shade Trees and White Surfaces

The objectives of this two-phase project, conducted at LBL, are to:

- Assess the effectiveness of various building surfaces and shade trees in reducing air conditioning energy use.
- Measure their effectiveness at selected residential, commercial, and public buildings.
- Refine and validate performance prediction algorithms.

CIEE and the Sacramento Municipal Utility District (SMUD) cofunded the first phase (1990-1992) of this project; CIEE provided \$40,000 and SMUD provided \$160,000. The second phase (1992-1993) is under development, with CIEE funding and sponsor cofunding levels to be established.

Project BEE.RCS.2

Alternatives to Compressor Cooling in Transition Climates

The overall goal of this multiphase effort is to demonstrate the feasibility of building residential structures that can maintain indoor comfort without the use of compressor air conditioning in California transition climate zones. The resulting low-energy cooling technologies and techniques may also help CIEE sponsors develop building designs that allow substantially downsized compressor systems for California's hot summer climate zones.

This project will investigate and develop alternatives to compressor-based cooling in transition climates with the objective of introducing residential buildings using low-energy systems and designs into the marketplace. R&D on promising new technologies and building engineering practices is anticipated to meet that goal. First-phase (1992-1993) tasks include:

- Development of working definitions for transition climates, prototypical buildings, and operating scenarios.
- Preliminary assessment of low-energy cooling technologies for residential buildings.

- Establishment of acceptable indoor comfort and health conditions related to evaluation of alternative cooling strategies.
- Experimental investigation of the effectiveness of night storage through ventilation or evaporative cooling.
- Development of an analytical procedure to account for the impact of air movement on convective heat transfer within a building in conjunction with hourly whole-building energy simulations.
- Improvement and validation of evaporative cooler models, with emphasis on part-load efficiency, water usage, and fan power consumption.
- Identification and evaluation of institutional and consumer barriers to alternative low-energy cooling strategies.
- Identification and development of integrated ventilation control strategies appropriate to transition climates, including control algorithms.
- Evaluation of the architectural implications of alternative low-energy cooling strategies, including window shading, ventilative and evaporative cooling, and passive thermal storage.

Future-phase objectives include:

- Production of building designs and control strategies that can meet performance requirements without radically altering current construction practices.
- Collaboration with builders, utilities, and local governments to build and monitor residential buildings using developed designs and control strategies.

First-phase (1992-1993) CIEE funding is \$375,500.

**Topic:
Building Commissioning, Operations, and Maintenance (COM)**

New buildings seldom perform over the long term to their design specifications, and certain types of retrofits to existing buildings may not deliver anticipated persistence of savings. Research subtopics being explored by CIEE include:

- Determining the causes of shortfall in building performance at the system and sub-system levels during each phase of the building's initial and retrofit design, construction, operation, and maintenance.
- Developing new building design, commissioning, operating, and maintenance practices.

- Developing performance monitoring and data analysis techniques that improve measurement and persistence of savings.

In 1991, CIEE initiated scoping activities to assess the operation and performance of existing building control systems, with an emphasis on commissioning as a possible solution to identified problems.

CIEE initiated additional scoping activities in 1991 to assess the potential of using new metering, communications, end-use equipment monitoring, data analysis, and energy management and control systems (EMCSs) to measure the kW and kWh savings derived from implementing various energy efficiency technologies (such as lighting, HVAC systems, efficient motors and adjustable-speed drives, and HVAC controls). CIEE is exploring the potential for collaboration with its sponsors in developing and testing new performance measurement technologies as part of ongoing energy efficiency retrofit and new-construction programs.

CIEE will coordinate R&D activities in this topic with related efforts in the Improved Building HVAC Controls (IHC) and Technology Performance Analysis (TPA) topics in the ERP program, discussed in Section 4.

Topic:

Improved Building HVAC Controls (IHC)

Evidence indicates that building EMCSs often do not perform effectively; there also appears to be a significant potential to improve their impact on energy efficiency. Improving EMCS performance at the system and subsystem levels could result in substantial energy use reduction and customer savings.

In 1992, CIEE initiated a Director's discretionary project to assess the field performance of EMCSs and evaluate the role of commissioning and other operational practices in improving energy efficiency performance and persistence of savings (see Attachment J for a description of the project).

CIEE will initiate a scoping study in 1992 to assess R&D needs and opportunities for improving the energy efficiency of major building HVAC subsystems controlled by EMCSs.

Table 2-1

**Building Energy Efficiency (BEE) Program
Expected Allocation of Available Funding by Topic
(1992 - 1996)**

Topic		1992	1993	1994	1995	1996
(Dollars in thousands)						
Integrated Lighting Systems		250	200	200	200	200
BEE.ILS.1	Integrated Envelope and Lighting Technology To Reduce Electric Demand		650	200	200	200
HVAC Distribution Systems			350	250	250	250
BEE.HDS.1	Efficient Systems for Thermal Distribution			450	250	250
Commercial Cooling Systems					250	250
BEE.CCS.1	Thermal Energy Storage					250
Residential Cooling Systems						250
BEE.RCS.1	Peak Power and Cooling Energy Savings of Shade Trees and White Surfaces					250
BEE.RCS.2	Alternatives to Compressor Cooling in California Transition Climates					250
New R&D Topics *		50	110	110	110	110
Program Total		1750	1010	1010	1010	1010

*Funding shown in this row may be used to scope COM and IHC topics or to expand funding of existing topics.

Section 3: CIEE's Air Quality Impacts of Energy Efficiency (AQI) Program

The purpose of the AQI program is to identify, develop, test, demonstrate, and evaluate energy-efficient end-use technologies and strategies that can contribute to the cost-effective improvement of air quality in California's urban and rural areas. Research in this program contributes to CIEE's mission by:

- Increasing the security and sustainability of energy systems
- Increasing the affordability of energy services
- Enhancing the productivity and competitiveness of California's industry and commercial services
- Improving air quality

The following program goals, along with CIEE's decision criteria (listed in Section 1), provide a framework for assessing research proposals and R&D progress. Projects funded within this program must demonstrably advance one or more of these goals:

- Identify and develop energy-efficient end-use technologies and processes that directly reduce transportation-related emissions and indirectly reduce the emissions from power plant fossil-fuel combustion by minimizing electric demand.
- Improve combustion technologies for end-use equipment to optimize energy efficiency and reduce pollutant emissions.
- Assess the impact of end-use energy technologies on pollutant emissions and air quality and the impact of air quality control measures on energy use and load shapes.
- Establish the potential for electricity DSM to meet resource needs associated with electrification as one element of an air quality management strategy.
- Extend the concepts of least-cost energy planning to air quality planning, incorporating air quality benefits into energy planning, regulatory, and policy decisions.
- Evaluate real-time-of-use DSM (for both electricity and gas) as a control strategy for air quality "episodes" and for periods of utility system peak demand.

CIEE collaborated with the Planning Committee and Research Board in selecting the following topics for emphasis within the AQI program: Alternative Transportation Systems (ATS), Gas Combustion Systems (GCS), and Emission Reduction Strategies (ERS). A discussion follows of two multiyear projects originally approved in 1990 and of two additional multiyear projects approved in 1991. Anticipated funding allocations by topic are shown in Table 3-1. Attachment I provides summary descriptions of current AQI multiyear projects, including project/subproject objectives, accomplishments of

prior phases (if applicable), current phase activities, current phase products, project/subproject benefits and impacts, future directions, principal investigator and research organization, and funding.

Procedures for funding future phases of existing multiyear AQI projects and for developing potential multiyear AQI projects are described in Section 6. CIEE will base future funding of existing multiyear projects on the results of previous phases and collaborative efforts to obtain cofunding support for future phases.

**Topic:
Alternative Transportation Systems (ATS)**

The introduction of clean-burning alternative transportation energy is a key feature of future strategies to meet ambient air quality standards in California and significantly reduce greenhouse gas emissions and petroleum imports. This topic focuses on electricity and natural gas, two of the most effective and practical alternative transportation fuels for achieving these goals in the near and medium term in California.

Project: AQI.ATS.1

Assessment of Natural Gas and Electric Vehicles

The overall objective of this three-year project, conducted by the University of California at Davis (UCD) in cooperation with the University of Southern California (USC), is to evaluate the potential impact and market acceptance of electricity- and natural-gas-powered transportation technologies for improving California's air quality.

This research project comprises four subprojects: household market potential of electric vehicles (EVs) and natural-gas vehicles (NGVs), fleet market potential of EVs and NGVs, economic incentives to introduce EVs and NGVs, and utility impacts of EVs in Southern California. The second project is new; the others are continuing projects.

The research had the following first-phase (1990-1991) objectives:

- Assessing the consumer market potential of EVs and NGVs in the Los Angeles region.
- Developing marketing incentives to introduce EVs and NGVs and reduce mobile source emissions.
- Analyzing the impact on the utility systems operated by Southern California Edison (SCE) of wide-scale implementation of EVs.

Second- and third-phase objectives include:

- Identifying the early markets for EVs and NGVs and determining the response of individuals and fleets to various incentives and economic and technological conditions.
- Forecasting the market penetration of EVs and NGVs.
- Designing and evaluating regulatory programs that target vehicle and energy suppliers and that use economic incentives for introducing EVs and NGVs in California.
- Evaluating the impact on utilities of the large-scale use of EVs.

First-phase (1990-1991) CIEE funding for this project was \$286,000. Second-phase (1992-1993) CIEE funding will be \$400,000.

**Topic:
Gas Combustion Systems (GCS)**

California air basins are negatively affected by nitrogen oxide (NO_x) emissions generated by a wide variety of combustion sources, including automobiles, boilers, stationary gas turbines, and water and space heating for commercial, industrial, and residential end-use. This topic aims to improve our understanding of how NO_x is formed in practical gas-fired systems within industrial and residential combustion systems.

**Project: AQI.GCS.1
Formation of Nitrogen Oxides in Industrial Gas Burners**

This three-year project is being conducted by the University of California at Irvine (UCI) in cooperation with Lawrence Livermore National Laboratory (LLNL) and Sandia National Laboratory (SNL). The Energy and Environmental Research Corp. is also participating in this project. The objective is to develop and demonstrate criteria for the design and operation of energy-efficient, ultra-low- NO_x industrial natural-gas-fired burners. Research products will include:

- An improved understanding of the process of fuel-air mixing in natural-gas burners.
- Design protocol for efficient, ultra-low- NO_x industrial burners.
- An advanced diagnostic tool for measuring nitric oxide (NO) and nitrogen dioxide (NO_2).
- Design databases for manufacturers.
- Advanced analytical design tools combining combustion kinetics with fluid mechanics.

- An active operating control methodology for maintaining ultra-low-NO_x and high-efficiency performance.

Initial first-phase (1991-1992) CIEE funding is \$376,000, with cofunding of \$100,000 provided by Southern California Gas (SCG) through CIEE. Second-phase (1992-1993) CIEE funding is anticipated to be \$376,000, with \$100,000 in cofunding provided by SCG through CIEE.

Project: AQI.GCS.2

Energy-Efficient, Low-NO_x and -CO Burners for Residential, Commercial, and Small Industrial Gas Appliances

Existing and new energy-efficient natural-gas appliances produce various types of NO_x emissions that play critical roles in photochemical smog formation, particularly in the South Coast Air Basin (SoCAB). The South Coast Air Quality Management District (SCAQMD) is considering more stringent emissions requirements for residential water heaters. While the formation mechanisms of NO are well-known, the formation and destruction of other nitrogen oxides are not; the interaction of chemical kinetics, fluid mechanics, and heat transfers hides the fundamental formation processes. Furthermore, undesirable products such as carbon monoxide (CO) appear in greater concentrations due to the reduced reaction rates and increased incomplete combustion associated with lower temperatures. Consequently, the theoretical and experimental base for designing energy-efficient appliances with very low emissions is lacking.

A two-phase research project led by UCB and LBL has the following objectives:

- Investigating the physical and chemical processes controlling the formation of CO and NO_x in natural-gas appliances.
- Creating analytical models for minimizing pollutant emissions in appliance design and operation.
- Transferring research results to appliance manufacturers.

First-phase (1992-1993) CIEE funding is \$350,000.

**Topic:
Emission Reduction Strategies (ERS)**

To improve air quality and assess the full benefits of end-use energy efficiency, it is important to develop improved quantitative models and data for assessing the relationships among end-use energy efficiency, pollutant emissions, and resultant air quality. This multiphase project will investigate the direct and indirect effects of end-use efficiency on the reduction of photochemical smog in the SoCAB.

Project: AQI.ERS.1
Analysis of Energy Efficiency and Air Quality

The overall objective of this research is to improve the ability of current air quality management models to analyze the smog-mitigation role of energy efficiency measures aimed at residential, commercial, and industrial buildings. Although the buildings sector contributes an average of only 14% of the annual SoCAB emissions, preliminary analyses indicate that measures intended to reduce building cooling load, such as planting trees and whitening surfaces, may significantly reduce smog-forming temperatures in the lower troposphere. Results of the project will allow policymakers and regulators to better address the relationship between energy efficiency improvements and air quality.

This research will be conducted by LBL in conjunction with UCLA. Systems Applications International will assist with parts of the project. First-phase (1991-1992) objectives include:

- Review of current calculation procedures used by the Air Resources Board (ARB) and SCAQMD to calculate fuel combustion emissions.
- Initial evaluation of how end-use efficiency changes and temperature affect emissions.
- Initial establishment of preliminary databases of the spatial characteristics of emissions and relevant surface parameters. Both anthropogenic and biogenic inputs will be used. Effects of temperature on biogenic emissions will be described.
- Development of a reliable parametric model that allows land-type data to be converted to surface heat fluxes for use in the meteorological modeling effort.
- Adaptation of a mesoscale meteorological model for interface with urban airshed modeling of the SoCAB to evaluate how end-use efficiency changes affect smog formation.
- Preliminary model implementation, including sensitivity analyses and assessment of air-flow effects from surface modifications.
- Initial investigation of the pollutant-trapping effectiveness of trees.

Future-phase objectives include:

- Refinement of emission and surface characteristic databases.
- Assessment of spatial, physical, and other constraints on tree planting, including evaluation of water use and fire hazards.
- Assessment of the pollutant-trapping effectiveness of various tree species.

- Testing of the hypothesis that wide-scale tree-planting efforts and increased surface albedo can contribute significantly to reducing photochemical smog as well as decreasing energy use.

First-phase (1991-1992) CIEE funding is \$230,000.

Table 3-1

**Air Quality Impacts of Energy Efficiency (AQI) Program
Expected Allocation of Available Funding by Topic
(1992 - 1996)**

Topic	1992	1993	1994	1995	1996
(Dollars in thousands)					
Alternative Transportation Systems (ATS)	400	—	185	185	185
AQI.ATS.1 Assessment of Natural Gas and Electric Vehicles					
Gas Combustion Systems (GCS)	400	685	400	400	400
AQI.GCS.1 Formation of Nitrogen Oxides in Industrial Gas Burners					
AQI.GCS.2 Energy-Efficient, Low-N ₂ O _x and -CO Burners for Residential, Commercial, and Small Industrial Gas Appliances					
Emission Reduction Strategies (ERS)	325	—	100	100	100
AQI.ERS.1 Analysis of Energy Efficiency and Air Quality					
Program Total	1125	685	685	685	685

Section 4: CIEE's End-Use Resource Planning (ERP) Program

The purpose of the ERP program is to research the measurement and quantification of energy and load-shape impacts, reliability, life-cycle costs, environmental emissions, and other impacts that result from consumer implementation of energy-efficient end-use technologies and other efficiency measures. Research in this program contributes to CIEE's mission by:

- Improving the ability of CIEE sponsors to determine the energy, load-shape, and environmental impacts of energy efficiency measures and to plan for the long-term acquisition of supply and DSM resources.
- Increasing the security and sustainability of energy systems.
- Increasing the affordability of energy services.
- Enhancing the productivity and competitiveness of California's industry and commercial services.

The following program goals, along with CIEE's decision criteria (listed in Section 1), provide a framework for assessing research proposals and R&D progress. Projects funded within this program must demonstrably advance one or both of these goals:

- To develop data and models that can be used for effective, integrated resource planning and forecasting by California utilities, the CEC, and other energy and environmental policymakers.
- To improve the ability of utilities to determine the energy and demand impacts that result from customer adoption of energy-efficient technologies.

ERP program research will be coordinated with the BEE and AQI programs because of the interrelated nature of the research in these areas.

CIEE collaborated with the Planning Committee and Research Board in selecting the Technology Performance Analysis (TPA) and Advanced Forecasting Methods (AFM) topics for emphasis within the ERP program. A discussion follows of two multiyear projects originally approved in 1990, TPA scoping conducted in 1991, and AFM scoping planned for 1992. Anticipated funding allocations by topic are shown in Table 4-1. Attachment I provides summary descriptions of current ERP multiyear projects, including project/subproject objectives, accomplishments of prior phases (if applicable), current phase activities, current phase products, project/subproject benefits and impacts, future directions, principal investigator and research organization, and funding.

Procedures for funding future phases of existing multiyear ERP projects and for developing potential new multiyear ERP projects are described in Section 6. CIEE will base its future funding of existing multiyear projects on the results of previous phases and collaborative efforts to obtain cofunding support for future phases.

Topic:

Technology Performance Analysis (TPA)

Improving the accessibility and usefulness of information on the measured performance of efficient end-use technologies will in turn improve building technologies and their application and, therefore, improve the efficiency of existing and new buildings. Improved performance data and measurement techniques will enhance end-use resource planning and contribute to the implementation of more effective DSM programs. The objectives of this topic are to:

- Improve the availability, quality, and value of monitored data on the initial and long-term persistence of kW and kWh savings from implementing energy efficiency measures.
- Develop new performance monitoring and data analysis techniques and models for accomplishing the first objective.

A 1991 CIEE scoping study on this topic identified opportunities for advancing the state of the art in DSM impact measurement techniques. In addition, a technical assessment of end-use metering technology was conducted. In 1992, CIEE initiated a scoping study on the related topics of Building Commissioning, Operations, and Maintenance and Improved Building HVAC Controls, as described in Section 2. In 1992, CIEE will evaluate the results of these scoping efforts and plan expanded multiyear research in one or more of these topics.

Project: ERP.TPA.1

California Utility Database on Monitored Performance of Efficient End-Use Technologies

The overall goal of this project, to be conducted by LBL, is to assess the value and accessibility of utility-generated monitored data and technical evaluations concerning end-use energy efficiency. The feasibility of establishing a database of the identified technical reports will be evaluated. The project will also assess the needs of utility personnel for monitored data. First-phase objectives include:

- Identification and location of reports and the staff responsible for them, followed by assessment and prioritization of the most valuable collections of reports.

- Review of reports from the most prominent collections, focusing on building sector reports, most recent information, and information on emerging technologies.
- Creation of an initial database that constitutes the framework for establishing a comprehensive and continuously updated version.
- Evaluation of the potential for further use of this approach to obtaining monitored end-use technology data.

First-phase (1992) CIEE funding is \$100,000. Future-phase funding will depend on the success of the first phase and an assessment of the viability of this approach.

**Topic:
Advanced Forecasting Methods (AFM)**

New models that incorporate the latest end-use energy data need to be developed to improve the ability of utilities and regulatory agencies to forecast energy use and peak demand. This topic includes the development, testing, and refinement of advanced methods of analyzing and forecasting changes in energy use.

In 1992, CIEE plans to conduct scoping of research needs to improve its sponsors' ability to forecast energy use and evaluate how energy efficiency and other DSM technologies can contribute to least-cost planning and meeting environmental goals.

Project: ERP.AFM.1

Integrated Estimation of Load Shapes and End-Use Energy Intensities in Commercial and Residential Buildings

The objective of this project is to develop methods for estimating end-use electric load shapes and energy utilization intensities (EUIs) and for developing, testing, and refining advanced methods of analyzing and forecasting changes in energy use in the commercial and residential sectors. Since forecasters and planners at California's electric utilities and the CEC will be the primary users of the project results, they will be involved in research planning and supervision.

CIEE's work in this area began in 1989 with support from the CEC and was pursued in 1990 with a CIEE exploratory project and support from SCE. This multi-year project, led by researchers at LBL, was initiated in 1991 with support from Pacific Gas and Electric (PG&E). First-phase (1991-1992) accomplishments include development of a new technique for extrapolating additional values from metered data for residential air conditioners, development of a spreadsheet model for forecasting the energy use of office equipment, and estimation of end-use load shapes and EUIs for four of the twelve commercial building types used by the CEC and PG&E for forecasting. Second-phase activities will extend

this work by comparing the residential load shapes developed for PG&E and the CEC with those used in EPRI's HELM model, enhancing the office equipment model, and estimating load shapes and EUIs for the remaining commercial building types.

First-phase (1991-1992) CIEE funding of \$193,000 was provided by PG&E. Funding of future phases is contingent on additional cofunding support by CIEE sponsors, including the CEC.

Table 4-1

**End-Use Resource Planning (ERP) Program
Expected Allocation of Available Funding by Topic
(1992 - 1996)**

Topic	1992	1993	1994	1995	1996
Technology Performance Analysis					
ERP.TPA.1	650	300	300	300	300
Advanced Forecasting Methods					
ERP.AFM.1	50	50	50	50	50
Program Total	700	350	350	350	350

Section 5: CIEE's Exploratory Program

CIEE conducts \$50,000-\$60,000 one-year exploratory research projects on a wide range of energy efficiency topics. Projects are selected by CIEE based on a review of proposals submitted in response to a competitive solicitation. Attachment H contains the 1991 Solicitation for Exploratory Projects. CIEE anticipates issuing the 1992 solicitation in August of 1992.

The principal goal of the exploratory research program is to develop new energy-efficient end-use technologies and evaluate their potential impact in practical end-use applications. Promising exploratory research results may be integrated into existing CIEE multiyear research projects or may stimulate the initiation of new multiyear projects. Sponsor R&D may also be influenced by the results of CIEE exploratory research. In limited cases, CIEE may also fund future phases of promising exploratory projects within this exploratory program. Increasing the energy efficiency research capability at California research institutions is another important secondary goal of CIEE's exploratory program.

CIEE provided \$597,000 in funding for 1990 exploratory projects and \$600,000 for 1991 exploratory projects. The exploratory projects funded in 1991 are briefly summarized in the following paragraphs, as are the currently active exploratory projects funded in 1990. A limited number of promising technologies researched in the 1990 exploratory program are being considered for further exploratory program funding during this planning period.

1991 Exploratory Projects Underway

Project: E.91.01

Optimizing the Use of EMCS Technologies to Reduce Peak Loads and Energy Consumption in Non-Residential Buildings

This research, conducted at California State University (CSU) Sacramento, focuses on developing a simulation-based adaptive control methodology for night precooling of building thermal mass. The effort will include an initial field-test evaluation in a large classroom building. Questions surrounding the potential effectiveness of precooling strategies in peak-load reduction will be addressed. Other objectives are to evaluate simulation models' accuracy in predicting building thermal performance, assess the applicability of EMCS technology in reducing peak load, and examine the effectiveness of adaptive control strategies based on concise mathematical models.

Project: E.91.02**In-Field Investigation of Weatherization Instrumentation, Co-Heating, and Cost-Effectiveness Protocol for Mobile Homes in California**

This project, being conducted at CSU Chico, will obtain data on the effectiveness of weatherization efforts for mobile homes in California's various climate zones. Evaluation of the costs and benefits of weatherization efforts will include an assessment of the cost-effectiveness of standard diagnostic and analysis techniques. Emphasis will be placed on determining the best measures or combinations of measures for different climates. Practical issues surrounding implementation of those measures will also be a focus of this research.

Project: E.91.03**Preparation of High-Strength, Low-Density Polymeric Insulation Material with Environmentally Sound Foaming Agent**

This research will investigate a promising alternative to chlorofluorocarbon-(CFC-) based methods for making foam insulation. The project, conducted at UCB, will evaluate the technical and economic feasibility of using high-temperature-stable polymers such as polyetherimide and polyether sulfone to produce a non-CFC-based foam insulation with good mechanical performance, reduced weight, and other desirable properties.

