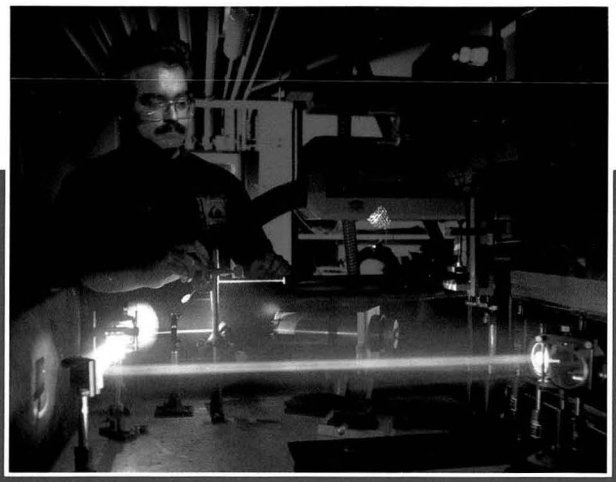
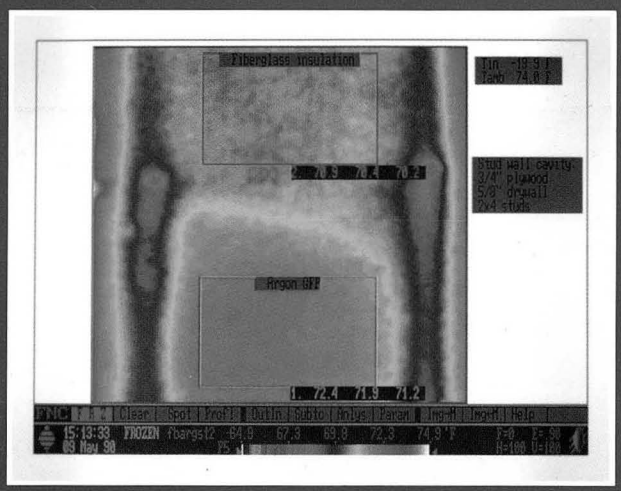
California Institute for Energy Efficiency
1991 Annual Report



Building Research Capabilities



Energy Efficiency R&D

Technology Transfer

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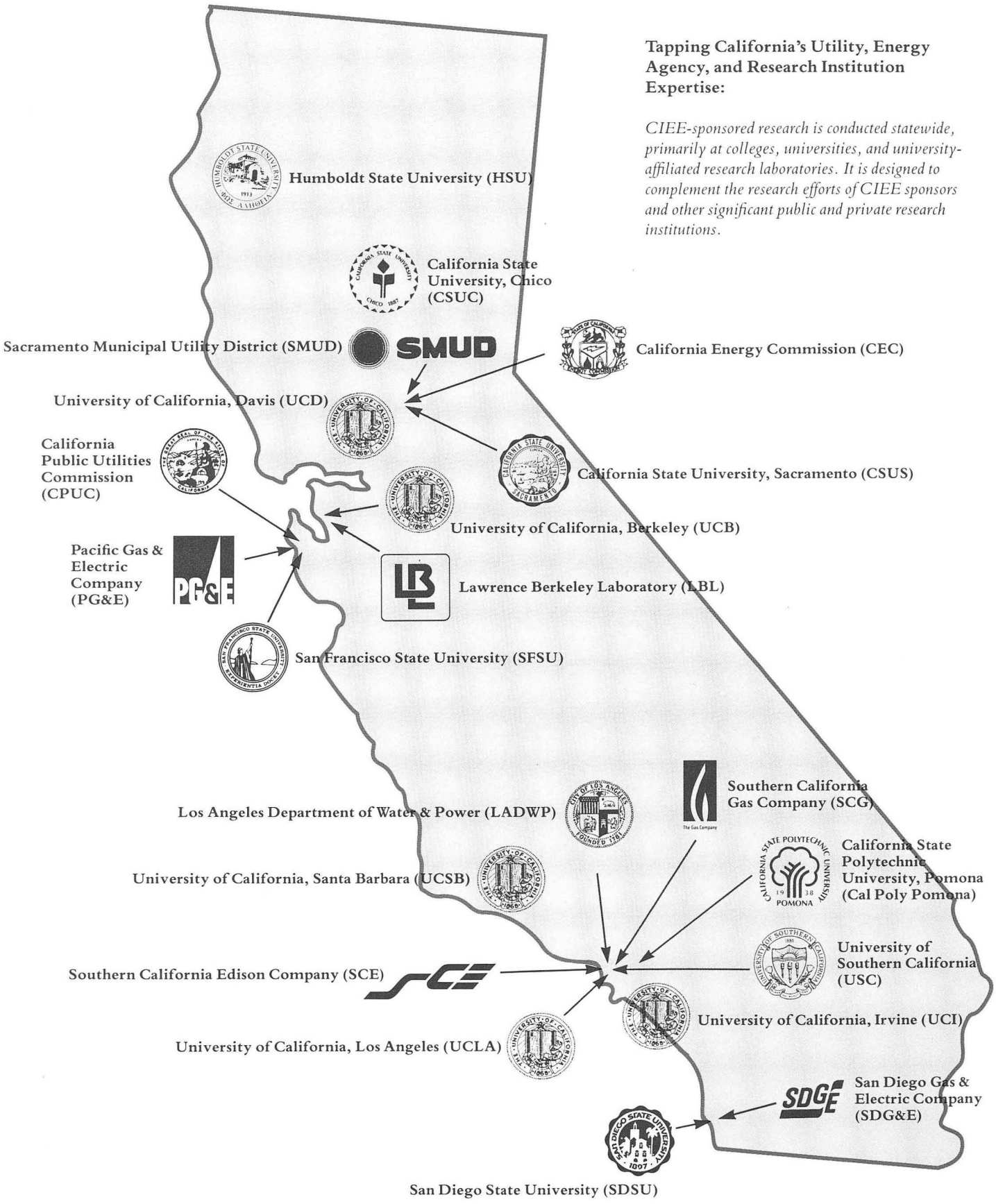
CIEE Sponsors and Participating Research Institutions

Tapping California's Utility, Energy Agency, and Research Institution Expertise:

CIEE-sponsored research is conducted statewide, primarily at colleges, universities, and university-affiliated research laboratories. It is designed to complement the research efforts of CIEE sponsors and other significant public and private research institutions.



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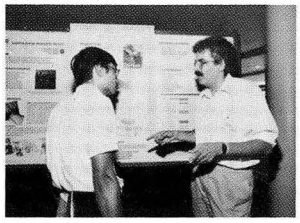
CIEE 1991 Annual Report