Project: E.91.04**Improved Energy Efficiency for HVAC Systems via Advanced Process Control**

Contemporary HVAC control systems for large buildings include digital computers potentially capable of monitoring large numbers of process variables and evaluating control system performance. However, typical HVAC applications perform only basic control calculations and simple diagnostic checks. This research, conducted at UCSB, will investigate control strategies that could allow realization of the potential for computer-based control systems in energy management. The prototype HVAC control strategy to be developed in this research project will improve monitoring of control system performance and fault detection by integrating physically based knowledge, statistical quality control, and on-line updating of process models.

Project: E.91.05**Reducing Environmental Impact and Energy Use Through Water Recycling and By-Product Recovery in Food Processing**

The objective of this research project, conducted at UCD, is a comprehensive accounting study of water use and associated energy use in the California food industry with respect to quantity, quality, and thermal energy content of influent and effluent streams. An economic analysis will be conducted to evaluate the feasibility of using membrane systems in selected food processing plants.

Project: E.91.06**Comfort-Based Control Logics for Natural and Low-Energy Cooling Systems in California Residences**

This project, conducted at California State Polytechnic University Pomona, will assess the major issues in control and operation of natural ventilation and evaporative cooling systems to minimize energy use while maintaining occupant comfort. Computer modeling (DOE-2) with modifications adopting various control logics will be used to determine energy impacts and comfort conditions in residences. Limitations in typical control technologies and interactions between users and control technology will be investigated.

Project: E.91.07**Design of a Phase-II Study of Sick Building Syndrome**

An improved understanding of the causes of Sick Building Syndrome (SBS) is needed to develop energy-efficient solutions to this important problem. This research, conducted at LBL, will use existing data and incorporate current research findings to develop an interdisciplinary approach to the study of SBS. It will develop hypotheses related to factors recently reported to correlate with SBS, including pollutant generation in ventilation systems, dust of biologic origin, specific microbiological organisms, high-surface-area materials, and quality of ventilation system maintenance and building cleaning. Methods for testing these hypotheses will be developed and evaluated.

Project: E.91.08**Assessment of Peak Power Reduction Potential of Radiant Cooling Systems**

The goal of this project, conducted at LBL, is to assess the application of radiant cooling systems as a peak-load-reducing, energy-efficient alternative to conventional air conditioning in California. These systems are typically characterized by hydronic thermal distribution with radiative and convective heat transfer to the air and space enclosures. Ventilation is provided by separate systems designed to meet outside air requirements without energy-intensive air recirculation. This project will include review of radiant cooling systems available in the U.S. and Europe, estimation of typical cooling loads and peak power savings potential for different climate zones, and development of control strategies.

Project: E.91.09**Spectrally Selective Glazings for Residential Retrofits**

This research, also conducted at LBL, will assess the potential for developing spectrally selective glazings for residential retrofit applications. The project will evaluate potential energy savings; identify applications for commercializing existing, partially selective glazings; and define obstacles to the direct

production of durable, highly selective glazings. A database of existing and emerging technologies will be created.

Project: E.91.10

Indoor Ozone Concentrations: Quantification of Mechanisms of Outdoor Concentration Attenuation

Indoor ozone concentrations are critical determinants of human ozone exposure. This project, conducted at LBL, will improve quantitative understanding of the relationship between building factors and indoor/outdoor ozone concentration ratios and of the energy implications of indoor ozone mitigation strategies. Such an understanding can serve as a foundation for reducing human ozone exposures in a manner consistent with energy efficiency objectives.

Currently Active 1990 Exploratory Projects

Project: E.90.1

Low-Heat-Loss, Non-CFC-Based Appliance and Building Insulation

A new high-performance, non-CFC-based insulating material potentially suitable for use in refrigerator/freezers and building walls is being developed and tested using an infrared video imaging system (provided by DOE). Finite-element heat-transfer modeling is a technique used to analyze the thermal characteristics of specific alternative design concepts. Thermal performance results are being communicated to key appliance manufacturers with the intent of securing industry support for a major development and testing program.

CIEE is coordinating with its sponsors in deciding whether additional CIEE funding is needed to develop this promising technology and demonstrate its cost-effectiveness and market acceptance. This project is being conducted at LBL.

Project: E.90.2

An Assessment of Residential Evaporative Cooling Technologies in California

The overall goal of this project, conducted at LBL, is to evaluate the major issues affecting wide-scale implementation of evaporative cooling as an alternative to conventional air conditioning in single-family residences. Technical and economic analysis of various types of evaporative cooler designs (direct and indirect) is being conducted for residential buildings in sixteen California climate zones. Factors related to American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and state Building Energy Efficiency Standards (Title 24) are being examined. Potential barriers to the wider implementation of evaporative cooling are also being evaluated.

In some California climate zones, CIEE will factor the results of this project into the Alternatives to Compressor Cooling in California Climates multiyear project. It will also coordinate with its sponsors in deciding whether additional follow-up activities are appropriate and whether additional CIEE funding is needed to assess and develop the potential of this technology.

Project: E.90.3

High-Albedo Materials for Reducing Building Cooling Energy Use

One mechanism for reducing building cooling loads and urban heat island impacts is to use light-colored surfaces—such as building rooftops and walls, streets, and parking lots—to reflect incident solar radiation. This project, conducted at LBL, is assessing the ability of existing methods and materials to increase the reflectance of these surfaces. An array of alternatives for each surface are being identified, the cost-effectiveness of each option determined, and possible technical, maintenance, and environmental problems assessed. The effects of surface weathering on reflectance properties and building energy consumption are also being analyzed. CIEE is integrating the results of this project into the projects being conducted under the Residential Cooling Systems research topic.

Project: E.90.7

Integrated Estimation of Commercial Load Shapes and Energy Use Intensities

The objectives of this project are:

- To develop an analytical model to estimate commercial-sector load shapes and EUIs using a combination of whole-building load research data, engineering audit-level data on individual premises, and mail survey data for several commercial buildings. This approach was initially developed through funding provided by the CEC and SCE in 1988.
- To validate the accuracy of this technique using commercial building end-use metering data provided by SCE and PG&E.

This exploratory project is a major component of the Integrated Estimation of Load Shapes and End-Use Energy Intensities in Commercial and Residential Buildings (ERP.AFM.1) multiyear project, which is summarized in Section 4 and discussed in more detail in Attachment I.

Section 6: CIEE's R&D Program Implementation Process

This section outlines the procedures used to implement CIEE's R&D program. The Multiyear Research Plan, updated annually, provides the framework for this process.

Multiyear Research Projects

Multiyear research projects are selected, developed, and approved for funding through the collaborative efforts of CIEE, the Planning Committee, and the Research Board. Project results are disseminated widely, as described in "Technology Transfer" later in this section.

A summary of the processes for implementing new multiyear projects and launching future phases of existing multiyear projects follows. Research Board approval of the Multiyear Research Plan allows CIEE to develop future phases of existing multiyear projects beginning with step 5 below and to develop new multiyear research projects as described in steps 1 through 4.

New Multiyear Projects

Step 1: Identifying and Scoping Topics

As described in Section 1, the term *topics* refers to research subjects that are important to CIEE's sponsors. These topics are generally identified and agreed upon during the Multiyear Research Plan review and approval process, although topics can also be introduced by the Research Board or CIEE (see step 6) throughout the year. CIEE conducts scoping activities within topics that interest its sponsors to examine opportunities for future CIEE research (and possibly utility-sponsored research) that can significantly benefit ratepayers over a five- to fifteen-year period. Scoping is also undertaken to identify an appropriate research role for CIEE in a given topic and to clarify the potential benefits of alternate research directions.

By approving the Multiyear Research Plan, the Research Board authorizes CIEE's Director to use up to 10% of CIEE's total multiyear research budget (comprising the BEE, AQI, and ERP program budgets) for scoping topics identified in the Plan.

CIEE and the Planning Committee will review the results of scoping activities to determine the advisability of initiating multiyear or possibly exploratory

research projects at any time during the period covered by the Multiyear Research Plan. Performing a scoping study of a given topic in no way obligates CIEE to fund any subsequent research in that topic.

The initiation of a new multiyear focused research project is usually preceded by and based on the results of either a scoping study, a Director's discretionary project, an exploratory project, or another related multiyear research project.

Scoping may take many forms, depending on the topic. Typically, a scoping effort includes:

- Review of the state of the art within the topic
- Workshops
- CIEE staff discussions with the Planning Committee and other sponsor representatives
- CIEE staff discussions with potential cofunders
- Advice of the Research Board

The product of a scoping effort is an assessment of the research opportunities in the topic, including key research issues, the status of ongoing research on the topic, potential benefits and costs of various research options, and recommendations for CIEE (and possibly sponsor) R&D activities. All of these can contribute to the development of a Topical Research Plan (TRP) as described below.

Step 2: Preparation of a Topical Research Plan

CIEE develops a TRP based on the results of an existing exploratory, Director's discretionary, technology transfer, or multiyear research project, a scoping effort, or a project proposal.⁷ It is a summary of research objectives and goals for the topic, including proposed projects. The TRP's plan for initiating research includes the contracting approach,⁸ approximate funding levels, and duration of one or more projects.

CIEE begins preparing a TRP when the Director determines that sufficient resources are available to develop one or more new multiyear research projects. The Director considers staff commitments, funding requirements for existing multiyear projects, and budgetary targets for the three multiyear programs in assessing the availability of resources. In preparing the TRP, the Director will review the potential need, benefits, costs, and other factors associated with alternative research options.

A draft of the TRP is distributed to the Planning Committee for its review and comment. A final version of the TRP is prepared by CIEE staff based on Planning

⁷ Unsolicited proposals may be introduced into this process at any step, as determined by the Director. CIEE uses the criteria listed in Section 1 to evaluate unsolicited proposals.

⁸ The contracting approach will be coordinated with the appropriate LBL contracting office.

Committee comments and is approved by the Director. The Director then requests Research Board approval of the TRP.

Step 3: Project Development

Following Research Board approval, CIEE carries out the project development activities described in the TRP. Potential projects identified in the TRP are described as “under development.” In many instances, this project development process includes the preparation and issuance of a Program Opportunity Notice or other competitive solicitations. Following the review and ranking of proposals, CIEE may select one or more proposals as the basis for multiyear research projects, as specified in the TRP.

In other instances, the project development process may involve CIEE review of proposals (both solicited and unsolicited) submitted by researchers for significant expansion of existing CIEE exploratory, Director’s discretionary, and multiyear projects.

The final stage of step 3 is the Director’s approval of a memorandum prepared by the CIEE Project Manager recommending funding of specific proposals.

Step 4: Request for Planning Committee Comments

The Director will distribute this funding recommendation and the proposal(s) to Planning Committee members for comment. If the Planning Committee identifies major concerns, the Director shall decide what actions should be taken to address these concerns. These might include requesting appropriate modifications to the proposal(s) and arranging for special Planning Committee meetings to discuss the revisions.

The Director will consider Planning Committee comments on the draft recommendations, the TRP, and the final proposal(s) in deciding whether to seek Research Board or Executive Committee approval to fund the proposal(s) as described in the CIEE Management Plan.

Step 5: Contract Execution

After the Research Board or Executive Committee approves funding of a proposal, CIEE negotiates research agreements with the R&D organizations selected in step 4.

Existing Multiyear Projects

Step 6: Project Management and Technology Transfer

CIEE’s Director assigns a CIEE technical staff member as Project Manager. That person monitors the performance of the project’s Principal Investigator and team in meeting the objectives of each phase. CIEE usually establishes a PAC to provide technical guidance and assistance throughout the project. The Project Manager and Principal Investigator coordinate with the Planning Committee in

identifying appropriate sponsor representatives and other interested parties to constitute the PAC.

The Principal Investigator submits quarterly reports to the CIEE Project Manager and the PAC. These reports document the project's progress and interim results. The Principal Investigator submits a technical report describing the results of each project phase to the Project Manager and the PAC for review and comment. The Project Manager coordinates with CIEE's Director to evaluate the results of each phase and to decide on ways to disseminate these results to potentially interested parties.

During the management of research projects, CIEE may gain new insights into energy efficiency research opportunities. Following discussions with the Planning Committee, the Director may authorize scoping studies according to the process described in steps 1 through 4. The results of such scoping studies may spur the initiation of a new multiyear research project or the modification of an existing project.

Step 7: Contract Renewal Planning

As part of ongoing contract management responsibilities, the CIEE Project Manager will review a project's current phases with input from the PAC. When approximately 70% of the current project phase is completed, the Project Manager will prepare an updated TRP that identifies the key research and other issues that should be addressed in the next project phase. The Project Manager will consider the recommendations of the Principal Investigator(s) and the PAC when updating the TRP. The CIEE Director will approve the TRP.

The Director will request Planning Committee comments on the TRP and make the appropriate modifications. The Director will then submit the final TRP to the Board for approval.

Step 8: Selection of Proposals for Continuing Research

The CIEE Project Manager will guide those researchers who are preparing proposals for continuing research. This guidance will incorporate research progress, CIEE research priorities, funding limitations, potential cofunders, R&D opportunities, and Planning Committee and Research Board comments on the TRP. CIEE will review the proposals and may request further modifications to comply with the requirements of the TRP.

The Director will approve a memorandum recommending Research Board approval to fund one or more specific proposals. The Director shall distribute this recommendation and the proposal(s) to the Planning Committee for comment.

If the Planning Committee identifies major concerns, the Director will decide what actions should be taken to address these concerns. This might include

requesting appropriate modifications to the proposal(s) and arranging for special Planning Committee meetings to discuss revisions.

The Director will consider Planning Committee comments on the funding memorandum, the TRP, and the final proposal(s) in deciding whether to seek the approval of the Research Board or its Executive Committee to fund the proposal(s), as described in the CIEE Management Plan.

CIEE will contract for the continuing research phases approved by the Research Board (step 5). Steps 5 through 8 are repeated until the project is completed.

Exploratory Research Projects

The project selection process begins when CIEE issues a solicitation for proposals offering to fund proposals to develop new, efficient end-use energy technologies when appropriate and conduct a pilot-scale test that demonstrates their technical and commercial feasibility. As determined by the CIEE Director, the solicitation may highlight research topics of special interest to CIEE. The CIEE Director coordinates with the Planning Committee to select these research topics before finalizing the solicitation. UERG then conducts a peer review of acceptable proposals. Proposals that address the special topics and include cofunding by industry (and other energy efficiency developers) receive special consideration. Following the UERG-administered peer review, CIEE's Director determines the proposal rankings. The Director recommends the selection of approximately ten exploratory project proposals to the Research Board or the Executive Committee, as described in the CIEE Management Plan. The selection process ends with Director and Research Board approval.

CIEE then contracts with the proposing organizations and designates a CIEE staff person as Project Manager. That person is responsible for overseeing the efforts of the project's Principal Investigator. Research results are documented in a final report, which is distributed to interested parties following CIEE review and comment. The results of these exploratory projects are also presented at an annual R&D conference, as described in Section 1.

Solicitations for exploratory projects are issued every fall, and the final proposals are funded in the second quarter of the following year. Attachment H is the 1991 exploratory solicitation for the projects funded in 1992.

Director's Discretionary Projects

The CIEE Director initiates discretionary projects after reviewing letter proposals from researchers outlining a proposed scope of work, budget, and schedule. The projects are launched when the researchers inform the Director of promising ideas or as management and staff resources become available for developing projects of special interest to

CIEE. The results of discretionary projects are documented in letter reports that are reviewed by the Director and other interested parties and distributed to CIEE sponsors. The results of selected projects may also be presented at CIEE's annual R&D conference.

Technology Transfer

CIEE uses the majority of its technology transfer funding to communicate the results of CIEE-funded multiyear, exploratory, and Director's discretionary projects to its sponsors, industry, the research community, government, and other organizations. This includes the publication and distribution of reports, the preparation of special publications, and the conduct of workshops and conferences.

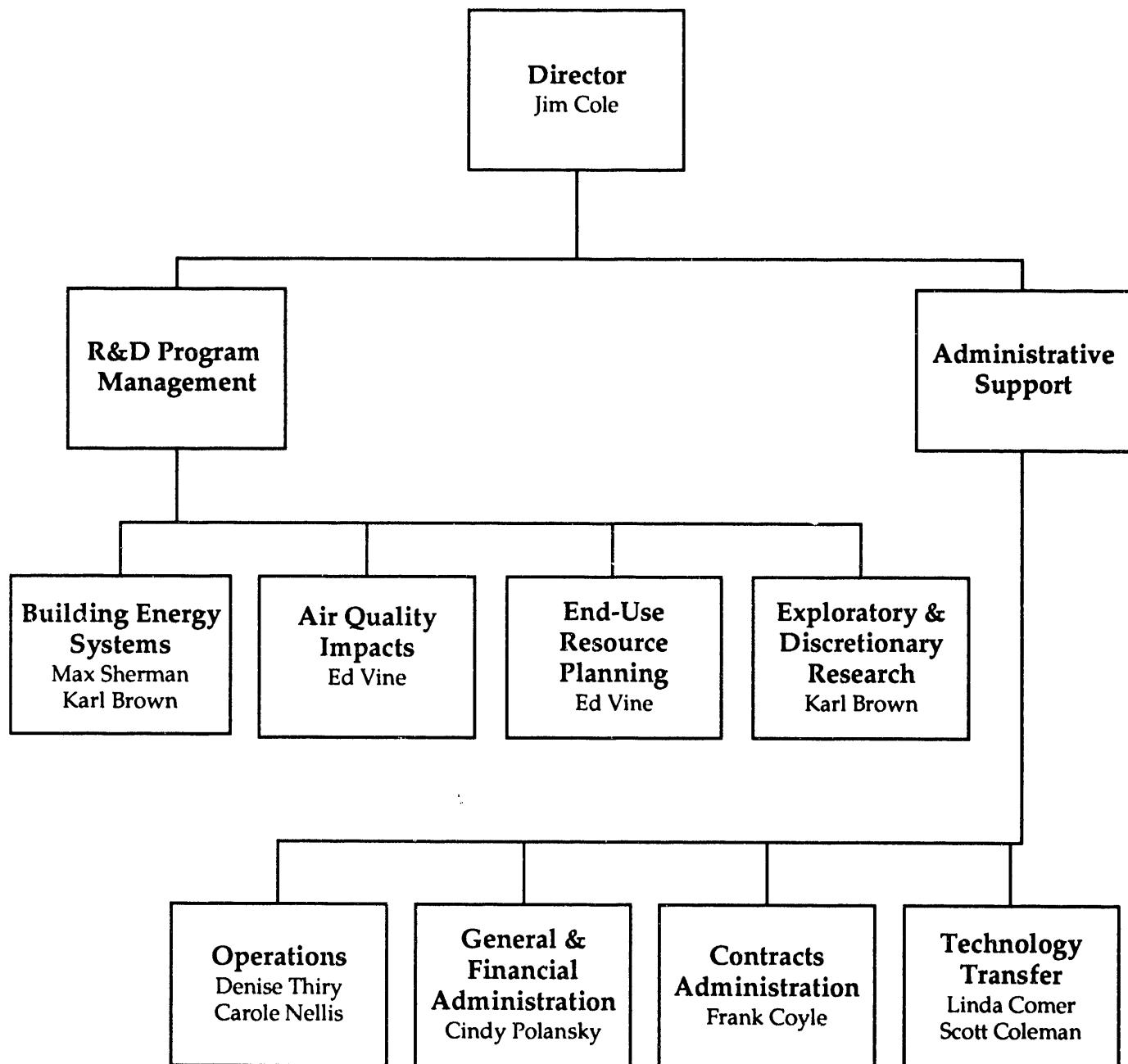
Attachment A

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Figure A-1

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Attachment F
CIEE's Planning Context

CIEE designs and conducts its multiyear R&D program in the context of California's energy, environmental, and economic goals. An annual review of the state's energy use and efficiency progress is conducted as part of the CIEE planning process leading to a finalized Multiyear Research Plan.

California's Energy Past

While California's population increased 33% from 1973 to 1987,¹ energy use per capita declined 15% (CEC 1990). Significant improvements in energy end-use efficiency during the past two decades resulted from efficiency improvements adopted in response to high energy prices, from California's Title 24 building standards, and from conservation programs conducted by utilities and by local and state governments. Measures of energy efficiency such as use per household, use per square foot of commercial floor space, use per constant dollar of industrial output, use per vehicle mile traveled (VMT), and use per gross state product show that energy efficiency improved by 20 to 30% in the decade following the first oil embargo. Californians saved nearly \$12 billion in annual energy costs, or approximately \$1,000 per year for each family, as shown in Figure F-1 (NRDC 1990). Since 1982, however, California's per capita energy use has been increasing.

California's Energy Present

The Role of Fossil Fuels

Figure F-2 shows that fossil fuels supplied nearly 85% of California's energy end-uses in 1987. In that year, California depended on petroleum for 54% of its primary energy: 41% for transportation end-uses and 13% for industrial end-uses (CEC 1990).

In 1987, natural gas supplied 31% of the state's primary energy use: 20% for residential, commercial, and industrial end-uses and 11% for electricity production (CEC 1990).

Adverse Impacts of California's Fossil-Fuel Dependence

As a consequence of its reliance on fossil fuels, California is vulnerable to petroleum supply disruptions and related price increases, such as those recently experienced during Iraq's invasion and occupation of Kuwait.

California's dependence on fossil fuels also affects its atmosphere. The California Air Resources Board has determined that fossil-fuel combustion is responsible for 80% of California's local air pollution (CEC 1990). As Figure F-3 illustrates, transportation

¹ 1987 is the last year of complete data for California energy use.

sources are the most important contributors to smog-producing NO_x emissions in California.

Californians also share the growing concern regarding the role of carbon dioxide (CO₂) emissions in global warming and adverse climate change. Figure F-4 shows the principal contributors of CO₂ emissions in California.

California's Energy Future

California's overall energy use is expected to increase by almost 50% over the next twenty years (CEC 1990). The potential effect of projected changes in California's fossil fuel and electricity use is illustrated in Figure F-5.

Electricity

The CEC projects that electricity consumption will increase 50% by the year 2010, as illustrated in Figure F-6 (CEC 1990). Projections indicate a comparable increase in peak electric demand. Most of the growth in electricity consumption is expected to occur in the commercial sector due to increased electric and electronic office equipment. Figure F-7 indicates that lighting, cooling, ventilation, and refrigeration are the major end-uses of commercial electricity. Figure F-8 indicates that refrigerators, freezers, and miscellaneous other end-uses are major factors in residential electric demand. Although air conditioning is only a modest component of overall residential energy use, it is a major contributor to peak electric demand.

Natural Gas

The CEC anticipates that natural gas use will increase by 33% over the next twenty years, as illustrated in Figure F-9. Most of the growth is expected to occur in the industrial sector as natural gas is substituted for higher-priced petroleum. Building and appliance efficiency standards are projected to cause a decline in natural gas use per household. Space and water heating are the most significant energy services in this sector (see Figure F-10). Projections show a decline in commercial natural gas use per square foot due to efficiency improvements in heating, cooling, water heating, and cooking equipment (see Figure F-11).

Transportation-Related Energy Use

A recent CEC report indicates that the consumption of fossil fuels for transportation will increase during the next twenty years, as illustrated in Figure F-12 (CEC 1990). VMT will increase significantly, as will time spent burning fuel in traffic congestion.

As Figure F-13 illustrates, there is considerable uncertainty about future consumption of gasoline. Increases in alternative-powered vehicles and improvements in the fuel economy of conventional vehicles contribute to this uncertainty. Electric and gas utilities are aggressively pursuing the development and application of EVs and NGVs in cooperation with air quality management agencies and vehicle manufacturers. Widespread implementation of EVs and NGVs should improve air quality in the Los Angeles Basin.

and other regions. The CEC has also been promoting the adoption of methanol-powered vehicles by state and local government agencies.

California's Energy Efficiency Opportunities

California will remain vulnerable to supply disruptions, high energy prices, and the atmospheric pollution associated with fossil-fuel combustion unless extensive efforts are made to tap the state's energy efficiency and alternative energy supply potential.

Electricity

Table F-1 summarizes California's 1987 end-use consumption by energy type. A recent study of California's energy conservation potential (CEC 1990) estimates that 25% of residential and commercial electricity use could be saved through the adoption of efficient lighting, refrigerating, and air-conditioning technologies. It estimates that efficient motors could save 15% of industrial electricity use. Figure F-14, from a recent CEC study, shows that energy-efficient lighting, residential appliances, and commercial display refrigeration could reduce California's electricity consumption by 56,000 GWh. This is nearly 50% of the anticipated growth in electricity use projected in Figure F-15.² Figure F-16 (Fickett et al. 1990) identifies many of the energy-efficient technologies that could contribute to significant electricity savings.

The CEC plans to prepare a more comprehensive inventory of electricity and natural-gas energy efficiency opportunities in California. Lighting, efficient drive systems for industrial and building applications, industrial process heating, building cooling, commercial refrigeration, and improvements in residential appliances represent major efficiency opportunities.

Natural Gas

Several studies have estimated potential reductions in residential furnace, water heater, and commercial boiler natural-gas consumption. Table F-1 summarizes 1987 gas consumption by end-use and estimates California's conservation potential to be 30 to 50% in 2010. CO₂ and NO_x emissions could also be reduced by a comparable amount (Akbari and Rosenfeld 1990).

Transportation-Related Energy Use

Several studies indicate that the energy efficiency of new cars can be significantly improved, even if average size and acceleration performance are held constant. One study (Akbari and Rosenfeld 1990) indicates that 41% of gasoline use can be saved at an average cost of conserved energy of \$0.25 per gallon by the year 2010, as illustrated in Table F-1. California is precluded by federal law from establishing fuel use efficiency standards, but it can implement incentive programs such as DRIVE+,³ for consumer

² The bottom two curves in Figure F-15 are based on a preliminary analysis of the potential to further reduce electricity demand and energy use through the adoption of cost-effective energy efficiency measures.

³ A proposed "fee-bate" incentive promoting the purchase of clean, fuel-efficient vehicles in California.

purchases of more fuel-efficient vehicles. Alternative-powered vehicles (such as EVs and NGVs) are additional options for reducing California's dependence on petroleum.

Tapping California's Energy Efficiency Potential

California's energy, environmental, and regulatory policymakers are interested in tapping the state's energy efficiency potential in four primary ways: through energy efficiency R&D, through building and appliance standards, through utility DSM programs, and through federal fuel-efficiency automobile standards and market incentives promoting clean, fuel-efficient vehicles. CIEE can assist its sponsors in achieving significant energy efficiency gains in the first three areas. Policymakers are also interested in pursuing the development and implementation of alternative-powered vehicles.

R&D

Many of the technologies included in estimates of California's energy efficiency potential (identified in Figures F-14 and F-15) and other promising technologies (Figure F-16) are not commercially available. Moreover, many technologies included in utility DSM programs are still in the early stages of development. R&D that improves operational reliability and other performance characteristics and reduces implementation costs is needed to realize this technical potential. Field tests are necessary to evaluate the performance of promising technologies, facilitate further product improvements, and reduce the risk of customer and industry dissatisfaction. CIEE intends to collaborate with its sponsors—CURC, EPRI, GRI, DOE, and other interested partners in R&D, as described in Sections 2, 3, and 4—to help realize California's energy efficiency potential while reducing indoor and outdoor air pollutants.

Building and Appliance Energy Efficiency Performance Standards

The CEC anticipates that Title 24 commercial and residential construction standards will be tightened in the mid-1990s. The impact on indoor air quality of tightening commercial building standards is an area of major concern.

Although the CEC is precluded by federal legislation from tightening appliance efficiency standards, it anticipates providing input during periodic DOE assessments of standards needs and opportunities.

Advocating tighter building standards will require that the CEC have access to:

- Building performance analysis models that can be used by the CEC, architects, and engineers.
- Data and analyses projecting the potential impact of ~~tighter standards on indoor air quality.~~
- Data on the performance and cost of emerging and new energy technologies (for example, new indoor air quality sensors and controls and removal technologies) that may affect the standards-setting process.

CIEE is interested in collaborating with the CEC and California utilities in conducting R&D activities that enhance this standards-setting process. Related R&D activities are discussed in Section 2.

Demand-Side Management Programs

Energy-efficient technologies sometimes cost more up front than conventional alternatives in new-construction situations, while energy-efficient retrofits usually have higher up-front costs than do-nothing alternatives. As a result, consumers may be reluctant to adopt them. Other barriers to market penetration include:

- Uncertainty about energy and cost-saving performance and reliability
- Lack of technical expertise to design, procure, install, or operate the technology
- Physical constraints

The CEC, CPUC, and environmental and consumer groups are encouraging California's electric and gas utilities to actively promote and provide incentives for customer adoption of reliable DSM technologies that are more cost-effective than building new power plants or operating existing facilities. The CPUC recently adopted new rate-making mechanisms that will enable California's electric and gas utilities to earn increased profits when they overcome barriers to the market adoption of energy-efficient technologies.

Key issues impacting the success of utility DSM programs include developing and implementing effective marketing programs that achieve customer participation by:

- Removing structural barriers to customer and developer participation.
- Measuring the energy and peak-demand reduction impacts of DSM programs.
- Communicating DSM program results to customers so that public support is maintained for continued DSM implementation despite potential rate increases.

CIEE is interested in collaborating with the California utilities, the CEC, and the CPUC in conducting R&D and technology transfer activities that:

- Facilitate effective, integrated resource planning by improving the data on energy-efficient technology load-shape impact, life-cycle cost, reliability, and availability.
- Advance the state of the art in DSM impact measurement techniques.
- Promote the transfer of CIEE-developed technologies through utility DSM programs.

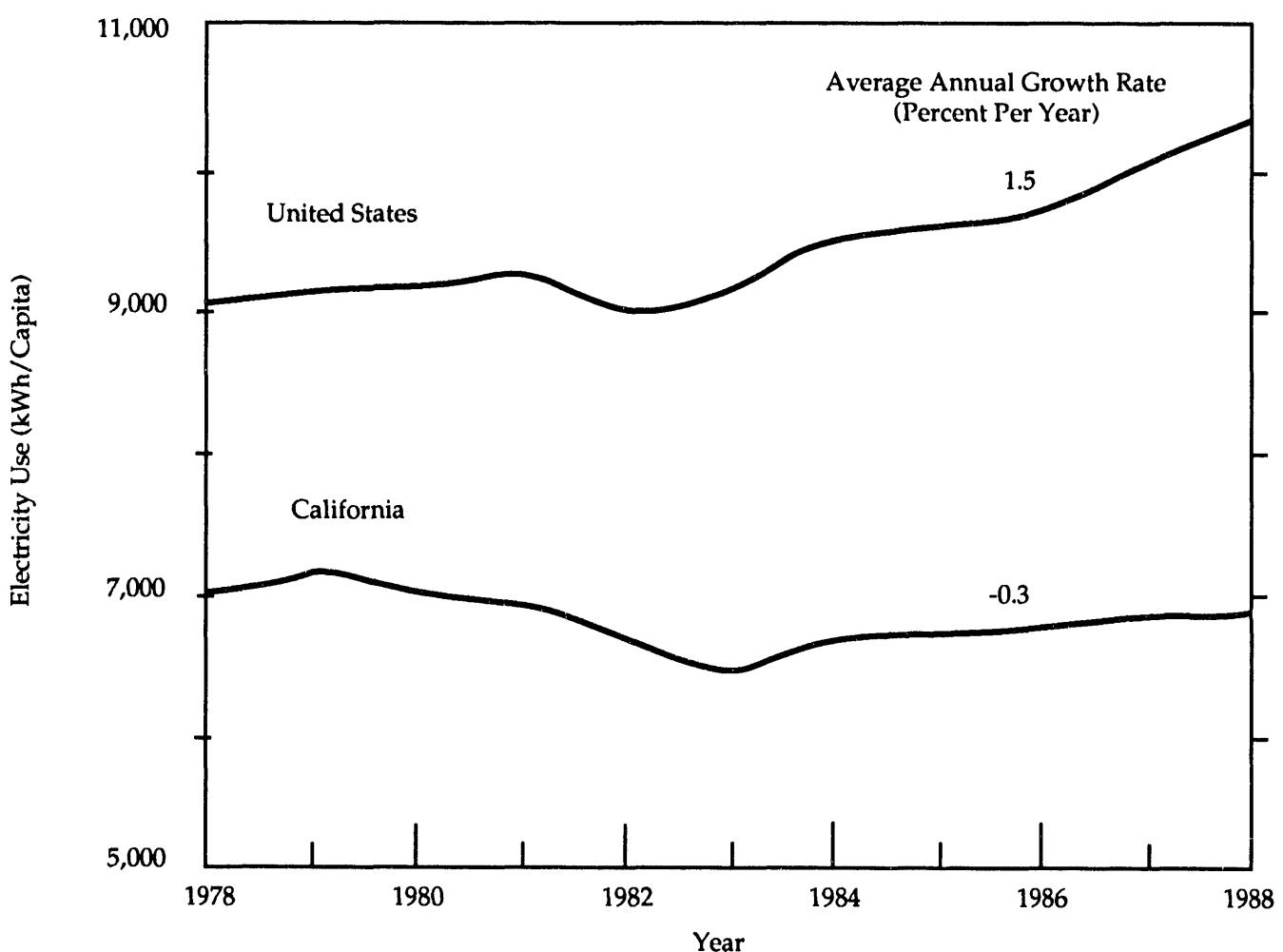
CIEE R&D efforts relating to the first two goals are described in the ERP program discussion in Section 4; the third aim is an overall goal of CIEE's R&D program.

Table F-1
1987 Primary Energy Use and Selected Conservation Potential

Sector	Consumption 1987			Conservation Potential	
	[A] Primary Energy Use* (10 ¹⁵ Btu)	[B] % of Sectorial Energy Use	[C] % of CA Energy	[D] % Saving Use Available by 2010	[E]=[A]¥[D] Energy Savings (10 ¹⁵ Btu)
Transportation	2.82	100.00	40.90		
Cars	1.56	55.40	22.60	41.00	0.64
Others	1.26	44.60	18.30		
Residential	1.20	100.00	17.40		
Electricity	0.54	45.00	7.80	25.00	0.14
Natural gas	0.64	53.40	9.30	50.00	0.32
LPG and petrol	0.02	1.70	0.30		
Commercial	0.81	100.00	11.70		
Electricity	0.55	68.50	8.00	25.00	0.14
Natural gas	0.20	25.30	3.00	30.00	0.06
LPG and petrol	0.05	6.20	0.70		
Industrial	2.07	100.00	30.00		
Electricity	0.69	33.30	10.00	15.00	0.10
Natural gas	0.55	20.40	3.00		
LPG, petrol, and coal	0.82	39.90	12.00		
Total	6.90	100.00			
Selected Conservations Extrapolated to Total	4.19		60.70	33.00	1.40
	6.90	100.00	100.00	33.00	2.30

Source: Akbari and Rosenfeld (1990).

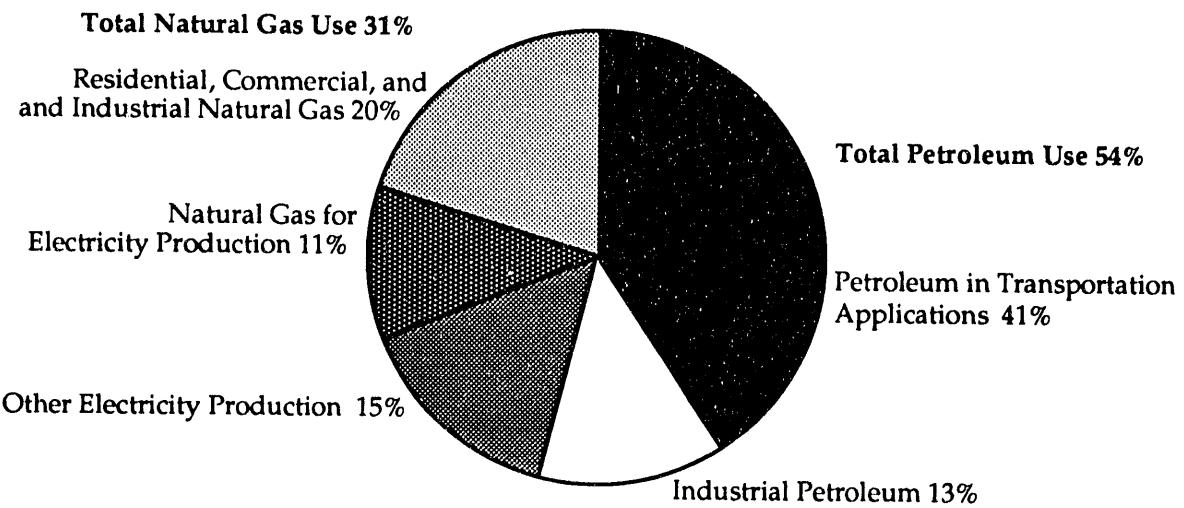
Figure F-1
**Per Capita Electricity Use in California and the United States,
1978–1988**



California's building and appliance standards and progressive energy policies have significantly reduced per capita electricity use over the past decade. In 1988 the average Californian used 210 kWh less than in 1978, while in 1988 the average American used 1,220 kWh more than in 1978.

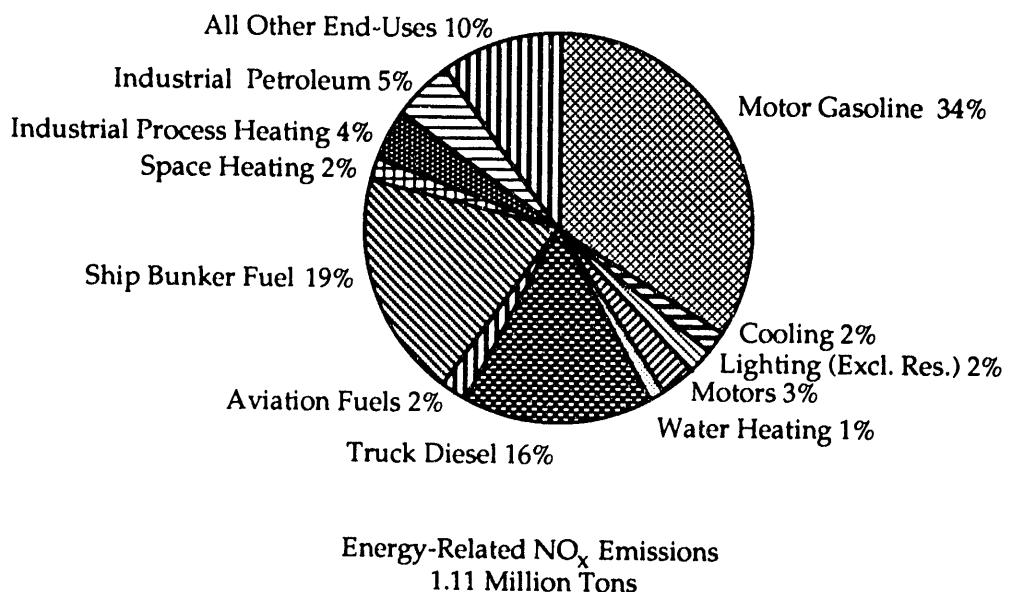
Source: NRDC (1990).

Figure F-2
California Primary Energy Sources (1987)

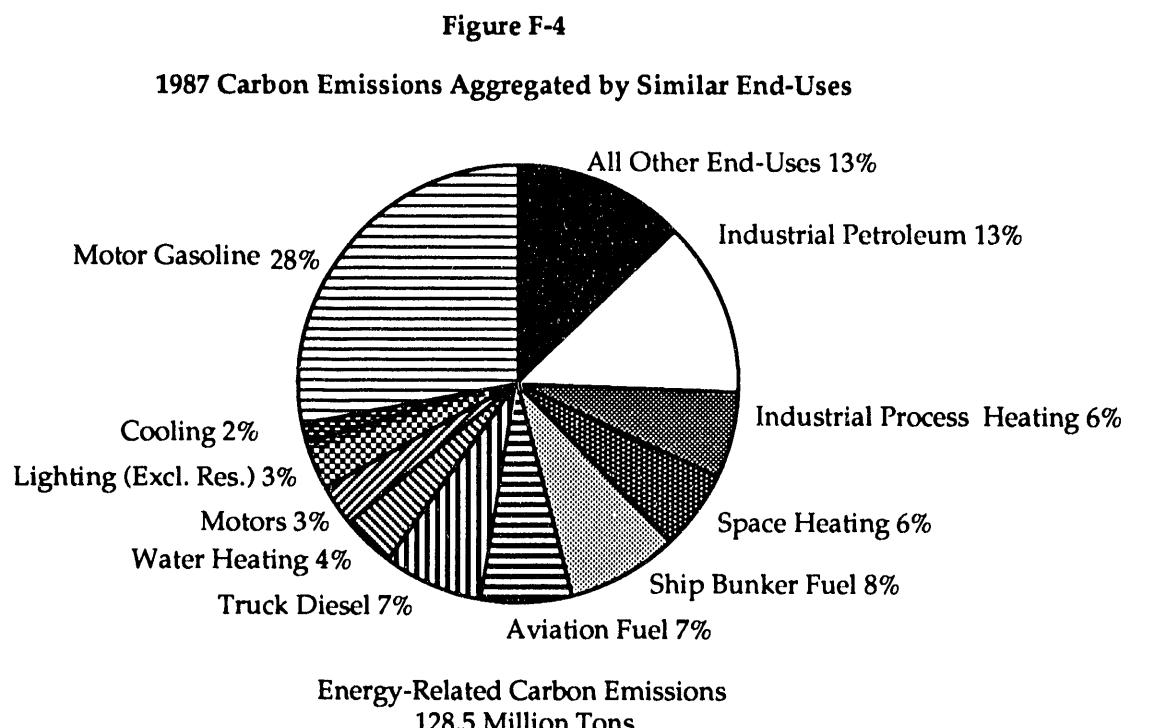


Source: CEC (1990).

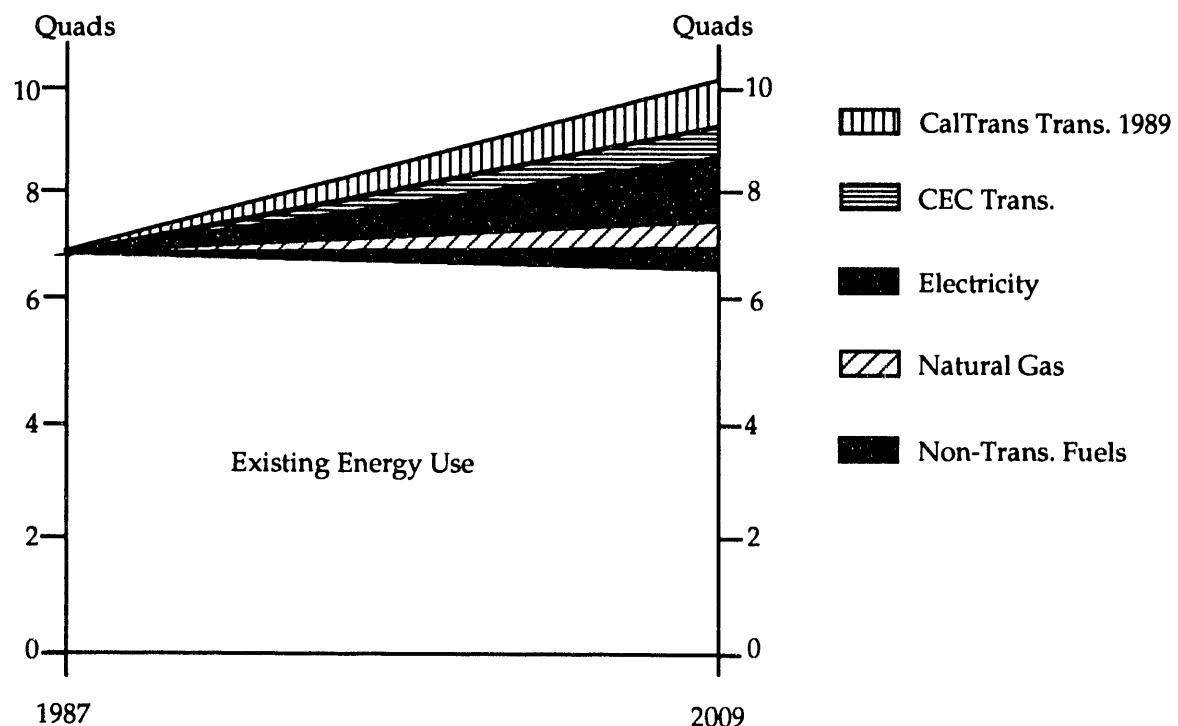
Figure F-3
1987 California NO_x Emissions Aggregated by Similar End-Uses



Source: CEC (1990).



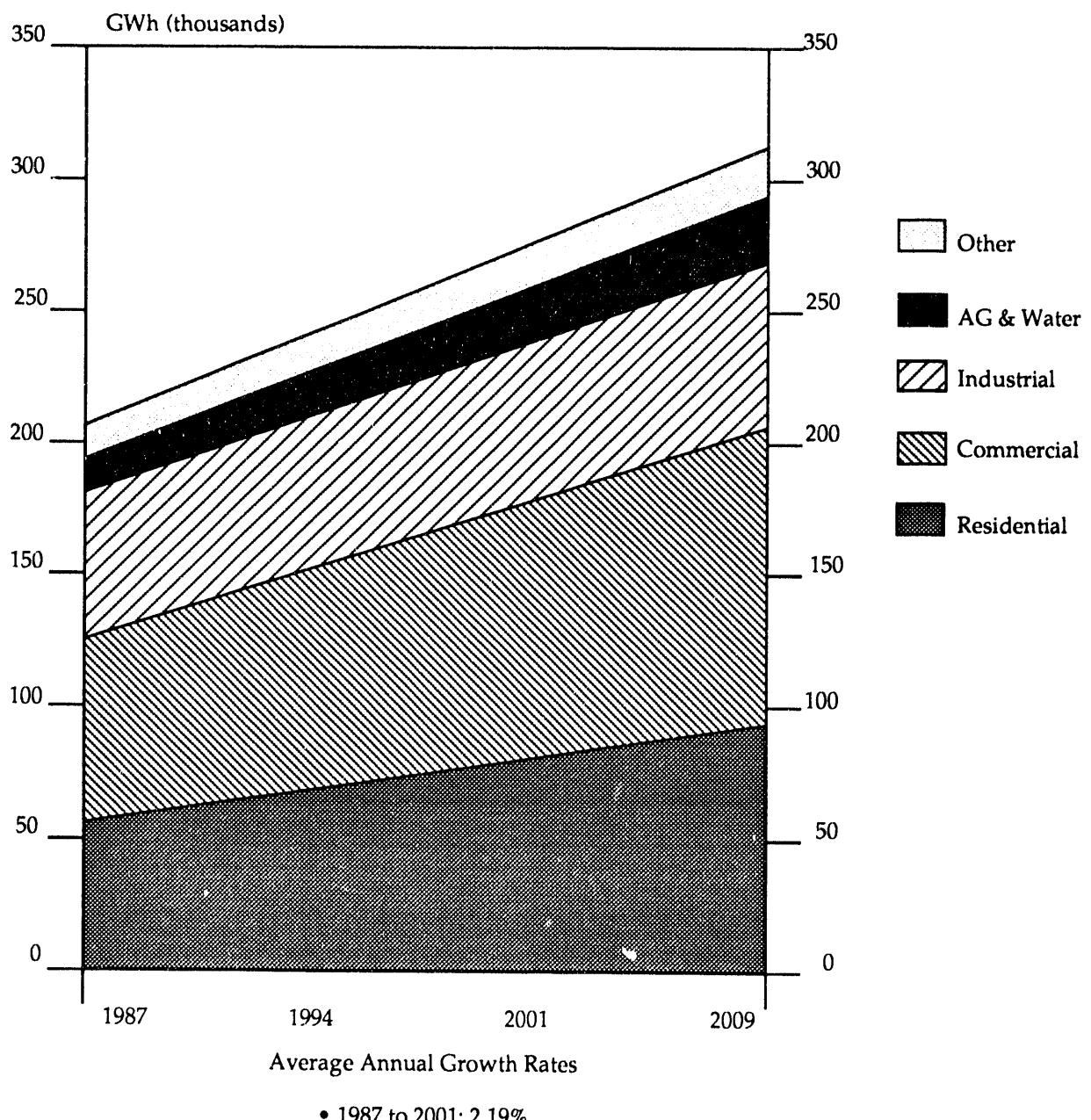
Source: CEC (1990).



Source: CEC (1990).

Figure F-6

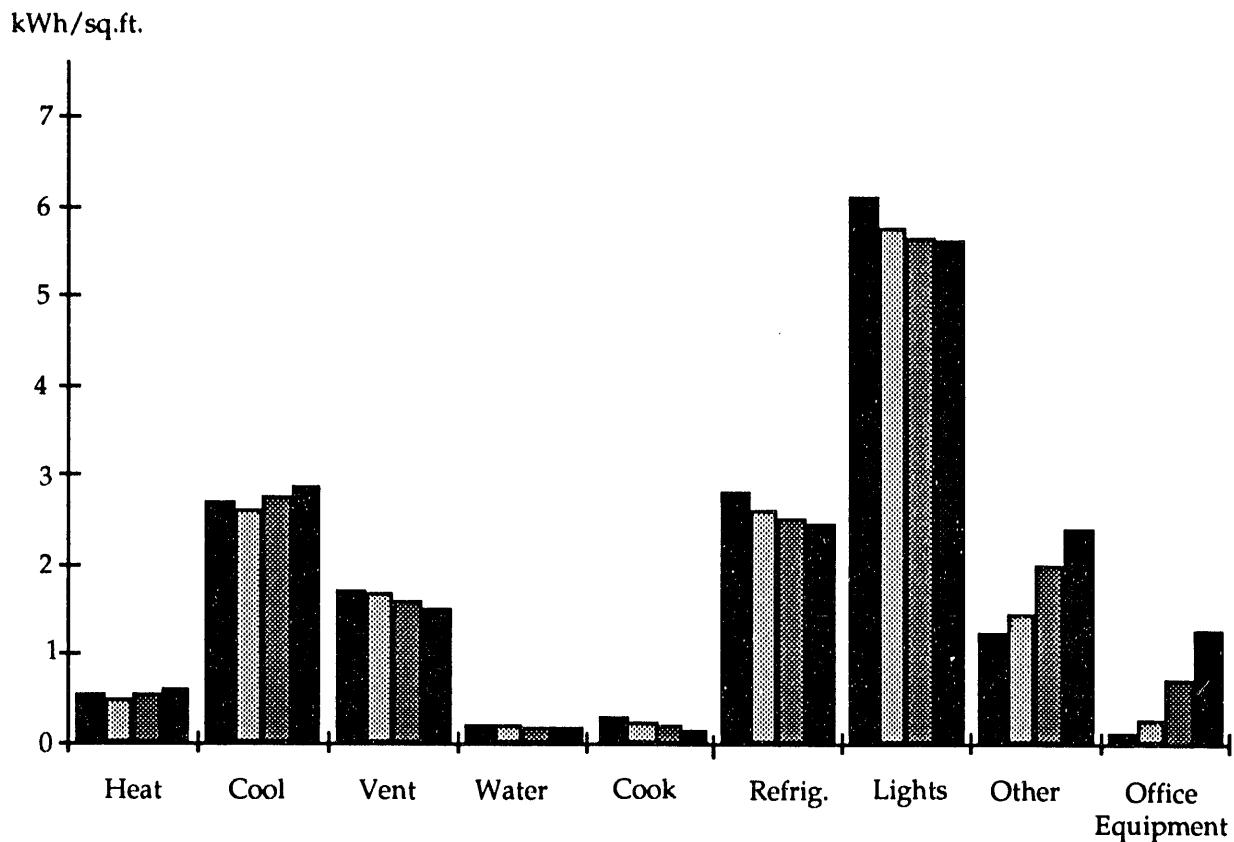
Electricity Use in California
Sector Projections 1987–2009



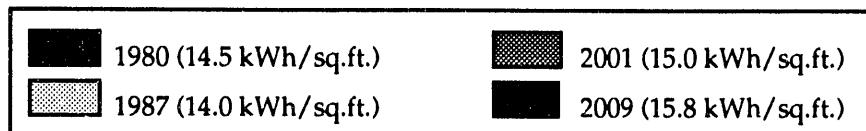
Source: CEC (1990).

Figure F-7

Electricity Use per Square Foot
Commercial Sector—Statewide



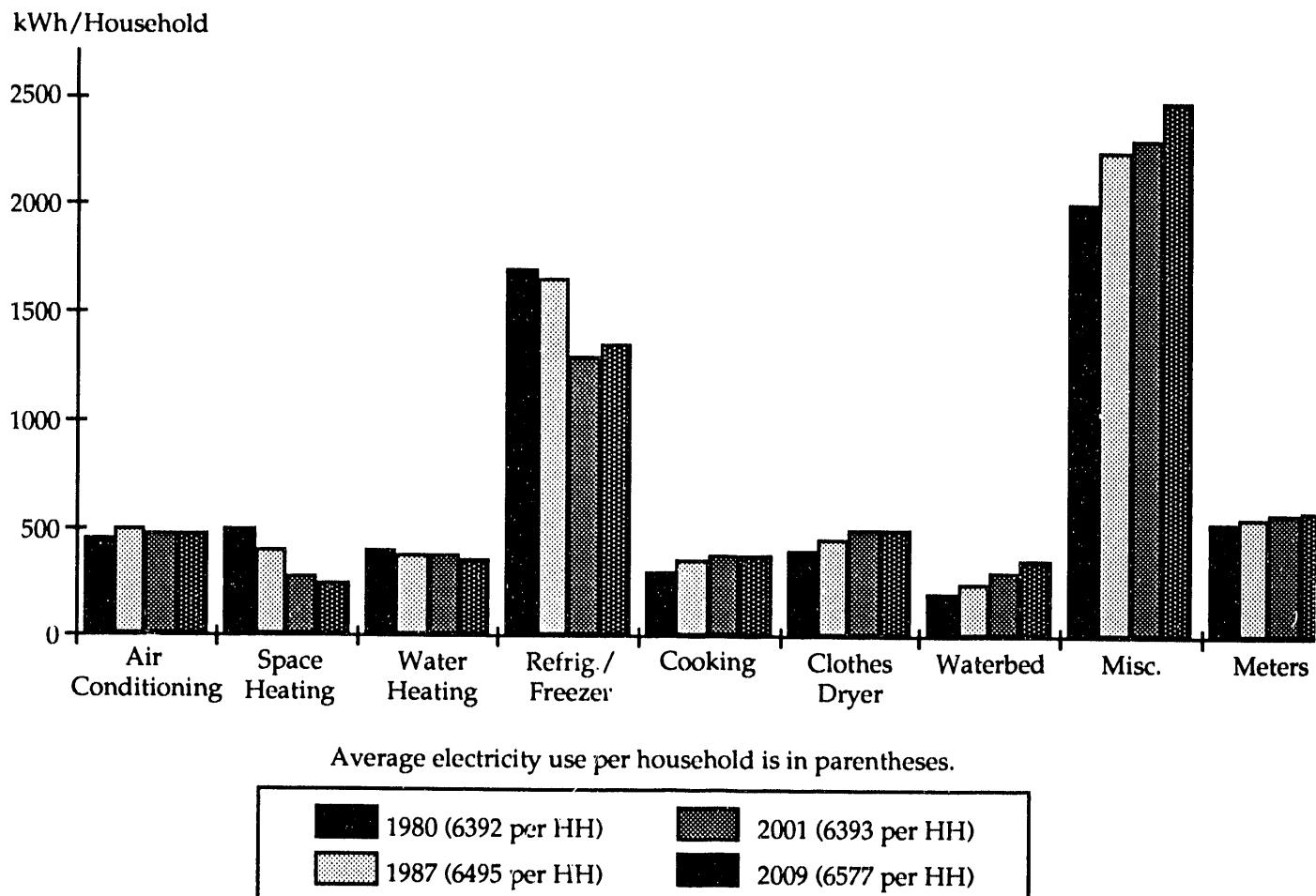
Average electricity use per square foot for each forecast year is in parentheses.



Source: CEC (1990).

Figure F-8

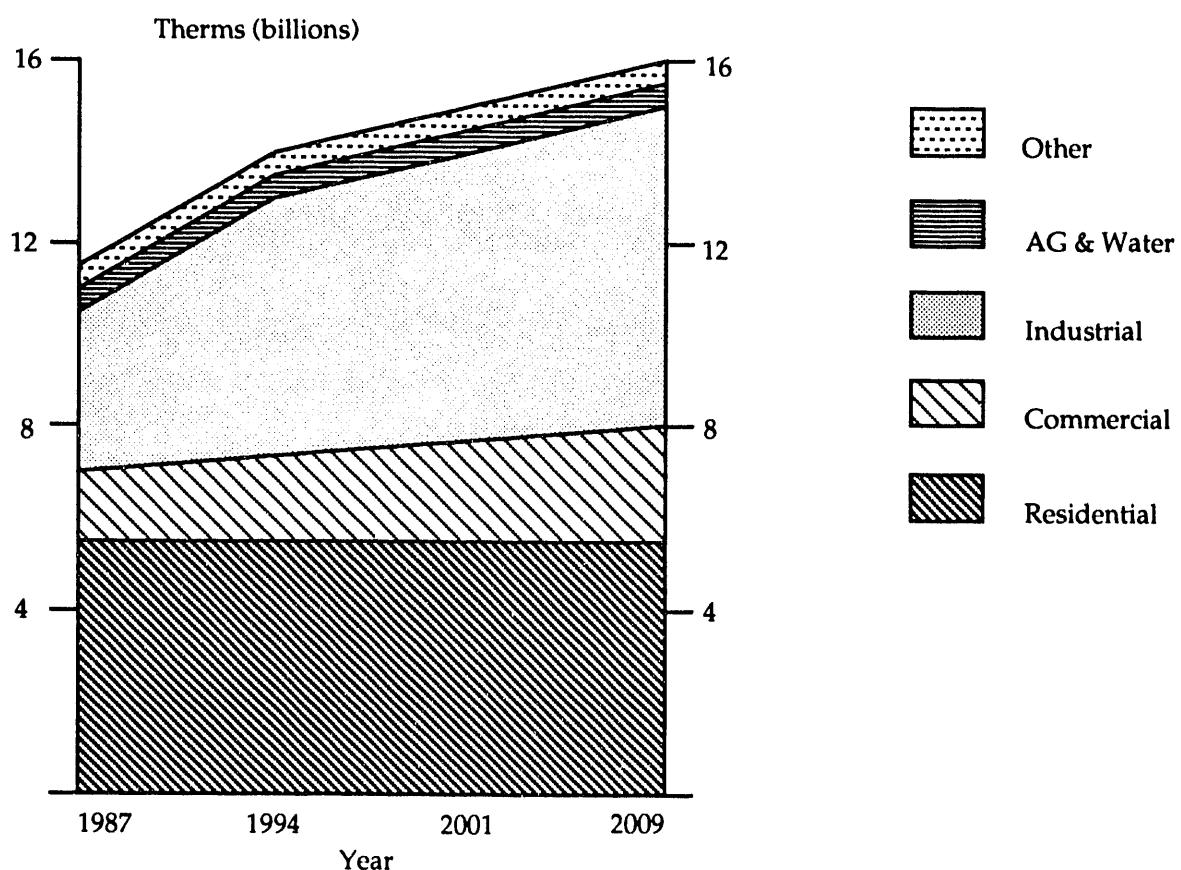
Electricity Use per Household
Residential Sector—Statewide



Source: CEC (1990).

Figure F-9

**Natural Gas Use in California
Sectorial Projections 1987–2009**

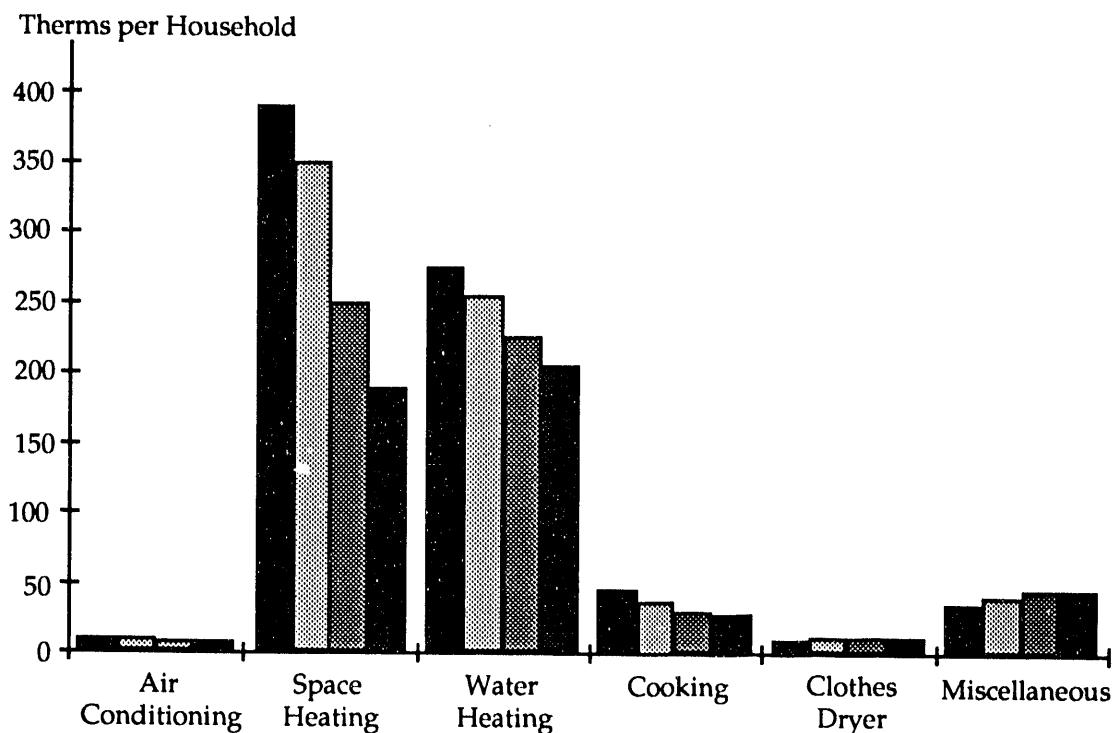


Average Annual Growth Rates

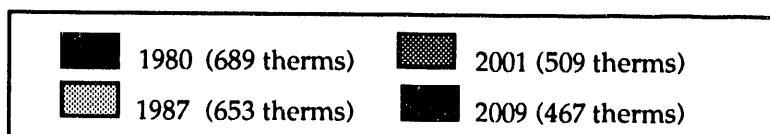
- 1987 to 2001: 1.84%
- 1987 to 2009: 1.38%

Source: CEC (1990).

Figure F-10
Natural Gas Use per Household
Residential Sector—Statewide

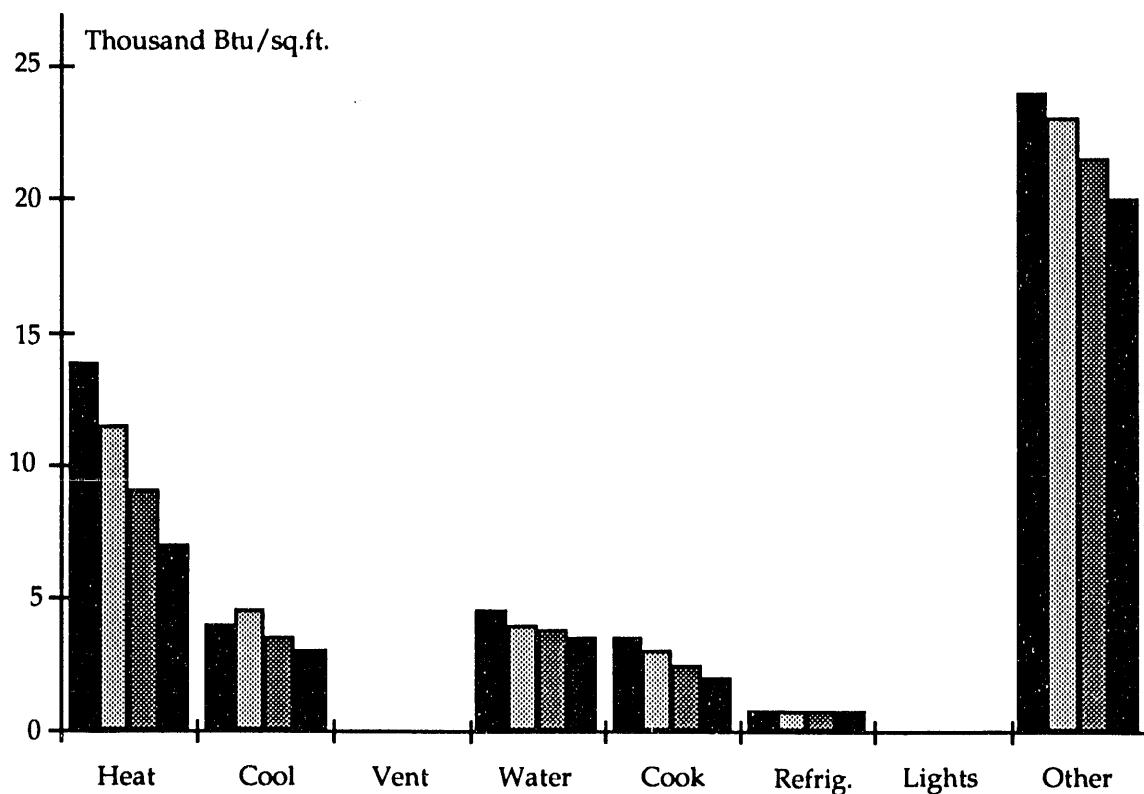


Average consumption per household is in parentheses.

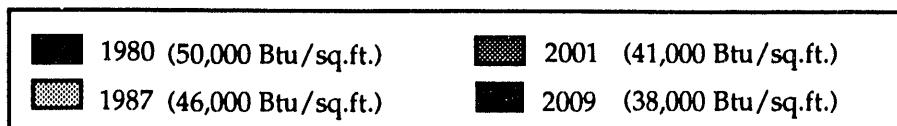


Source: CEC (1990).

Figure F-11
Natural Gas Use per Square Foot
Commercial Sector—Statewide

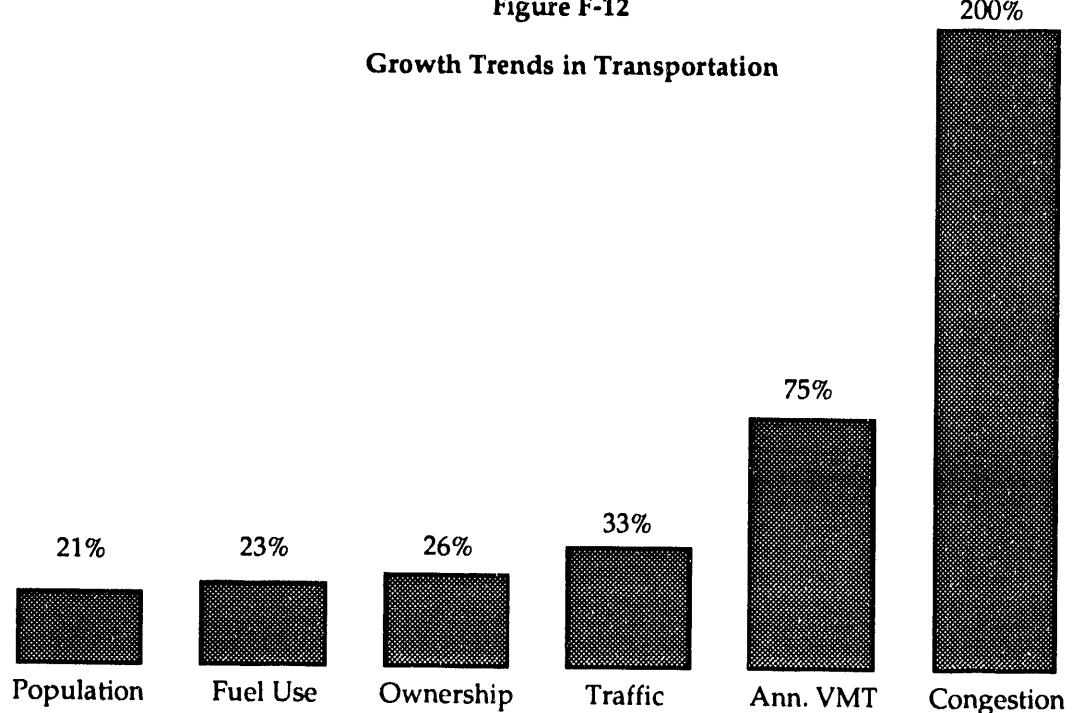


Average natural gas use per square foot for each forecast year is shown in parentheses.



Source: CEC (1990).

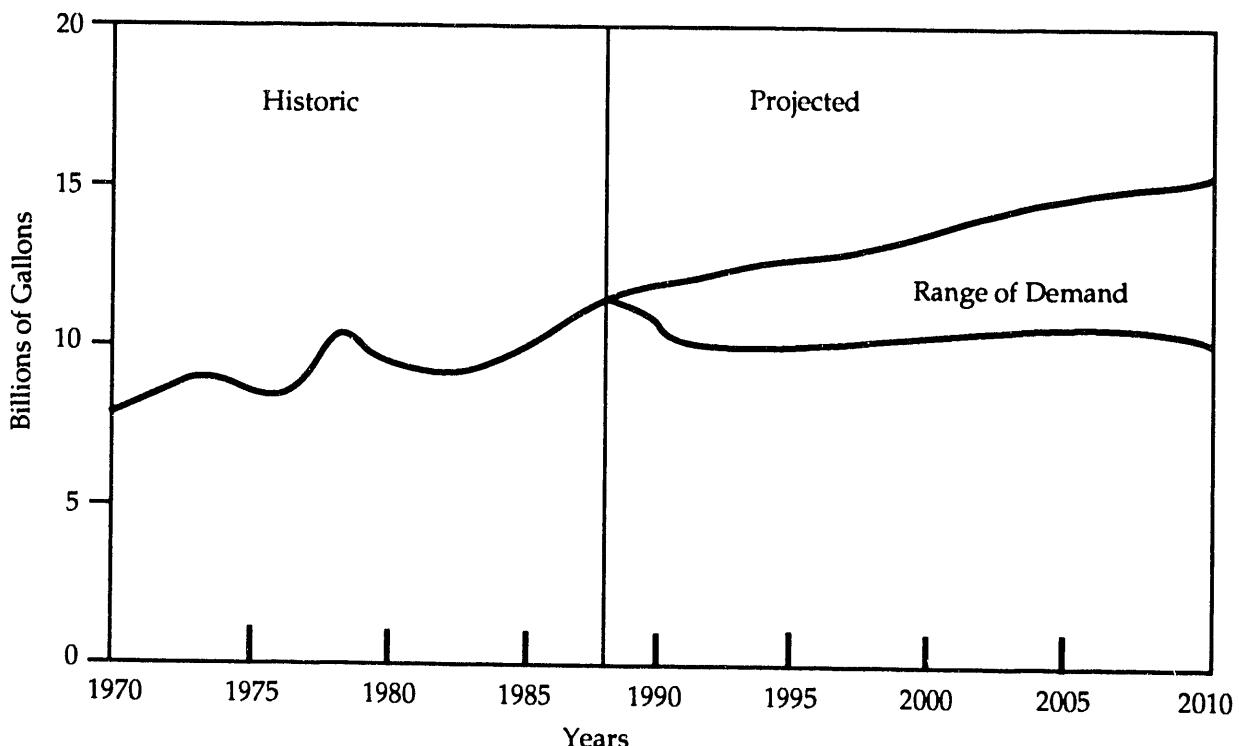
Figure F-12
Growth Trends in Transportation



By 2005, population, fuel use, traffic, and car ownership will grow 20 to 30%, while vehicle miles traveled (VMT) will grow by 75% and congestion by 200%.

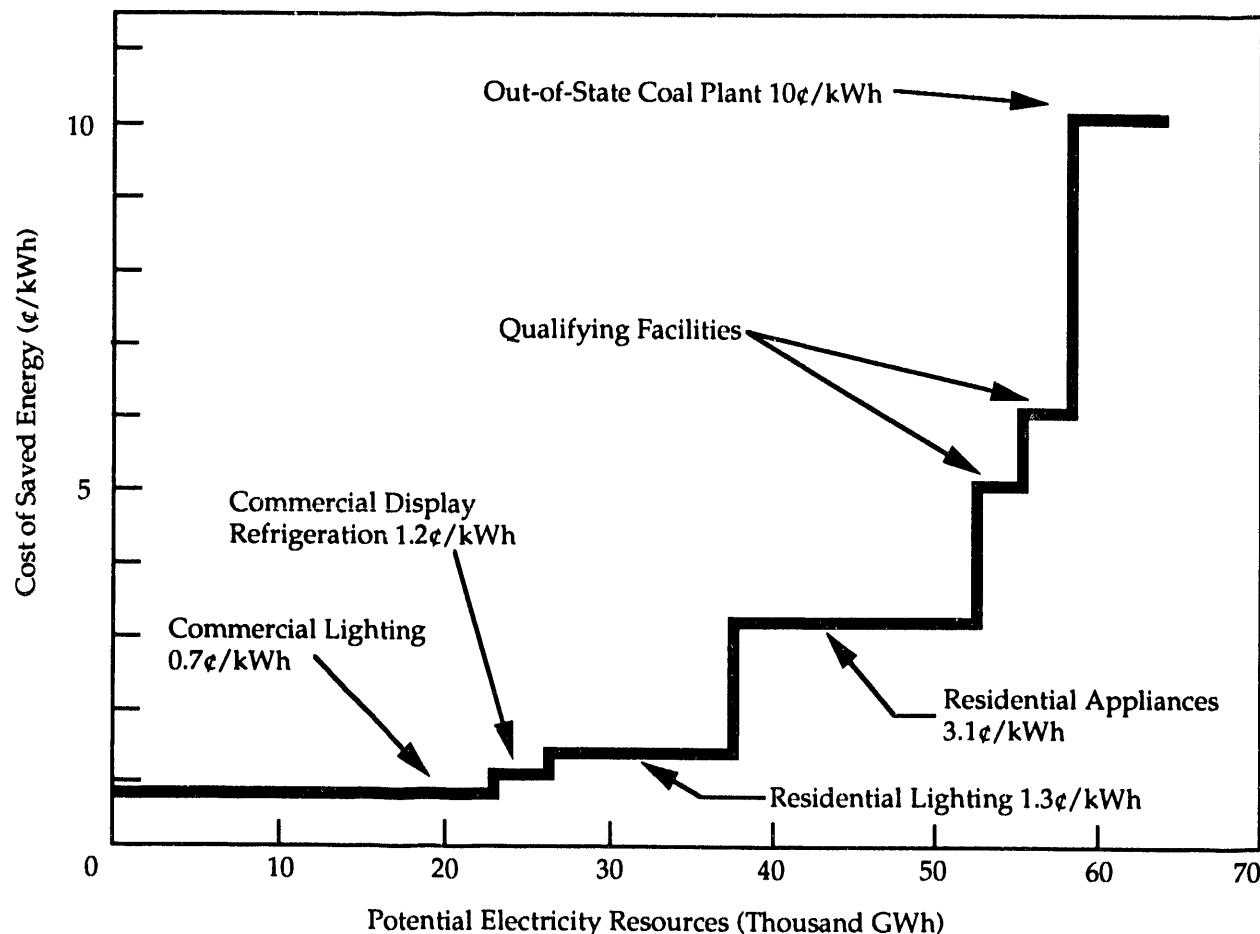
Source: CEC (1990).

Figure F-13
California Highway Gasoline Demand



Source: CEC (1990).

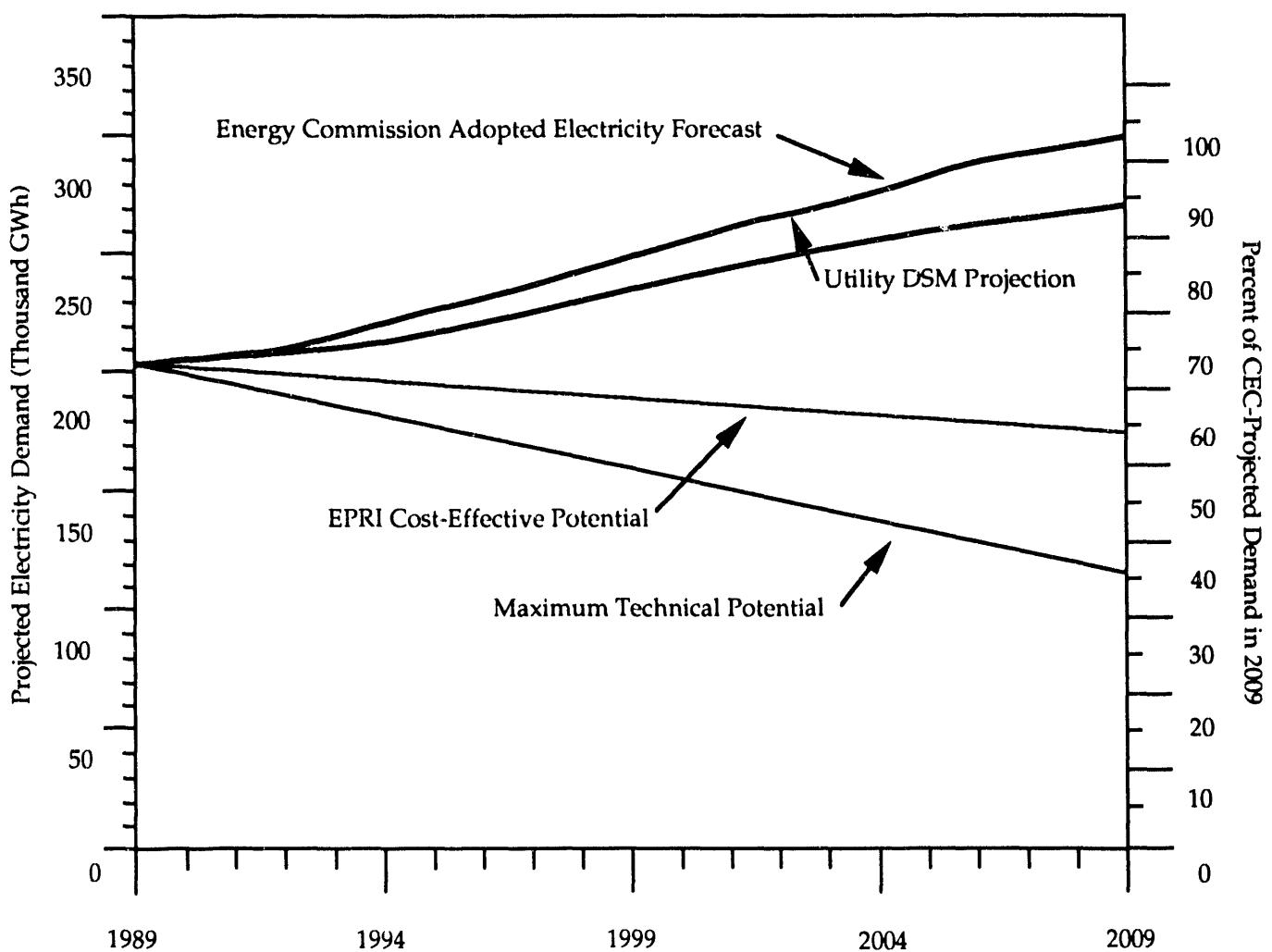
Figure F-14
Energy Efficiency Report, October 1990



Least-cost supply curve: Comparing improved electricity efficiency to conventional sources of supply. The average costs and availability of energy savings for commercial lighting, commercial display refrigeration, residential lighting, and residential appliances are compared to hypothetical qualifying facilities and out-of-state coal resources. No new supply options should be considered until all cost-effective efficiency options have been exhausted.

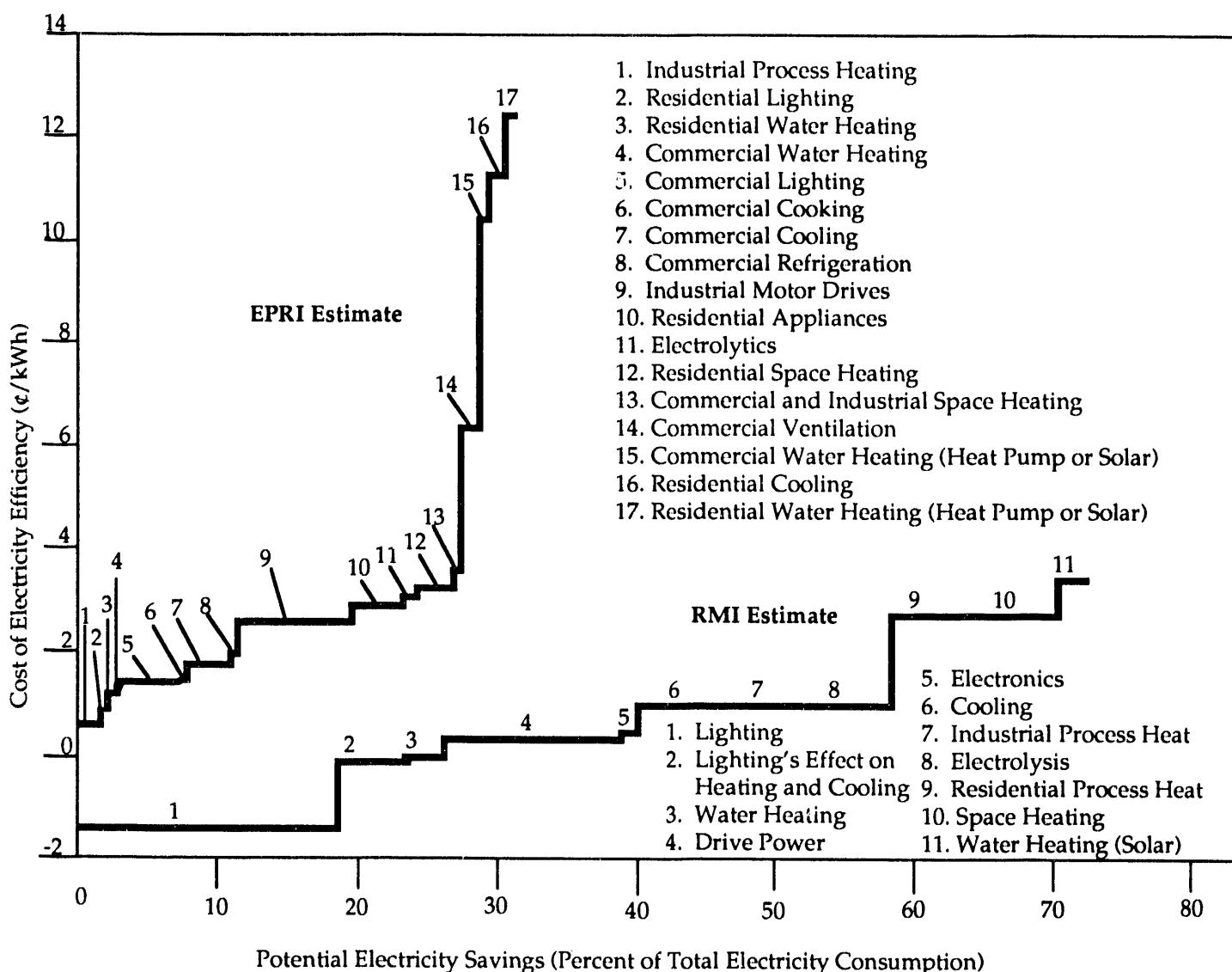
Source: CEC (1990).

Figure F-15
Comparison of Future Electricity Demand Scenarios for California



Source: CEC (1990).

Figure F-16
Comparison of the Energy Efficiency Potential of Promising Technologies



Source: Fickett et al. (1990).

Attachment G

**CIEE Exploratory Projects
(1991 and 1990)**

1991 Exploratory Projects

E.91.01 Optimizing the Use of EMCS Technologies to Reduce Peak Loads and Energy Consumption in Non-Residential Buildings

Sukhbir Mahajan, phone (916) 278-6518
California State University, Sacramento

E.91.02 In-Field Investigation of Weatherization Instrumentation, Co-Heating, and Cost- Effectiveness Protocol for Mobile Homes in California

Jim O'Bannon, phone (916) 898-6355
California State University, Chico

E.91.03 Preparation of High-Strength, Low-Density Polymeric Insulation Material with Environmentally Sound Foaming Agent

David Soane, phone (510) 642-7998
University of California, Berkeley

E.91.04 Improved Energy Efficiency for HVAC Systems via Advanced Process Control

Dale Seborg, phone (805) 893-3352
University of California, Santa Barbara

E.91.05 Reducing Environmental Impact and Energy Use Through Water Recycling and By-Product Recovery in Food Processing

Paul Singh, phone (916) 752-0811
University of California, Davis

E.91.06 Comfort-Based Control Logics for Natural and Low-Energy Cooling Systems in California Residences

Hofu Wu, phone (714) 869-4527
California State Polytechnic University, Pomona

E.91.07 Design of a Phase-II Study of Sick Building Syndrome

William Fisk, phone (510) 486-5910
Lawrence Berkeley Laboratory

E.91.08 Assessment of Peak Power Reduction Potential of Radiant Cooling Systems

Helmut Feustel, phone (510) 486-4021
Lawrence Berkeley Laboratory

E.91.09 Spectrally Selective Glazings for Residential Retrofits

Michael Rubin, phone (510) 486-7124
Lawrence Berkeley Laboratory

E.91.10 Indoor Ozone Concentrations: Quantification of Mechanisms of Outdoor Concentration Attenuation

Mark Modera, phone (510) 486-4678
Lawrence Berkeley Laboratory

Currently Active 1990 Exploratory Projects

E.90.1 Low Heat Loss, Non-CFC-Based Appliance and Building Insulation

Stephen Selkowitz, phone (510) 486-5064
Dariush Arasteh, phone (510) 486-6844
Lawrence Berkeley Laboratory

Publication pending: *High-Performance Insulation: Gas-Filled Panels*

E.90.2 An Assessment of Residential Evaporative Cooling Technologies in California

Ron Ritschard, phone (510) 486-6328
Joe Huang, phone (510) 486-7082
Lawrence Berkeley Laboratory

E.90.3 High-Albedo Materials for Reducing Building Cooling Energy Use

Haider Taha, phone (510) 724-7423
Joe Huang, phone (510) 486-7082
Lawrence Berkeley Laboratory

Publication pending: *High-Albedo Materials for Reducing Building Cooling Energy Use*

E.90.4 Lighting Audit Tool: A Precursor to an Expert System for Specifying Energy-Efficient Lighting

Rudolph Verderber, phone (510) 486-6398
Lawrence Berkeley Laboratory

E.90.5 Interactive Graphic Input to Superlite

Marc Shiler, phone (213) 743-2723
University of Southern California

E.90.6 Customer Participation and End-Use Load Response to Voluntary DSM Programs

Kenneth E. Train, phone (510) 642-6172
University of California, Berkeley

Publication pending: *Optional Time-of-Use Prices for Electricity: Analysis of PG&E's Experimental TOU Rates*

E.90.7 Integrated Estimation of Commercial Load Shapes and Energy Use Intensities

Hashem Akbari, phone (510) 486-4133
Lawrence Berkeley Laboratory

E.90.8 Analysis of Energy Use in Building Services of the Industrial Sector in California

Hashem Akbari, phone (510) 486-4133
Ashok Gadgil, phone (510) 486-4651
Lawrence Berkeley Laboratory

E.90.9 Flow and Energy Transfer in Enclosures

Ralph Greif, phone (510) 642-6462
Joseph A. C. Humphrey, phone (510) 642-6460
University of California, Berkeley

E.90.10 Comparative Evaluation of the Impacts of Domestic Gas and Heat Pump Heating on Air Pollution in California

Ahmad R. Ganji, phone (415) 338-7736
San Francisco State University

Publication pending: *Comparative Evaluation of the Impact of Domestic Gas and Electric Heat Pump Heating on Air Pollution in California*

Attachment H

1991 SOLICITATION OF EXPLORATORY PROJECTS CALIFORNIA INSTITUTE FOR ENERGY EFFICIENCY

The California Institute for Energy Efficiency (CIEE) is soliciting proposals for its Exploratory Research Program. Proposed projects should address one of the following two goals:

- Identify, develop, and demonstrate efficient end-use technologies and processes that:
 - Increase the security and sustainability of energy systems in California.
 - Help assure continued access to reliable, affordable energy services for all California end users.
 - Enhance the productivity and competitiveness of California's agricultural, manufacturing, and service industries.
 - Contribute to the improvement of regional air and water quality in California and to the quality of the indoor environment in California buildings, while also recognizing the potential for energy efficiency to help mitigate global climate change.
- Improve the data and analytical tools related to end-use of energy, in order to support sound utility and public sector planning decisions on the balanced development of demand- and supply-side energy resources in California.

CIEE is a research unit of the University of California, funded primarily by California's energy utilities. CIEE funds three types of projects: multi-stage programs and single-stage projects focused on several aspects of end-use of particular importance to Californians, and exploratory research projects addressing the broader CIEE mission.

The objective of CIEE's Exploratory Research Program is to support innovative energy end-use research within the scope of CIEE's mission that (a) benefits California utility ratepayers and (b) generates ideas and capabilities that are potential future components of CIEE's focused, multiyear programs.

Size and term of awards: Awards will be in amounts up to \$60,000. Projects will have a term of up to one year, and are anticipated to begin 1 May 1992; some adjustment of the contract period can be negotiated to resolve scheduling constraints. These are one-time awards; requests to continue a project beyond the initial year must be made in the form of a new proposal. CIEE anticipates making ten awards under this program.

Who is eligible to apply: Researchers at any California college or university and those laboratories or research centers that are affiliated with a California college or university and that are located in California. At least one of the applicants must be designated as the Principal Investigator, must be qualified by his or her own institution to serve as such, and must be included in the project's effort plan. A PI can receive only one Exploratory award per year.

Proposal Submission Instructions and Proposal Evaluation Process and Criteria are described in the attachments.

Due Date: Complete and officially authorized proposals must be received by 5:00 pm, Friday, 1 November 1991. NO EXCEPTIONS.

PROPOSAL SUBMISSION INSTRUCTIONS

A proposal checklist is attached for your use. Details of requirements are given below.

Format and content of proposals:

1. **Title page.** Use the form attached to this solicitation (or a photocopy). The form **MUST** be signed by an institutional representative who is authorized to negotiate and approve contracts on behalf of your organization. Projects are anticipated to start by 1 May 1992.
2. **Abstract.** One page maximum, double-spaced.
3. **Main Text.** Eight pages maximum, double-spaced; should cover the following:
 - (a) The particular energy end-use problem addressed by the proposed research, its importance to California utility ratepayers, and the relevance of proposed research to understanding the problem and/or developing and applying efficient end-use energy technologies to solve the problem.
 - (b) The history of research on the problem, including contributions by the investigator.
 - (c) The proposed research objectives and method.
 - (d) Specific tasks that will be performed to accomplish the research objectives, along with deliverables and due dates.
 - (e) Any co-funding anticipated from other sponsors. Describe co-sponsor's role and tasks to be funded. (Note: letter of interest from potential co-sponsor *must be attached*.)

References should be provided to document the problem, previous research, and the proposed methods.

4. **Budget.** Please submit your budget grand total to the nearest \$100. Follow the attached format (your own spreadsheet may be used, as long as all required information is given), and double-check your figures before submission. The following information is REQUIRED:
 - (a) Name and title of all senior research personnel; category of support personnel (e.g., technician, graduate student, administrative assistant).
Show effort level (e.g., FTEs, work-months), rate, and cost for each individual. Show academic year and summer rates separately (e.g., "Student, summer" and "Student, academic year").
 - (b) Fringe benefits: Show rate and base to which rate applies. If different rates apply, show separately and discuss on Explanation page.
 - (c) Consultants: On Explanation page, state name of consultant, effort (e.g., hours or days), and rate charged. Give brief description of activities/tasks (e.g., "responsible for integrating time-of-use curves into calculation tool").
 - (d) Subcontracts: On Explanation page, give name of subcontractor, brief description of work, and total cost. For any subcontract over \$10,000, attach a complete budget following the format given here. A letter from each subcontractor indicating concurrence with the scope of work and budget **MUST BE INCLUDED**.
 - (e) Equipment or single purchases over \$1,000: Equipment is any item costing \$1,000 or more and having a useful life of two years or more. Identify single items costing \$1,000 or more. Items

must be necessary and specific to the proposed research. CIEE will not provide funds for general-purpose equipment such as computers or printers.

(f) Travel: For *each* anticipated trip, give *specific* information on destination, estimated airfare/transportation costs, lodging/per diem, registration fees, and other related costs. The proposed travel must be related to the project, and costs must be reasonable. Foreign travel is not permitted.

NOTE: All projects must allow costs for travel to the annual CIEE Conference to present project results (conference date and location TBA). We suggest you budget \$200 for housing/reg fee, \$200 for airfare, and \$100 for miscellaneous costs.

(g) Computing: CIEE will not provide funds to acquire computing equipment. However, charges for computer time are allowed.

(h) Miscellaneous office expenses: Includes office supplies, postage, telephone, etc.

(i) Other direct costs: Include such items as departmental recharges, utilities, and intangible procurements (e.g., costs for hosting a proposed workshop).

(j) Indirect costs: Show rate(s) and base(s); if some items have different rates or are excluded from the base, explain.

5. Curricula Vitae. Include for the PI, other senior research personnel, and any consultants.

Deliverables: Quarterly reports will be required, and a final report will be due at the end of the project. It is expected that the project will result in the timely production of at least one technical paper that would be submitted by the PI to a professional, peer-reviewed journal. All reports and/or technical papers may be distributed by CIEE under its own cover. Awardees are expected to participate in an annual CIEE conference to present results of the project to CIEE sponsors and other interested colleagues. As noted in 4(f) above, proposals must include the costs of attending this conference.

PROPOSAL EVALUATION PROCESS AND CRITERIA

Review process: Each proposal will be screened for consistency with CIEE's mission (summarized on page 1 of this announcement). Eligible proposals will be subjected to peer review, to be coordinated by the Universitywide Energy Research Group (UERG) of the University of California. Reviewers will be selected from energy researchers in universities, industry, utilities, and government; names of the reviewers will be confidential. Final decisions will be the responsibility of the Director of CIEE, with the advice and approval of the CIEE Research Board.

Criteria for awards: Proposals will be scored by the reviewers on the following criteria (in descending order of importance):

(a) Importance of the energy end-use problem to California utility ratepayers and citizens and the relevance of the proposed research to understanding the problem and/or developing and applying efficient end-use energy technologies and methods that help solve the problem.

(b) Originality and technical excellence of the proposal, including awareness of relevant prior research.

(c) Qualifications of the investigators.

(d) Feasibility of the research approach and plan for accomplishing the stated project objectives (including practicality and appropriateness of the budget in relation to the proposed research).

To the extent possible and appropriate, the importance of the problem will be judged in quantitative terms (e.g., total energy and/or peak-load savings).

Proposals that contain numerous typographical errors, poorly structured sentences, or budget errors may receive lower scores from peer reviewers and/or CIEE because such errors may affect the reviewers' assessment of the qualifications of the proposers.

Proposals that address one of the following issues of special interest to CIEE are eligible to receive bonus points in addition to the peer review score:

- Improved controls for energy-using equipment that enhance energy efficiency and reduce indoor and/or outdoor environmental emissions.
- Detecting, controlling and/or removing indoor and/or outdoor pollutants that result from energy end-use or adversely affect end-use energy efficiency.
- Innovative methods for measuring and/or quantifying the energy and/or peak load savings resulting from utility demand side management programs.
- The development and/or demonstration of new technologies that improve the efficiency of energy used in industrial and agricultural processes.
- The development and/or demonstration of new technologies that improve the efficiency of energy used to treat industrial, agricultural, and/or municipal wastes.

Proposals that include co-funding equal to at least 50% of the requested CIEE funds will also receive bonus points in addition to the peer review score. Eligible co-funders include private industry and state, regional, and local government organizations that are interested in developing or applying the energy efficient technology or problem solution. Proposals including co-funding MUST include (1) a budget for the total project that delineates the co-funded components, and (2) a letter of support signed by a responsible official of the co-funding organization summarizing the organization's interest in the technology or problem solution and the nature of the co-funding support.

Final review will be made by the CIEE Director in consultation with the Research Board; the final score will be based on the Director's assessment of the overall contribution of the proposed project to CIEE's mission.

Where to send proposals: The original and seven single-sided copies of the proposal should be sent, with official signatures from the proposer's Contract/Grant office, to:

Jim Cole, Director of CIEE
c/o UERG
2539 Channing Way
Berkeley, California 94720

Proposals must be RECEIVED by CIEE no later than 5:00 p.m., Friday, 1 November 1991. All proposals received after this deadline will be returned without consideration.

Further information:

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Carl Blumstein or Mike Lederer: (510) 642-9588

Attachment I

Multiyear Project Summaries

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Introduction

The attached summaries of eleven current CIEE multiyear projects describe:

- Project (or subproject) multiyear objectives
- Accomplishments of prior phases (if applicable)
- Current phase activities
- Current phase products
- Project (or subproject) benefits and impact
- Future directions
- Principal investigator and research organization (along with the supporting investigator and research organization, if applicable) and the CIEE program manager
- Funding

The summaries are organized by program in the following order: Building Energy Efficiency (BEE), Air Quality Impacts of Energy Efficiency (AQI), and End-Use Resource Planning (ERP).

Three multiyear projects—Efficient Systems for Thermal Distribution, Assessment of Natural Gas and Electric Vehicles, and Integrated Estimation of Load Shapes and End-Use Energy Intensities in Commercial and Residential Buildings—are composed of three or more subprojects. Full descriptions of the subprojects are included.

Building Energy Efficiency (BEE) Program

Topic

Integrated Lighting Systems (ILS)

Project BEE.ILS.1

Integrated Envelope and Lighting Technology to Reduce Electric Demand

Multiyear Project Objectives

1. Develop integrated building envelope and lighting systems that enhance comfort and productivity while minimizing energy use and peak demand.
2. Stimulate industry development and market introduction of promising integrated systems.
3. Provide utility planners with measured energy and demand performance databases and projections of probable impacts.
4. Provide design tools and information that will enable designers, engineers, and owners to specify these technologies confidently.

Accomplishments of Prior Phases

1. Assessed potential energy/demand reduction benefits, performance targets, and probable market acceptance of various envelope and lighting technologies.
2. Reviewed existing, emerging, and future technologies in hardware, technology, and systems areas. Completed list of promising glazing and lighting systems. Compiled summaries of technical data for important system components.
3. Identified integrated sets of technologies for future study, including assessment of opportunities for and obstacles to integration.
4. Developed plans for demonstrations in future project phases. This involved identifying and planning specific demonstration projects and developing plans for monitoring performance and conducting post-occupancy evaluations.
5. Reviewed available design tools and utility design assistance programs.

Current Phase Activities

(The current phase is under development.)

Project Benefits and Impact

Electrical energy use in the commercial sector accounts for approximately one-third of all electricity use in California. Approximately 40% of this sector's electric energy consumption is directly attributable to lighting, while approximately 20% is used for cooling needs resulting in part from lighting heat loads. These two interrelated building subsystems also account for more than half of typical peak demand in California commercial buildings.

Building envelopes, especially building glazings, are a major source of peak cooling demand and energy use. They are also a source of daylight that may be exploited to offset electric lighting loads. Integrated with daylighting, lighting controls can allow significant reduction of lighting electrical demand and cooling loads.

Key building technology elements are now available but are not being used to their fullest potential. The goal of this project is to assemble the key elements into an integrated system in which the individual envelope and lighting technologies are linked by a "smart" control system.

Future Directions

The *Integrated Envelope and Lighting Technology to Reduce Electric Demand* PAC, consisting of CIEE sponsor representatives, will review the results of the prior phase, help disseminate these results, and provide comments to CIEE on the objectives, scope, and funding of future phases.

Future phases of this project could involve two activities: (1) field demonstrations, monitoring, evaluations, and transfer of integrated technologies identified in Phase I; and (2) R&D on promising components and systems identified in Phase I.

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Funding

Source	Prior Phases	Current Phase
CIEE	\$425,000	TBD*

NOTE: DOE continues to fund related R&D work at LBL, estimated at \$4,000,000 in 1991. Promising technologies developed through this separate effort will be considered in this CIEE project.

* The current phase is under development.

Building Energy Efficiency (BEE) Program

Topic

HVAC Distribution Systems (HDS)

Project BEE.HDS.1

Efficient Systems for Thermal Distribution

Subproject BEE.HDS.1.1

Improving the Energy Efficiency of Residential Air Distribution Systems

Subproject Multiyear Objectives

1. Measure the thermal performance and air-leakage characteristics of air distribution systems in representative homes in California and conduct analyses to understand the principal mechanisms that reduce thermal energy distribution efficiency and increase electrical peak demand for space heating and cooling.
2. Develop, test, and evaluate the cost-effectiveness of alternative approaches for improving thermal distribution efficiencies and reducing peak demand in both new and existing buildings (including duct installation standards, sealing technologies, and non-air distribution systems).
3. Develop and field-test a system for sealing leaks in existing duct systems.
4. Develop technically and economically defensible recommendations for improving efficiency and reducing peak demands for new buildings, including recommendations for the Title 24 residential energy code.

Accomplishments of Prior Phases

The first phase of the project focused on the basic research needed to lay the groundwork for larger-scale technology development, policy design, and policy implementation for residential thermal energy distribution. The principal accomplishments of the first phase's efforts were the completion of a 31-house field study to characterize residential air distribution performance and the development of a simulation tool that can accurately account for inefficiencies in the air distribution system and interactions with the house.

The field-study results generally correspond to the findings of earlier, less detailed studies, provided field confirmation of improved diagnostic tools, and provided system/house characterization data for use in the simulation codes and in the development of retrofit protocols. Highlights of the field results include:

1. Building envelopes appear to be approximately 30% tighter for houses built after 1979.
2. Duct system air tightness showed no apparent improvement in post-1979 houses.

3. Distribution-fan operation added an average of 0.45 air changes per hour (ACH) to the average measured rate of 0.24 ACH.
4. An average of 20% of the furnace heating effect was lost due to duct conduction alone.

The simulation tool is based on DOE-2 for the thermal simulations, MOVECOMP (an air-flow network simulation model) for the duct/house leakage and flow interactions, and a simplified combined heat and mass transfer model of the duct performance. The first complete set of simulations performed for a new ranch house in Sacramento indicated that steady-state duct-system efficiencies vary from 50% to 90% with outside temperature and that the location of the return duct has a large impact on duct-system efficiency during the cooling season.

Current Phase Activities

1. Performing laboratory testing of an internal-access sealing technology for residential air distribution systems. This includes a literature review to select appropriate aerosol-sealant technologies for laboratory testing. The material delivery efficiency and sealing effectiveness (as a function of leak size) of the promising alternatives under varying conditions in the laboratory will also be quantified.
2. Performing simulation-based sensitivity analysis to extend the limited-impact analysis performed in Phase I to other house/system types and to evaluate and compare the savings potential of various retrofit options. The parameters that will be varied in the simulations include the level of insulation and air-tightness of the building envelope, the location and leakage level of both supply and return ducts, the size and operating characteristics of heating and cooling equipment, and the severity of the climate.
3. Extending the simulation tool and field-monitoring capabilities to single-family houses with zone conditioning, including detailed field measurements in one house.
4. Developing a detailed retrofit protocol and simulating its expected effectiveness for a well-defined housing stock and climate. This effort represents a crucial technology transfer component of this project and will require close cooperation with utility staff in charge of DSM programs.

Anticipated Products of Current Phase

- Laboratory-based feasibility analysis of internal-access sealing
- Sensitivity analysis of air distribution inefficiencies
- Analysis of residential zone conditioning performance
- Detailed retrofit protocol for residential air distribution systems
- Final report

Future Directions

The *Efficient Systems for Thermal Distribution PAC*, consisting of CIEE sponsor representatives, will review the results of the current phase, help disseminate these results, and provide comments to CIEE on the objectives, scope, and funding of future phases.

The third phase of this subproject will focus on field testing of the technologies and protocols developed in the current phase, on additional technology development, and on additional technology transfer through California's Title 24, the California Home Energy Rating System, and utility DSM programs. In the future, this subproject might expand to include examination of small commercial buildings.

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Funding

Source	Prior Phases	Current Phase
CIEE	\$90,000	\$185,000
SCE	—	\$20,000
PG&E	—	\$50,000
SMUD	—	\$20,000
TOTAL	\$90,000	\$275,000

NOTE: DOE has supported related research by the Principal Investigator in a parallel effort that complements this CIEE-funded project; estimated DOE complementary funding was \$90,000 in prior phases and is \$130,000 in the current phase.

CIEE Publications

The following CIEE research report documents the findings of this project. The projected date of publication is June 1992.

Improving the Energy Efficiency of Residential Air Distribution Systems in California

Building Energy Efficiency (BEE) Program

Topic

HVAC Distribution Systems (HDS)

Project BEE.HDS.1

Efficient Systems for Thermal Distribution

Subproject BEE.HDS.1.2

Localized Thermal Distribution Systems for Office Buildings

Subproject Multiyear Objectives

1. Develop a better understanding of the thermal comfort, ventilation, energy, and overall economic performance of LTD systems as compared to conventional centralized HVAC systems.
2. Develop analytical techniques and data needed to model the performance of LTD systems in building energy analysis and simulation programs.
3. Identify key areas where the energy efficiency of LTD systems could be improved without significantly compromising worker satisfaction.
4. Develop an engineering/applications guide describing recommended practices for applying LTD systems in an energy-efficient manner and disseminate results to the building industry, utilities, and building code officials.
5. Identify the applicable California building standards and codes that require modification to allow compatibility with LTD technology.
6. Recommend changes to applicable ASHRAE and current California building codes and standards to promote the energy-efficient and cost-effective application of LTD systems.

Accomplishments of Prior Phases

1. Conducted a series of tests to determine the thermal and ventilation performance of two LTD systems (the Task Air Module floor-supply and Personal Environments Module desk-level supply systems) in UCB's controlled environment chamber.
2. Developed a plan for field study of LTD systems in open-plan offices. This study determined the impact of LTD technology on building energy consumption and thermal comfort.
3. Using computer simulation, evaluated LTDs' influence on building energy consumption to determine optimum ways of designing and operating such systems in the future.

Current Phase Activities

1. Performing two field studies in selected buildings with operational LTD systems according to the experimental plan prepared in Phase I.
2. Performing experiments on LTD systems in the controlled environment chamber based on an analysis of Phase I results.
3. Making recommendations for LTD system design and operating procedures that minimize system costs and energy use while optimizing overall system effectiveness.
4. Identifying key elements required to model the effects of LTD technology in preparation for whole-building energy simulations using the latest version of DOE-2 during Phase III.

Anticipated Products of Current Phase

- California office building code and standards analysis
- Office building field experimentation plan
- Laboratory experiments on LTD
- Assessment of LTD system energy modeling issues

Subproject Benefits and Impact

It has become increasingly difficult for conventional, centralized HVAC systems to satisfy the environmental preferences of individual office workers. Offices now have heat-generating equipment whose loads may vary substantially among workstations and that may be rearranged periodically. There is also a growing awareness of the importance of workers' comfort, health, and productivity. In response to these developments, LTD systems have been introduced to supply air in the vicinity of the occupants and under their direct control.

The comfort and energy-use characteristics of these systems are poorly understood. This project will provide technical information to the industry and design professions to encourage energy-efficient product development and design approaches, assist utilities in projecting future energy-use trends resulting from the use of such systems, and recommend approaches to regulating these systems within California codes and standards.

Future Directions

The *Efficient Systems for Thermal Distribution* PAC, consisting of CIEE sponsor representatives, will review the results of the current phase, help disseminate the results, and provide comments to CIEE on the objectives, scope, and funding of future phases.

The second phase includes an LTD field test, a whole-building energy analysis, and an assessment of design, subsystem components, and operational practices to improve energy and environmental performance. It also includes an evaluation of building standards and code revisions.

The third phase will emphasize technology-transfer activities, which include developing an LTD applications and engineering guide, conducting a workshop, and providing information on necessary changes to building standards and codes.

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Funding

Source	Prior Phases	Current Phase
CIEE	\$130,000	\$135,000
SCE	-	\$12,500
PG&E	-	\$20,000
TOTAL	\$130,000	\$167,500

NOTE: DOE has supported related work by LBL in a parallel effort that complements this CIEE-funded project; estimated DOE complementary funding was \$100,000 in prior phases and is \$35,000 in the current phase.

CIEE Publications

The following CIEE research report documents the findings of this project:

Localized Thermal Distribution for Office Buildings (publication pending)

Building Energy Efficiency (BEE) Program

Topic

HVAC Distribution Systems (HDS)

Project BEE.HDS.1

Efficient Systems for Thermal Distribution

Subproject BEE.HDS.1.3

Cold-Air Distribution (CoAD) Systems for Office Buildings

Subproject Multiyear Objectives

1. Investigate the thermal and ventilation performance of devices and systems for implementing CoAD in commercial office buildings.
2. Determine the energy and electric power demand associated with different CoAD options.
3. Recommend guidelines for designing, installing, and operating CoAD diffusers to provide adequate ventilation efficiency and thermal performance in rooms.
4. Transfer results to potential users of CoAD via a design guidebook and a workshop.
5. Recommend desired changes in existing building standards and codes to ensure compatibility with CoAD technology.

Accomplishments of Prior Phases

1. Tested a commercially available diffuser, recently developed for CoAD applications, under typical commercial office building operating conditions at UCB's controlled environment chamber.
2. Developed and tested a performance simulation technique that provided results in agreement with prior published data on laminar and turbulent flows. The simulation model was based on a k-e model of turbulence generated by both shear and buoyancy.
3. Transferred the latest version of DOE-2 to Humboldt State University (HSU).
4. Identified and installed necessary weather tapes for selected California sites at HSU.
5. Calibrated standard outputs with standard inputs using DOE-2.
6. Formulated a preliminary definition of the prototype commercial building to be used in the second phase of the work.

Current Phase Activities

Current phase activities have focused on assessing the relevance and importance of CoAD to California commercial buildings. The following issues are being examined:

- Trade-offs between CoAD installation and the loss of economizer operation.
- Current practices and trends in California's new commercial buildings and their implications for CoAD acceptability in the future.
- Site-specific economic attractiveness of CoAD for selected California climates.
- Comparisons between CoAD energy consumption and a "base case" of a conventionally cooled building, first with no TES and then with partial and full TES. The most recent version of DOE-2 was modified to simulate CoAD and TES systems.

Anticipated Products of Current Phase

- Assessment report on the site-specific relevance and usefulness of CoAD technology to new commercial buildings in California
- Completion of analysis and results of experimental investigation of diffuser performance under realistic conditions in an office environment
- Numerical model of occupant comfort for zones cooled with CoAD
- Final report

Subproject Benefits and Impact

Since CoAD delivers air at a lower temperature than conventional systems, a smaller volume of air is needed, thus decreasing the size of the required air distribution system. A savings in either distribution energy or building volume can occur and may offset the additional costs associated with producing air at lower temperatures. CoAD systems may be most beneficial with low-temperature TES.

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Funding

Source	Prior Phases	Current Phase
CIEE	\$135,000	\$155,000

Building Energy Efficiency (BEE) Program

Topic

HVAC Distribution Systems (HDS)

Project BEE.HDS.1

Efficient Systems for Thermal Distribution

Subproject BEE.HDS.1.4

Reducing Losses in Hydronic Distribution Systems with Fluid Additives

Subproject Multiyear Objectives

1. Evaluate the feasibility of using drag-reducing additives to reduce pumping power in hydronic thermal distribution systems in buildings.
2. Investigate and measure the relevant characteristics of the fluids in question.
3. Conduct experiments to validate performance and economic projections.
4. Disseminate the results to building energy system engineers, utilities, building managers, and key organizations.

Accomplishments of Prior Phases

The first phase of the project focused on a feasibility study of the use of drag-reducing additives in hydronic heating and cooling systems in buildings. The following activities were undertaken:

1. Reviewed the known flow characteristics of some drag-reducing fluids.
2. Analyzed the corresponding hardware and operational characteristics of a typical hydronic system.
3. Evaluated the most promising fluids, resulting in the identification of some that would be suitable as thermal transport agents.
4. Conducted an energy and economic study that concluded that as much as 50% of pumping power could be saved with existing technology.

Current Phase Activities

Current phase activities focus on acquiring a better knowledge of fluid characteristics, particularly their degradation and reconstitution characteristics. The following activities are being conducted to design new systems and implement a drag-reducing fluid approach:

1. Constructing an experimental installation that allows measurement of all the necessary fluid properties and their flow characteristics, such as the dynamic response to degradation and reconstitution.
2. Measuring heat transfer to determine the effect of the viscoelastic drag reduction on heat exchangers.
3. Refining predictive and design analyses and determining the need for more advanced experimental work.

Anticipated Products of Current Phase

- New experimental installation
- Experimental data on flow and heat-transfer characteristics
- Refinement of the proposed implementation approach

Subproject Benefits and Impact

This research will provide the information necessary to develop a technological approach that uses drag-reducing additives to achieve substantial energy savings in hydronic thermal distribution in buildings.

Laboratory and field tests have shown that surfactant additives significantly reduce the pressure drop in turbulent flow. Preliminary analyses indicate that pumping power can be reduced at full load by about one-half in a typical piping system. Analysis was also conducted on large hydronic cooling and heating systems in buildings (100,000 ft² minimum); savings were calculated to be 10% to 15% of the total energy consumption.

Preliminary analysis of hydronic systems suggests that the nationwide savings for commercial and large industrial/residential buildings would be on the order of \$285 million and \$350 million per year, respectively. For California, it is estimated that the savings for heating and cooling in buildings alone could be \$30 million per year.

Future Directions

The *Efficient Systems for Thermal Distribution* PAC, consisting of CIEE sponsor representatives, will review the results of the current phase and provide comments to CIEE on the objectives, scope, and funding of future phases.

The next phase will consist of additional experimental and design work in the technical areas identified in the current phase as being in need of further information or refinement. Experiments in actual building systems may also be conducted if necessary. Specific design recommendations based on research will be made, with an emphasis on technology transfer.

Principal Investigator and Research Organization

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Funding

Source	Prior Phases	Current Phase
CIEE	\$54,000	\$128,000

CIEE Publications

The following CIEE research report documents the findings of this project:

Reducing Pumping Power in Hydronic Distribution Systems by Use of Drag-Reducing Fluid Additives (publication pending)

Building Energy Efficiency (BEE) Program

Topic

Commercial Cooling Systems (CCS)

Project BEE.CCS.1 Thermal Energy Storage

Multiyear Project Objectives

The overall goal of this multiphase project is to develop comprehensive acceptance, start-up verification, and long-term diagnostic testing procedures and technologies that promote the cost-effective operation of TES systems.

Accomplishments of Prior Phases

1. Collected information from TES owners, system designers and engineers, manufacturers, contractors, utilities, and EPRI to determine the major TES operational problems and identify ways to eliminate these problems using commissioning procedures.
2. Conducted a workshop in which information on TES problems and solutions was exchanged among various TES industry groups.
3. Analyzed available data on TES systems' field performance in shifting electricity use from on-peak to off-peak periods; assessed measured performance data and loading conditions for conventional cooling systems.
4. Developed preliminary TES diagnostic, acceptance, and start-up verification procedures intended to improve TES system operation.
5. Developed case studies that examined existing TES facilities.

Current Phase Activities

1. Continuing to analyze TES field data and case-study information, measured performance data, and loading conditions for conventional cooling systems.
2. Completing prototype diagnostic, acceptance, and start-up verification procedures, including performance tests applicable to a broad range of TES systems.
3. Validating performance tests and other commissioning procedures through field trials.

Anticipated Products of Current Phase

- Prototype performance tests and other commissioning procedures
- Analyses of TES and conventional cooling system field data and case-study information

Project Benefits and Impact

Peak cooling loads in commercial-sector buildings contributed about 6,000 MW to the total utility peak load in California. Shifting a portion of this peak demand to off-peak hours would defer the need for utilities to acquire new peak generating capacity.

Many existing TES systems are not performing as originally anticipated. Often these systems are not constructed as originally designed. Start-up testing and operator training are also often limited. The acceptance and start-up verification procedures developed and tested in this project are intended to help TES owners and utilities eliminate these problems.

Future Directions

The *Thermal Energy Storage* PAC, consisting of CIEE sponsor representatives, will review the results of the current phase and assist in disseminating the results.

Future work in the topic of Commercial Cooling Systems will be developed based on the scoping activities completed in 1992.

Principal Investigator and Research Organization

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Funding

Source	Prior Phases	Current Phase
CIEE	\$245,000	\$150,000*

* Maximum funding available. Actual CIEE funding will depend on the level of in-kind utility cofunding. Up to \$100,000 of in-kind cofunding for test-site instrumentation and commissioning engineers is anticipated.

Building Energy Efficiency (BEE) Program

Topic

Residential Cooling Systems (RCS)

Project BEE.RCS.1

Peak Power and Cooling Energy Savings of Shade Trees and White Surfaces

Multiyear Project Objectives

1. Assess and document the reflective and absorptive characteristics of various building and paving materials for reducing building cooling loads and recommend ways to use these materials in utility DSM programs.
2. Document the air conditioning energy savings of shade trees and white surfaces by instrumenting and monitoring energy use in a few selected residential, public, and commercial buildings.
3. Compare building energy use simulation results with monitored data and refine and validate prediction algorithms.
4. Provide overall analyses of the impact of trees and white surfaces.

Accomplishments of Prior Phases

The direct (building-scale) effects of high-albedo coatings and increased vegetation were examined by monitoring the outdoor and indoor microclimates and cooling energy use in several buildings in Sacramento. Six houses and one school building were fully instrumented for this purpose, and variables were logged every ten or twenty minutes during September and October 1991. The variables included solar radiation on vertical and horizontal surfaces; surface temperature at several outside and inside points, such as roofs, external walls, ceilings, attics, and interior walls; indoor and outdoor air temperatures at several points; air conditioner supply and return temperatures; indoor and outdoor relative humidity; wind speed and direction; soil moisture at two levels and subsoil temperatures at three levels; and air conditioner energy use. The sites were categorized as either vegetation cases or albedo cases.

In one case, a house had an initial albedo of 0.18, which was increased to 0.77 after whitening with an elastomeric roof coating. The whitening of the roof eliminated all the cooling energy needs of that house during September (a particularly hot month) and October (with outdoor temperatures as high as 40°C).

Another house had no trees on the south and west sides except for some small plants along the walls. Two small trees (in pots) were positioned along the west wall to partially shade two windows and the middle area of the wall. A third small tree was positioned near a south window. Each tree was about 2.3 m tall and 1.5 m across, and the

leaves started at a height of about 1.5 m. Preliminary results indicate a savings of approximately 40% in cooling electricity at ambient temperatures of about 40°C.

Current Phase Activities

1. Assessing the reflective and absorptive (albedo) properties of various building and paving materials through a review of manufacturers' data and through contact with industry representatives. Cost-benefit analyses and assessments of various implementation strategies will be conducted.
2. Preparing an assessment plan to evaluate the impacts of shade trees and white surfaces on building energy and electrical demand. Two approaches will be considered: a parallel approach consisting of the concurrent monitoring of two identical and unoccupied buildings, one of which uses shade trees and white surfaces; and a serial approach consisting of the pre-retrofit monitoring of a building to establish baseline performance, followed by monitoring of the building retrofitted with shade trees and white surfaces. The approach taken will depend on the availability of similar buildings, the level of accuracy required, and various costs.
3. Evaluating the impact of shade trees and white surfaces on building energy use and electrical demand through an experimental plan for selected residential, small commercial, and small industrial-type buildings; audits conducted with installed monitoring equipment; analysis of electricity use, demand, and other building energy data collected for several months during the cooling season; and building simulations conducted as described in the experimental plan.
4. Determining energy and peak power savings attributable to shade trees and white surfaces and assessing the benefits and costs of various incentive mechanisms that encourage customer adoption of these energy efficiency options for three representative cities in California.

Anticipated Products of Current Phase

- Analysis of performance data on white surfaces
- Installation of monitoring equipment and acquisition of baseline measurements and data on energy and peak demand savings from white surfaces and shade trees
- Overall cost-benefit analyses and assessment of incentives for encouraging the use of white surfaces and shade trees

Project Benefits and Impact

Average and peak residential cooling loads are driven by solar gain for most California climates. Since opaque surfaces account for approximately 85% of the envelope area, control of the solar heat gain through those surfaces could substantially reduce or eliminate cooling loads in residential-scale buildings.

Future Directions

CIEE will collaborate with its sponsors in evaluating the results of this initial effort and in deciding whether expanded efforts are needed to quantify the impacts of shade trees and white surfaces on building cooling loads.

CIEE is also developing a parallel multiyear project, *Analysis of Energy Efficiency and Air Quality*, which will evaluate the wide-scale use of shade trees and white surfaces in reducing urban air temperatures (the heat-island effect). The potential impact of lower urban air temperatures on smog formation will also be examined.

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Funding

Source	Prior Phases	Current Phase
CIEE	—	\$40,000
SMUD*	—	\$160,000
TOTAL	—	\$200,000

* SMUD also supplied one-half FTE of field support staff and monitoring equipment for this project.

Building Energy Efficiency (BEE) Program

Topic

Residential Cooling Systems (RCS)

Project BEE.RCS.2

Alternatives to Compressor Cooling in California Transition Climates

Multiyear Project Objectives

1. Develop low-energy cooling technologies and building engineering practices as alternatives to compressor-based cooling in residential buildings.
2. For California transition climate zones, demonstrate that proper design of the building shell, alternative low-energy cooling equipment, and smart control strategies can maintain indoor comfort in residential buildings without the use of compressor air conditioning.
3. Apply research results to building designs, allowing downsized compressor systems and reduction of peak load in hotter California climates.

Accomplishments of Prior Phases

(This is the first phase of a multiphase effort.)

Current Phase Activities

1. Developing a working definition of transition climates.
2. Defining prototypical buildings and operating scenarios.
3. Performing a preliminary assessment of low-energy cooling technologies.
4. Performing a detailed characterization of the body's thermal conditions under typical noncompressor-cooled interior environments.
5. Experimentally measuring the potential of night storage through ventilation or evaporative cooling.
6. Developing an analytical procedure to account for the impact of air movement on convective heat transfer within a building in conjunction with hourly whole-building energy simulations.
7. Improving and validating evaporative cooler models, with emphasis on part-load efficiency, water usage, and fan power consumption.

8. Identifying and evaluating institutional and consumer barriers to alternative low-energy cooling strategies.
9. Identifying and evaluating integrated ventilation control strategies appropriate to transition climates, including development of control algorithms for implementing such strategies in a prototypical house.
10. Evaluating architectural implications of alternative low-energy cooling strategies, including window shading, ventilative and evaporative cooling, and passive thermal storage.

Anticipated Products of Current Phase

- Improved analytical tools and empirical knowledge necessary to predict the effectiveness of various low-energy cooling strategies, including proposed guidelines for establishing the value of air movement for offsetting elevated temperatures, augmentation of hourly whole-building energy simulations to account for the impact of air movement on convective heat transfer within a building, augmented and validated evaporative cooling models, and empirical data concerning night storage potential from natural ventilation and evaporative cooling.
- Definitive information concerning the acceptable indoor comfort and health conditions related to evaluation of alternative cooling strategies.
- Preliminary alternative cooling system strategies, including improved integrated control strategies and integrated envelope designs.
- Preliminary assessment of the potential for integration of alternative cooling strategies into building architecture, the need and potential for modification of building energy standards, and the potential for adverse public perceptions.

Project Benefits and Impact

In California, residential air conditioning currently has a very poor load factor. This is especially true in the transition climates, where systems may be operated for only a few hundred hours per year. The investment in generation, transmission, and distribution capacity required to meet this load is enormous.

This research will examine low-energy alternatives to compressor systems. Though the emphasis is on eliminating compressors in California's transition climates, many of the strategies to be examined could also reduce demand in hotter regions. The research focuses on transition climates because load factor is so poor and because noncompressor cooling is technically easier in these climates.

Eliminating compressor cooling systems in transition climates appears to be technically and economically feasible. Among the low-energy technologies applicable to cooling residences are evaporative cooling, natural and induced ventilation, reflective coatings, shading with vegetation and improved glazing, passively charged thermal storage, and radiative cooling. In addition to reducing electrical peaks, noncompressor cooling alternatives reduce the need for production and use of CFCs or hydrochlorofluorocarbons.

Despite these alternatives, compressor-driven cooling consumes a large and growing share of peak power in California transition climates. This research will address ways to mitigate this situation.

Future Directions

The *Alternatives to Compressor Cooling in California Transition Climates* PAC, consisting of CIEE sponsor representatives, will review the results of the first phase, help disseminate these results, and provide comments to CIEE on the objectives, scope, and funding of future phases.

Future phases of this project are anticipated to involve two activities: (1) development of building designs and control strategies that can meet the stated criteria without radical alterations to current construction practices; and (2) collaboration with builders, utilities, and local governments to build and monitor residential buildings using such designs and control strategies.

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Funding

Source	Prior Phases	Current Phase
CIEE	-	\$375,000

Air Quality Impacts of Energy Efficiency (AQI) Program

Topic

Alternative Transportation Systems (ATS)

Project AQI.ATS.1

Assessment of Natural Gas and Electric Vehicles

Subproject AQI.ATS.1.1

Alternative Fuels Market Study

Subproject Multiyear Objectives

1. Identify groups of consumers most attracted to the attributes of alternative-fueled vehicles (AFVs) and most willing to adapt to their constraining attributes.
2. Observe how these consumers make their decisions and respond to a variety of incentives.
3. Analyze how these consumers will influence the purchases of later buyers.
4. Estimate the market penetration of EVs and NGVs under a range of market, economic, and technological conditions.

Accomplishments of Prior Phases

1. Developed a theoretical framework for studying consumer demand for alternative fuels in terms of the decision-making process of individuals disaggregated by market segment.
2. Conducted an auto clinic at the Rose Bowl in which 250 randomly selected individuals test-drove electric, natural gas, and methanol vehicles, followed by interviews of eleven focus groups.
3. Evaluated national survey data of house infrastructure and trip length to estimate the initial target market for EVs.
4. Developed and performed initial testing (with three households) of an interview game called PIREG (Purchase Intentions and Range Evaluation Game) to simulate the purchase and use of EVs using detailed travel diaries from households for validation.

Current Phase Activities

Research in Phases II and III has three central goals: to study in more depth consumer responses to home refueling and recharging as well as limited range and slow

recharge/refuel time; to measure the potential market for AFVs in California; and to initiate a longitudinal (panel) study of the AFV market. This year's activities include the following:

1. Conducting a telephone survey of current EV owners in California to study recharging habits, travel behavior, consumer satisfaction, and innovator characteristics.
2. Interviewing 100 compressed natural gas (CNG) home-refueling users in Ontario, Canada, focusing on recharging habits, travel behavior, consumer satisfaction, and innovator characteristics. The study is being conducted in Ontario because it is the only location in North America with a large number of CNG home-refueling units in place.
3. Conducting at least 15 PIREG interviews to understand how households with good information will make decisions about purchasing and using limited-range vehicles. In the gaming interview, potential purchases or uses of the EV are tested against the actual habits and decisions of the participants for validation.
4. Conducting a random-sample mail survey to identify the portions of the market most likely to purchase AFVs in the early market and to understand how to identify those persons by demographics and other variables found in the previous research. This market survey will be mailed to a scientific sampling of the population in the air quality nonattainment regions of California.
5. Conducting a panel study to better understand the travel behavior (specifically trip length) of individuals and consumer responses regarding their choices for AFVs. A randomly selected sample of several hundred citizens from air quality nonattainment areas will be contacted periodically to track their response to developments in the AFV market.

Anticipated Products of Current Phase

- Study of current EV owners
- Study of CNG home refuelers
- PIREG report

Subproject Benefits and Impact

This project will identify the early household markets for EVs and NGVs and indicate the responsiveness of individuals in these market segments to various incentives. Market penetration of AFVs will be forecast for a range of economic and technological conditions. Findings from this study can be used to guide investment decisions in AFVs, electricity capacity, refueling infrastructure, and support services for the vehicles. Findings can also be used to create the most effective incentives and pricing structures for increasing market penetration of EVs, NGVs, and methanol vehicles and the fuels they use.

Future Directions

The *Assessment of Natural Gas and Electric Vehicles* PAC, consisting of CIEE sponsor representatives and other interested organizations, will review the results of the current effort and assist CIEE in defining the scope and funding of future project phases.

The next phase of this project will continue the work with PIREG, the random-sampling mail survey, and the panel study.

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Funding

Source	Prior Phases	Current Phase
CIEE	\$116,000	\$103,000
UERG	-	\$20,000
TOTAL	\$116,000	\$123,000

CIEE Publications

The following CIEE research report documents the findings of this project:

Market Potential of Electric and Natural Gas Vehicles (publication pending)

Air Quality Impacts of Energy Efficiency (AQI) Program

Topic

Alternative Transportation Systems (ATS)

Project AQI.ATS.1

Assessment of Natural Gas and Electric Vehicles

Subproject AQI.ATS.1.2

Fleet Market Potential of Natural Gas and Electric Vehicles

Subproject Multiyear Objectives

1. Compile a complete inventory of government and private fleets in California and create a database for future reference.
2. Identify organizations with fleets amenable to the use of AFVs and determine which of those would be most willing to incorporate AFVs into their fleets.
3. Analyze the criteria used in fleet vehicle purchase decisions and how these criteria vary among fleet types (large vs. small, public vs. private, and so on).
4. Develop a framework for continual evaluation of AFV fleet market potential.

Accomplishments of Prior Phases

(This is the first phase of this subproject.)

Current Phase Activities

1. Performing a literature review and inventory of fleets to collect all data and information available on fleets and to review all relevant studies, including the recent survey by the CEC and, possibly, current surveys by SCE and PG&E; proprietary studies conducted in California by various auto, oil, electric, and natural gas companies; and previous fleet studies funded by EPRI, the Electric Vehicle Development Corp., and Argonne National Laboratory (ongoing).
2. Identifying of the position and role of individuals responsible for making fleet vehicle purchases in an organization. Emphasis will be placed on identifying those who are influential in the decision-making process. The activities in this task will be accomplished via phone inquiries and interviews.
3. Conducting personal interviews with fleet managers and operators to gain insights that will aid in designing the questionnaire for the subsequent mail survey. Primary decision-makers will be screened for their willingness to participate in the mail survey.

Anticipated Products of Current Phase

- Inventory of California fleets
- Assessment of the criteria used in fleet vehicle purchase decisions across the fleet population
- Forecasts of fleet market penetration by AFVs for a range of economic, technological, and regulatory conditions
- Analytical framework for continued analysis of AFVs in fleet applications
- Taxonomy framework for vehicle fleets
- California fleet inventory database

Subproject Benefits and Impact

This project will identify the early fleet markets for EVs and NGVs, characterize the diverse fleet market for AFV market studies, determine the responsiveness of fleet owners and operators to various incentives, and forecast the likely market penetration of AFVs into the fleet market for a range of economic and technological conditions.

Findings from this study can be used to guide investment decisions in AFVs, electricity capacity, refueling infrastructure, and support services for the vehicles. Findings can also be used to create the most effective incentives and pricing structures for increasing market penetration of electric, natural gas, and methanol vehicles and the fuels they use.

Future Directions

The *Assessment of Natural Gas and Electric Vehicles* PAC, consisting of CIEE sponsor representatives and other interested parties, will review the results of the current effort and assist CIEE in defining the scope and funding of future project phases.

In the second phase of this project, a mail survey will be administered to collect detailed information on fleet characteristics and vehicle purchase decisions. The questionnaire will be sent to a scientifically selected sample of fleet managers representative of the different fleet types. The first part of the survey will be designed to collect descriptive data on fleet characteristics and practices, such as fleet composition, refueling methods, and special vehicle features. The second part of the survey will solicit information regarding vehicle purchase decisions, such as the importance of resale value, range limitations, air conditioning (an amenity not conducive to EV operation), and possible consideration of an AFV purchase.

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Funding

Source	Prior Phases	Current Phase
CIEE	N/A	\$95,000

Air Quality Impacts of Energy Efficiency (AQI) Program

Topic

Alternative Transportation Systems (ATS)

Project AQI.ATS.1
Assessment of Natural Gas and Electric Vehicles

Subproject AQI.ATS.1.3
Economic Incentives Study

Subproject Multiyear Objectives

1. Examine economic incentive systems to introduce alternative fuels and AFVs.
2. Estimate the cost savings associated with the use of these economic incentives.
3. Assess the overall feasibility of emissions trading as a means to introduce alternative fuels and AFVs.

Accomplishments of Prior Phases

1. Reviewed relevant literature on marketable permit systems and completed a case study of the Environmental Protection Agency's lead phase-down program.
2. Surveyed car dealers for twelve vehicle manufacturers in the Sacramento area from January through July 1991. Dealers were asked to provide cost information on emission control parts for a variety of engine families. This data was combined with information on manufacturers' and dealers' markup and assembly costs to estimate the total cost of emissions control per vehicle.
3. Built a simulation model using the cost and emissions data described above. The model solves for the least-cost allocation of emissions control among manufacturers, subject to meeting emission standards.

Current Phase Activities

1. Completing the simulation work for vehicles and incorporating the information for AFVs in the simulation model. Cost savings associated with a marketable permit system for introducing EVs and NGVs will then be estimated. In addition, the costs of obtaining emission standards under the conventional regulatory approach will be estimated.
2. Examining the robustness of the simulation results and their sensitivity to the choice of functional forms for gasoline vehicles, the emission characteristics of EVs and NGVs, and assumptions about the costs of producing these vehicles.

3. Designing a marketable permit system for fuel suppliers by analyzing four options: 1) the fuel volumes approach, where fuel suppliers are required to provide a minimum assigned volume of fuels based on projected demand; 2) the separate criteria pollutants approach, where fuel suppliers must meet a fuel-sales-weighted standard for individual pollutants; 3) the fuel pool emission standard, where each fuel is assigned a rating and fuel suppliers must meet an average rating; and 4) the fuel components approach, where fuel suppliers are required to meet standards on the components of their fuels. In each case, fuel suppliers could either meet these requirements directly or purchase credits from other firms to satisfy the requirements.
4. Collecting data and performing initial work on a simulation model of fuel suppliers used to estimate cost savings associated with a marketable permit system compared to traditional command and control regulatory approaches.

Anticipated Products of Current Phase

- Simulation model for conventional vehicles
- Report on cost savings for AFVs with marketable permits
- Report on marketable permit system design for fuel suppliers

Subproject Benefits and Impact

This project will design and evaluate regulatory programs that use economic incentives targeted at vehicle and energy suppliers to introduce EVs and NGVs in California. The costs of reducing air pollution using various marketable credit schemes will be quantified. The relative costs of reducing emissions with zero-emission-vehicle mandates, uniform vehicle emission standards, tradeable and bankable credits for vehicle and fuel suppliers, and the prescriptive specification of fuels will be compared. The value of tradeable pollution credits for suppliers of EVs and NGVs, electricity, and natural gas energy will be calculated. These findings can be used to estimate the economic benefits of market-based regulatory programs for suppliers of alternative fuels and vehicles and to design more economically efficient regulatory programs.

Future Directions

The *Assessment of Natural Gas and Electric Vehicles* PAC, consisting of CIEE sponsor representatives and other interested parties, will review the results of the current effort and assist CIEE in defining the scope and funding of future project phases.

The next phase of this project will analyze the marketable permit for fuel suppliers.

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Funding

Source	Prior Phases	Current Phase
CIEE	\$60,000	\$103,000
UCTC*	-	\$75,000
TOTAL	\$60,000	\$178,000

* University of California Transportation Center

CIEE Publications

The following CIEE research report documents the findings of this project:

Economic Incentives to Introduce Electric and Natural Gas Vehicles and Reduce Mobile Source Emissions (publication pending)

Air Quality Impacts of Energy Efficiency (AQI) Program

Topic

Alternative Transportation Systems (ATS)

Project AQI.ATS.1

Assessment of Natural Gas and Electric Vehicles

Subproject AQI.ATS.1.4

Utility Impacts of Electric Vehicles

Subproject Multiyear Objectives

1. Understand the energy and emissions impacts of EVs and NGVs on utilities.
2. Transfer to other organizations the ability to estimate the impacts of EVs and NGVs.

Accomplishments of Prior Phases

1. Developed a method of analysis that uses EV attributes and assumed levels of market penetration and calculates electricity demands based on a variety of assumptions regarding whether the customer or the utility controls the timing of nighttime charging.
2. Applied this method to eight scenarios with EV populations in the SCE service territory ranging from 50,000 to 2 million vehicles.

Current Phase Activities

1. Extending the SCE analysis to other EV scenarios, specifying the need for supplementary energy from EV battery packs after normal nighttime charging. The analysis will cover supplemental energy supplied through greater "opportunity recharging" at normal power levels, through fast recharging at high power levels, or through hybrid EVs that derive such energy from a small internal-combustion engine. The impact of EVs is being examined, with closer attention paid to the means of achieving "smart control" of nighttime charging and to the miles-per-day of EV travel.
2. Conducting a modeling workshop on EV analysis to illustrate some of the modeling steps that may be useful to utility planners.
3. Expanding the SCE analysis to understand the impact of specific utility financial incentives designed to encourage the purchase and use of EVs. Of particular interest is the extent to which a utility may provide financial incentives without canceling out the benefits in the average electric rate expected from EVs. Utility incentives

will be examined in isolation and in combination with those provided by auto manufacturers or local and state agencies.

Anticipated Products of Current Phase

- Report of extended SCE analysis with additional EV scenarios
- Modeling workshop
- Report of utility impacts with financial incentives

Subproject Benefits and Impact

A method has been developed and demonstrated to study the impacts of EVs on an electric utility company. This analytical method extends utility impact studies by previous investigators and uses the production costing methods commonly employed by utility planners in California. Studies show that within the SCE service area, 2 million EVs could be powered with no need to build additional electricity-generating capacity. The method has been demonstrated in an analysis of eight scenarios for SCE. The analysis was conducted jointly by the principal investigator and planners in SCE's Electric System Planning group.

This analysis is being used to determine the cost savings associated with increasing levels of EV market penetration and the relative benefits of recharging those vehicles at different times of the day. These findings can be helpful in determining the implications of various levels of EV market penetration on electricity capacity planning, how much internal cross-subsidy of EVs and NGVs is justified for utilities, and the optimal method and investments for recharging EVs (for example, the use of "smart" pricing techniques).

Future Directions

The *Assessment of Natural Gas and Electric Vehicles* PAC, consisting of CIEE sponsor representatives and other interested parties, will review the results of the current effort and assist CIEE in defining the scope and funding of future project phases.

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Funding

Source	Prior Phases	Current Phase
CIEE	\$110,000	\$80,000

CIEE Publications

The following CIEE research report documents the findings of this project:

The Impact of Electric Vehicles on the Southern California Edison System (publication pending)

Air Quality Impacts of Energy Efficiency (AQI) Program

Topic

Emission Reduction Strategies (ERS)

Project AQI.ERS.1 Energy Efficiency and Air Quality

Multiyear Project Objectives

1. Investigate the direct and indirect effects of end-use efficiency on the reduction of photochemical smog in the SoCAB.
2. Improve the ability of current air quality management models to analyze the smog-mitigation role of energy efficiency measures in residential, commercial, and industrial buildings.
3. Investigate the potential for measures that reduce building cooling load, such as planting trees and whitening surfaces, to reduce temperatures in the lower atmosphere and slow smog formation.

Accomplishments of Prior Phases

(The current phase is the first of a multiphase effort.)

Current Phase Activities

1. Performing a literature review and field studies to develop surface parameterizations, including surface albedo, soil types and properties, anthropogenic heat release patterns, and biomass assessment. Performing initial investigation of the pollutant-trapping effectiveness of trees.
2. Reviewing current calculation procedures used by the ARB and SCAQMD to calculate fuel combustion emissions.
3. Compiling anthropogenic and biogenic emissions data for the SoCAB. This includes investigation of the effects of temperature.
4. Adapting a mesoscale meteorological model for interface with urban airshed modeling of the SoCAB and designing meteorological simulations.
5. Performing preliminary modeling, including sensitivity analyses and assessment of air-flow effects from surface modifications.

Anticipated Products of Current Phase

- Initial gridded database of surface characteristics for the SoCAB, including biomass inventory
- Recommendations for possible improvements to current methods for estimating end-use emissions
- Initial gridded database of emissions for the SoCAB
- Mesoscale meteorological model adapted for study of the SoCAB
- Preliminary meteorological data for input to simulations
- Technical progress report covering the results of sensitivity analyses and preliminary evaluation of air-flow effects

Project Benefits and Impact

Conventional mitigation strategies for air pollution typically emphasize source reductions at the point of emission without considering energy end-use patterns or energy efficiency measures. Policymakers and regulators generally do not have adequate information about the relationship of energy efficiency improvements and air quality. This multiphase project will address these issues directly by developing improved quantitative models and data for assessing the relationships among end-use energy efficiency, pollutant emissions, and changes in air quality. The results of this project will provide consistent information for the SoCAB on energy efficiency measures and emissions for incorporation into future air quality management plans.

This project is anticipated to resolve the issue of causality between urban temperature reduction and smog formation in the SoCAB. The research will test the hypothesis that wide-scale tree-planting efforts and surface whitening can contribute significantly to reducing photochemical smog as well as reducing energy use. The conclusions generated will be most relevant to the various policymakers involved in creating and modifying photochemical air quality requirements. In addition, new approaches and model enhancements providing better definitions of local and urban-scale transport processes will directly benefit the SCAQMD and possibly other local air quality management districts in California.

Future Directions

The *Energy Efficiency and Air Quality* PAC, consisting of CIEE sponsor representatives and other interested parties, will review the results of the first phase and assist CIEE in defining the objectives and scope of future project phases.

Future phases of this project will include reformatting of mesoscale simulations to include new data about surface characteristics and effects. Also, the meteorological input will be refined for use in urban airshed modeling of photochemical smog formation. Additional efforts will focus on completing the emissions and surface characteristics databases, integrating end-use energy improvements into future baseline emissions inventories, and validating emissions data. Assessments of the spatial and physical constraints of tree planting, the implications for water use in the Basin, the

potential for future fire hazard, and the pollutant-trapping effectiveness of various trees will be completed.

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Funding

Source	Prior Phases	Current Phase
CIEE	N/A	\$230,000

Air Quality Impacts of Energy Efficiency (AQI) Program

Topic

Gas Combustion Systems (GCS)

Project AQI.GCS.1

Formation of Nitrogen Oxides in Industrial Gas Burners

Multiyear Project Objectives

The overall goals of this three-phase project are to develop criteria for and demonstrate operation of ultra-low- NO_x , industrial, natural-gas-fired burners concomitant with the maintenance of high-energy efficiency. The following objectives have been established to accomplish these goals:

1. Understand the combustion processes and their relation to energy efficiency and the formation of nitrogen oxides in industrial natural-gas-fired burners; develop protocols by which burner performance can be optimized for low- NO_x and energy efficiency.
2. Develop and apply an advanced laser diagnostic for in-situ measurement of NO and NO_2 .
3. Extend current analytical capabilities for the design of practical burners by combining existing chemical kinetic and fluid dynamic models and apply this advanced capability systematically to the data acquired in support of the first objective.
4. Establish benchmark databases to evaluate analytical capabilities as design and predictive tools for end-use, natural-gas-fired burners in boilers, furnaces, and gas turbines of various sizes.
5. Develop and implement an active control methodology to achieve and maintain optimal performance of practical burners.

Accomplishments of Prior Phases

(The current phase is the first of a three-phase effort.)

Current Phase Activities

Phase I, currently in progress, is focused on developing the facility, diagnostics, and modeling. In addition, subscale testing is being conducted to assess the underlying hypothesis of the project and to evaluate experimental protocols. Phase II will demonstrate the various capabilities developed during the first phase and conduct the necessary screening studies to formulate a systematic plan for production testing (to be conducted during Phase III).

Phase I results will be documented in an interim report, which will be submitted at the end of that phase. A decision to proceed with Phase II will be based on interim progress in accomplishing the first-year objectives. First-phase activities include:

1. Designing, fabricating, installing, and testing a 100 MBtu/hr research burner at the UCI Combustion Laboratory (UCICL), scaled in relation to the Burner Engineering Research Laboratory furnace and developed under separate funding from GRI and the DOE. Burner design parameters are being developed in consultation with burner manufacturers and gas utilities.
2. Developing degenerate four-wave mixing (DFWM) technology to measure in-flame concentrations of NO and NO₂.
3. Developing and testing kinetic and mixing models in the context of a comprehensive code and applying state-of-the-art modeling to the UCICL burner to guide the experimental design, interpret the results of the experiment, and verify the format adopted for the database.
4. Surveying the burner and gas-user industry to determine the types of computer analysis models employed and their data requirements.
5. Conducting subscale testing on an existing test stand. The objectives are to test the hypothesis that mixing controls the attainment of ultra-low-NO_x performance in non-premixed burners and to develop the experimental protocols to be used for the 100 MBtu/hr burner.

Anticipated Products of Current Phase

- Design of 100 MBtu/hr research burner
- Construction of model furnace
- Protocol for ultra-low-NO_x, high-efficiency, commercial and industrial end-use natural-gas burners
- Advanced diagnostic for NO and NO₂ measurement
- Specification of benchmark-quality databases for development and evaluation by manufacturers and researchers

Project Benefits and Impact

The emission of NO_x from oil- and natural-gas-fired industrial and commercial boilers in the SoCAB must be reduced from current levels of 75 to 400 ppm to less than 30 ppm for boilers larger than 40 MBtu/hr and to less than 40 ppm for boilers greater than 5 MBtu/hr. Boilers with lower heat input ratings are excluded. Several boiler equipment manufacturers who attended a CIEE workshop expressed concern about their ability to comply with these emission requirements. Emission reductions are usually achieved through trial and error because current design tools do not adequately characterize NO_x emissions at these reduced levels. There is concern that boiler energy efficiency might be reduced by this trial-and-error process.

This project is intended to improve the understanding of the fundamental processes affecting NO_x production in industrial natural-gas burners and to develop design tools and controls that optimize overall low-NO_x and energy efficiency performance.

Future Directions

The *Formation of Nitrogen Oxides in Industrial Gas Burners* PAC, consisting of CIEE sponsor representatives and other experts, will review the results of the current effort, assist in disseminating the results, and provide comments to CIEE on the objectives, scope, and funding of future phases.

Phase II will bring together the capabilities developed and demonstrated in Phase I. The experimental facility will become the test bed, in conjunction with the DFWM and comprehensive modeling, to initiate screening studies. These studies will be used to establish the parametric sensitivity as well as resolve the challenges that develop in the integration of diagnostics and modeling with the experiment. Phase III will systematically study NO_x formation and energy efficiency performance of the 100 MBtu/hr burner at a variety of load levels, assess the predictive models and design databases, and verify and demonstrate the active control methodology.

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Funding

Source	Prior Phases	Current Phase
CIEE	N/A	\$376,000
SCG	N/A	\$100,000
TOTAL	N/A	\$476,000

NOTE: This CIEE-funded project will benefit from parallel GRI-funded research at SNL and LLNL and from GRI and DOE support of the Burner Engineering Research Laboratory, located at SNL.

Air Quality Impacts of Energy Efficiency (AQI) Program

Topic

Gas Combustion Systems (GCS)

Project AQI.GCS.2

Energy-Efficient, Low-NO_x and -CO Burners for Residential, Commercial, and Small Industrial Gas Appliances

Multiyear Project Objectives

The overall goal of this project is to understand the physical and chemical processes that control the formation and activity of nitrogen oxides and carbon monoxide in premixed combustion as it occurs in residential, commercial, and small industrial gas appliances. The research will evaluate the impact of new, low-polluting residential gas appliances (millions are now in use) on outdoor air-pollution levels.

The flames that occur in residential, commercial, and small industrial appliances are distinct from the large furnace flames under investigation in project AQI.GCS.1. These appliance flames are usually laminar rather than turbulent, premixed (in other words, air and fuel are mixed before being introduced into the combustion chamber), and in close contact with a heat transfer surface rather than far from wall interactions.

Diode laser spectroscopy has already demonstrated the remarkable sensitivity of 100 parts per billion for CO. The research team anticipates that a similar capability will be established for NO, N₂O, and NO₂ in the first phase of this project.

The multiyear objectives of this project are to:

1. Establish design criteria for ultra-clean (in other words, ultra-low emissions of NO_x, CO, and other nitrogen species), high-efficiency, end-use, premixed burners for residential and small industrial appliances.
2. Conduct analyses to help policymakers determine least-cost approaches to reducing NO_x emissions from residential and small industrial settings.
3. Develop laboratory models whereby optical species are measured by in-situ laser diagnostics that will be used to validate numerical models.
4. Develop numerical models that will be used in evaluating the end-use performance of premixed gas-fired burners.
5. Develop analytical tools that can predict the emission rates of NO_x in practical burners.

Accomplishments of Prior Phases

(This is the first of a two-phase effort.)

Current Phase Activities

1. Constructing a numerical model to simulate laboratory results.
2. Initiating minor species measurements using tunable laser diode absorption spectroscopy.
3. Designing and constructing a 30,000 Btu/hr laboratory experimental burner.
4. Concluding a literature search on the pollutant emission rates from natural-gas appliances used in the SoCAB.
5. Initiating laser Raman scattering measurements of temperature, N₂, O₂, CO₂, and H₂O.
6. Collecting appliance saturation and use data for assessing levels of pollutants emitted from residential gas appliances in the SoCAB.
7. Collecting rate data so that the gas-phase and surface-rate coefficients are incorporated in the numerical model.

Anticipated Products of Current Phase

- Preliminary results from modeling, laser Raman scattering, and tunable laser diode absorption spectroscopy
- Results of the literature search

Project Benefits and Impact

California urban air basins, especially the SoCAB, are greatly affected by NO_x emissions from a variety of sources, including cooking appliances, water heaters, and space heaters in residential and small industrial environments. Emission inventory and air quality monitoring data for the SoCAB show that NO_x emissions must be substantially reduced if the region is to meet the California and federal standards for NO₂, visibility, oxidant, and suspended particulate matter (PM10). To achieve this reduction, the SCAQMD has implemented several amendments for retrofitting existing power plants with NO_x-reducing techniques for stationary gas turbines, electric power generating boilers, industrial and commercial steam generators, and process heaters. In addition, more stringent emission requirements for residential water heaters are being considered. Additional opportunities for reducing NO_x emissions exist in the residential, commercial, and small industrial environments, where a significant fraction of natural-gas combustion occurs.

The results of this project will be used for designing and implementing state regulatory policies and utility DSM programs and to help industry comply with regulations affecting energy efficiency and air quality.

Future Directions

The *Energy-Efficient, Low-NO_x and CO Burners for Residential, Commercial, and Small Industrial Gas Appliances* PAC, consisting of CIEE sponsor representatives and other interested parties, will review the results of the current effort and assist CIEE in defining the scope and funding of future project phases.

Plans for the next phase include the following activities:

1. Collect additional data from the laboratory burner for model calculations.
2. Conduct sensitivity analysis on the numerical model.
3. Complete numerical modeling calculations for combustion-related variables.
4. Analyze strategies to reduce outdoor NO_x emitted from the residential sector.
5. Analyze experimental and modeling results.

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Funding

Source	Prior Phases	Current Phase
CIEE	N/A	\$400,000

End-Use Resource Planning (ERP) Program

Topic

Technology Performance Analysis (TPA)

Project ERP.TPA.1

California Utility Database on Monitored Performance of Efficient End-Use Technologies

Multiyear Project Objectives

The goals of this project are to identify, catalog, and evaluate utility and regulatory agency sources of measured data on the performance of energy end-use technologies and assess the needs of utility and CEC planners, program designers, and evaluators for measured data. The results of the first phase of this project will be used to determine the feasibility of developing an extensive database of information in future project phases.

Accomplishments of Prior Phases

(The current phase is the first of a possible multiphase effort.)

Current Phase Activities

1. Determining the characteristics of measured data in internal reports and memos prepared by technical and service staff of California utilities and the CEC. The conditions governing the availability of identified data will be assessed.
2. Evaluating the needs of utility and CEC planners, program designers, and evaluators for measured data. Their assessment of the adequacy of existing sources will be documented.
3. Creating a database on the performance of available end-use energy technologies containing information about sources and characteristics of measured data. If appropriate, procedures for expanding the database will be identified.

Anticipated Products of Current Phase

- An initial database containing monitored performance data generated by utilities and energy commission staff.
- A report documenting the feasibility of obtaining end-use data from informal utility and energy commission reports, including recommendations concerning the development of a more comprehensive database.

Project Benefits and Impact

Utilities and CEC staff need high-quality data on the field performance and load-shape impacts of new end-use energy-efficient technologies. This data can be used for least-cost planning and DSM program design and evaluation purposes.

Existing data on selected end-use technologies that is available from national organizations and utilities in other states may not adequately reflect the operational conditions in California end-use applications. California utilities have sponsored field tests of end-use energy technologies; however, much of this information is not readily available.

This project will attempt to make available an untapped source of end-use data and evaluations of conservation technologies. The resulting database, though not initially comprehensive, could help identify completed projects that provide useful information related to proposed DSM programs. This project will also provide a unique opportunity to assess the needs of planners, forecasters, and other potential users of the database.

Future Directions

The *California Utility Database on Monitored Performance of Efficient End-Use Technologies* PAC, consisting of CIEE sponsor representatives and other interested parties, will review the results of the first phase and assist CIEE in defining the objectives and scope of possible future project phases.

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Funding

Source	Prior Phases	Current Phase
CIEE	N/A	\$100,000

End-Use Resource Planning (ERP) Program

Topic

Advanced Forecasting Methods (AFM)

Project ERP.AFM.1

Integrated Estimation of Load Shapes and End-Use Energy Intensities in Commercial and Residential Buildings

Subproject ERP.AFM.1.1

Residential End-Use Energy Data and Load Profiles

Subproject Multiyear Objectives

The overall goal of this subproject is to analyze metered residential end-use data collected by California and other utilities to develop inputs for residential hourly load forecasting models. Analysis activities include developing methods for transferring end-use data collected in one service territory for use in forecasting hourly loads in another service territory. Model development activities include reviewing existing models and modeling procedures and recommending improvements based on findings from measured end-use data.

Accomplishments of Prior Phases

1. Obtained PG&E-monitored end-use residential load data; reviewed and edited the data to produce a fully debugged and consistent series of data files on residential energy end-use for analysis in subsequent project tasks.
2. Developed a method for extrapolating additional values from metered data for air conditioning equipment.
3. Used this method to develop inputs for existing CEC and PG&E peak-demand models.

Current Phase Activities

PG&E and the CEC are planning to adopt PC-HELM, a common hourly load forecasting model developed by EPRI. Researchers will be comparing the most advanced aspect of the current CEC peak-demand model—the representation of space-conditioning energy use as a function of time of day and climatic severity—with that currently used by PC-HELM. ICF Inc., EPRI's contractor for the development of HELM, has expressed interest in incorporating the findings into future releases of the product.

Anticipated Products of Current Phase

- Detailed report of findings
- Recommendations for improving the use of PC-HELM as a tool for forecasting hourly loads based on analysis of the PG&E data (if acceptable to the developer)
- Incorporation of recommended enhancements into the PC-HELM model (if acceptable to the developer)

Subproject Benefits and Impact

This project is developing improved tools and data for forecasting peak load in the residential sector; this will aid the CEC and California utilities both in increasing the accuracy of their forecasts and in developing load-management programs.

Future Directions

The *Integrated Estimation of Load Shapes and End-Use Energy Intensities in Commercial and Residential Buildings* PAC, consisting of CIEE sponsor representatives and other interested parties, will review the results of the prior phase and the scoping study on Advanced Forecasting Methods to determine the objectives and scope of future project (and subproject) phases.

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Funding

Source	Prior Phases	Current Phase
PG&E	\$25,000	—
CEC	—	\$50,000
TOTAL	\$25,000	\$50,000

End-Use Resource Planning (ERP) Program

Topic

Advanced Forecasting Methods (AFM)

Project ERP.AFM.1

Integrated Estimation of Load Shapes and End-Use Energy Intensities in Commercial and Residential Buildings

Subproject ERP.AFM.1.2

Commercial Sector End-Use Load Shape and Energy Utilization Intensity Data

Subproject Multiyear Objectives

1. Develop methods for accurately estimating commercial building end-use electric load shapes and EUIs that are less expensive than end-use metering.
2. Use these methods to refine current end-use estimates for representative commercial building types in the PG&E service territory.
3. Analyze the impact of these refined estimates of end-use load shapes and EUIs on predicted energy use and peak loads and on commercial-sector demand-side measures and programs.
4. Identify the methods' strengths and weaknesses; prioritize needs for additional data and analytical refinements; and help guide future end-use submetering, commercial submetering, and other utility efforts.

Accomplishments of Prior Phases

1. Using CIEE funding for a supplementary project in 1989 and an exploratory project in 1990, supported development of the End-Use Disaggregation Algorithm (EDA) by the principal investigator. This model disaggregates whole-building hourly loads into their end-use components using hourly weather data and some building characteristics and operational information.
2. Prepared the major data sets required to apply EDA to commercial buildings in the PG&E service territory, including more than 700 detailed on-site surveys, a year of hourly whole-building load shapes from more than 1,000 load research accounts, approximately 6,000 responses to a mail survey, and hourly weather data from five California sites.
3. Completed the analysis of these data sources to develop end-use load shapes and EUIs for four of the twelve building types used by PG&E and the CEC in forecasting commercial sector energy use. However, the final step in the analysis, which requires a major additional transformation of the data to represent buildings of different construction and equipment vintages, was reserved for the second phase.

Current Phase Activities

1. Completing the analysis of the first four building types.
2. Extending the analysis to the remaining eight building types used by PG&E and the CEC in forecasting commercial-sector energy use.

Anticipated Products of Current Phase

Report on the analysis and results from the project, including electronic data files that will allow direct incorporation of project results into CEC and PG&E commercial demand forecasting models.

Subproject Benefits and Impact

It is generally acknowledged that one of the problems in forecasting electricity demand and energy use is the absence of reliable data on end-use load shapes in the commercial sector. This multiyear subproject is intended to further develop and apply a model that can estimate end-use load shapes from data on whole-building load shapes. Successful development of this method will assist California utilities and the CEC in their commercial-sector demand-forecasting efforts and aid in the planning and evaluation of programs to manage demand.

Future Directions

The *Integrated Estimation of Load Shapes and End-Use Energy Intensities in Commercial and Residential Buildings* PAC, consisting of CIEE sponsor representatives and other interested parties, will review the results of the prior phase and the scoping study on Advanced Forecasting Methods to determine the objectives and scope of future project (and subproject) phases.

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Funding

Source	Prior Phases	Current Phase
CIEE	\$95,000	—
PG&E	\$108,000	\$175,000
CEC	—	\$100,000
TOTAL	\$203,000	\$275,000

End-Use Resource Planning (ERP) Program

Topic

Advanced Forecasting Methods (AFM)

Project ERP.AFM.1

Integrated Estimation of Load Shapes and End-Use Energy Intensities in Commercial and Residential Buildings

Subproject ERP.AFM.1.3

Office Equipment Energy Use, Load Profiles, Efficiency, and Trends

Subproject Multiyear Objectives

1. Develop methods for more accurate estimation of end-use electric EUIs for office information equipment used in the commercial sector.
2. Develop models to forecast energy use and peak demand for office information equipment used in the commercial sector.
3. Examine measures and programs for managing the load and reducing the energy use of office information equipment, using models developed in this subproject to assess the likely impact of these measures and programs.
4. Identify the strengths and weaknesses of the methods and results and prioritize needs for additional data and analytical refinements.

Accomplishments of Prior Phases

1. Reviewed available measured data and studies of energy use by various types of office information equipment.
2. Reviewed existing data from PG&E, CEC, SMUD, and other sources regarding the saturation of various types of office information equipment.
3. Developed a spreadsheet model to forecast energy use by seven categories of office information equipment in the PG&E service territory.

Current Phase Activities

First-phase analysis uncovered several areas for which additional analysis could substantially improve the accuracy of the spreadsheet model, including better data on equipment saturations in different building types and the possibility of using population, rather than floor area, as a driving force in the forecast.

Anticipated Products of Current Phase

- Revised spreadsheet
- Report documenting all new findings

Subproject Benefits and Impact

Uncertainty about the impact of office information equipment on commercial-sector electricity use is a major source of differences among forecasts of electricity use made by California utilities and the CEC. All parties acknowledge that better data and models are needed. This project is intended to improve the quality of future electricity forecasts for this rapidly growing end-use and to improve the methods for assessing the likely impacts of energy efficiency measures and programs that address this end-use.

Future Directions

The *Integrated Estimation of Load Shapes and End-Use Energy Intensities in Commercial and Residential Buildings* PAC, consisting of CIEE sponsor representatives and other interested parties, will review the results of the prior phase and the scoping study on Advanced Forecasting Methods to determine the objectives and scope of future project (and subproject) phases.

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Funding

Source	Prior Phases	Current Phase
PG&E	\$60,000	N/A

CIEE Publications

The following CIEE research report documents the findings of this project:

Office Equipment Energy Use and Trends (publication pending)

Attachment J

**Director's Discretionary Projects
(1990-1992)**

**Project: DD.90.05
An Efficiency Device for Exhaust Hoods**

Exhaust hoods are used in industrial spraying and painting operations to protect workers from fumes and aerosols. The exhaust hood draws air from the room over the industrial process area and vents it outside. The objective of this project is to develop and test a prototype airvest that draws air from the back of the worker and expels it from the front. This approach will eliminate the back-eddy that is caused when a worker blocks the air flow in conventional exhaust hoods. Tests indicate that this prototype airvest reduced tracer-gas concentrations at the facial level by factors of 100 to 800. In one test, the tracer-gas concentration at the facial level was 52 times smaller when exhaust air velocity was 56 feet per minute (fpm) with the airvest compared to a conventional exhaust hood operating at 118 fpm. CIEE is collaborating with the LBL researcher in distributing patent and other information to industrial exhaust hood manufacturers.

Ashok Gadgil, phone (510) 486-4651
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**Project: DD.91.01
Commissioning of Building Control Systems**

Many building EMCSs are not effective in reducing energy use and peak demand. The objective of this project is to collect and analyze field data on the performance of these systems, develop an understanding of the origins of performance problems, and make recommendations for future CIEE-sponsored research.

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University of California, Berkeley

**Project: DD.91.02
Methane Recovery in Advanced Integrated Ponding Systems (AIPS)**

Initial studies based on field tests have shown that construction, energy, and other operational costs of AIPS are significantly lower than those of conventional wastewater treatment plants. The purpose of this project is to develop a new methane gas recovery technology for AIPS. Methane-rich biogas is produced when settled organic solids are converted in the wastewater. CIEE support will be used to complete and conduct initial tests of the methane recovery technology. If results are promising, funding from other organizations will be sought to carry out more detailed testing and to analyze the costs and benefits.

William J. Oswald, phone (510) 689-3727
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Project: DD.92.01
Monitoring of Cool Roof System Performance

The Cool Roof system, developed by the Davis Energy Group, Inc., was installed at the Office of State Printing in Sacramento through funding provided by the CEC. This system reduces the cooling load and cooling energy use of low-rise commercial buildings while providing roof protection. The objective of this project, cofunded by SMUD, is to monitor the performance of the system during the heating and cooling seasons. This includes heat rejection via the night spray cycle, heat removal from the occupied space, electric energy, and thermal performance as compared to conventional roof, heating, and cooling systems.

Richard C. Bourne, phone (916) 753-1100
Davis Energy Group, Inc.

Project: DD.92.02
The Energy Performance of a Russian/German Modular Housing Technology

The objective of this project is to conduct a preliminary assessment of the energy performance of a modular housing technology developed by a German company, Bison, and marketed by a Russian company, Energotechpran, which produces modular housing panels under license from Bison. San Diego Gas and Electric Co. (SDG&E) has erected several modular housing units at a test site and is interested in evaluating their energy performance in various California climate zones and their compatibility with current construction practices and energy standards.

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Attachment K

Acronym List

ACH	Air changes per hour
AFM	Advanced Forecasting Methods (topic)
AFV	Alternative-fueled vehicle
AIPS	Advanced Integrated Ponding Systems
AQI	Air Quality Impacts of Energy Efficiency (program)
ARB	Air Resources Board
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ATS	Alternative Transportation Systems (topic)
BEE	Building Energy Efficiency (program)
CCS	Commercial Cooling Systems (topic)
CEC	California Energy Commission
CFC	Chlorofluorocarbon
CIEE	California Institute for Energy Efficiency
CNG	Compressed natural gas
CO	Carbon monoxide
CO ₂	Carbon dioxide
CoAD	Cold-air distribution
COM	Building Commissioning, Operations, and Maintenance (topic)
CPUC	California Public Utilities Commission
CSU	California State University
CURC	California Utility Research Council
DFWM	Degenerative four-wave mixing
DOE	U.S. Department of Energy
DSM	Demand-side management
EDA	End-Use Disaggregation Algorithm
EMCS	Energy management and control system
EPRI	Electric Power Research Institute
ERP	End-Use Resource Planning (program)
ERS	Emission Reduction Strategies (topic)
EUI	Energy utilization intensity
EV	Electric vehicle

GCS	Gas Combustion Systems (topic)
GRI	Gas Research Institute
HDS	HVAC Distribution Systems (topic)
HEV	Hybrid electric vehicle
HSU	Humboldt State University
HVAC	Heating, ventilating, and air conditioning
IAC	Intercampus Advisory Committee
IHC	Improved Building HVAC Controls (topic)
ILS	Integrated Lighting Systems (topic)
LADWP	Los Angeles Department of Water and Power
LBL	Lawrence Berkeley Laboratory
LLNL	Lawrence Livermore National Laboratory
LTD	Localized Thermal Distribution
NGV	Natural-gas vehicle
NO	Nitric oxide
NO ₂	Nitrogen dioxide
NO _x	Nitrogen oxide
PAC	Project Advisory Committee
PG&E	Pacific Gas and Electric
PIREG	Purchase Intentions and Range Evaluation Game
R&D	Research and development
RCS	Residential Cooling Systems (topic)
SBS	Sick Building Syndrome
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SCG	Southern California Gas
SDG&E	San Diego Gas and Electric
SMUD	Sacramento Municipal Utility District
SNL	Sandia National Laboratory
SoCAB	South Coast Air Basin
TES	Thermal energy storage
TPA	Technology Performance Analysis (topic)
TRP	Topical Research Plan
UC	University of California
UCB	University of California, Berkeley
UCD	University of California, Davis

UCI	University of California, Irvine
UCICL	UCI Combustion Laboratory
UCLA	University of California, Los Angeles
UCSB	University of California, Santa Barbara
UERG	Universitywide Energy Research Group
USC	University of Southern California
VMT	Vehicle miles traveled

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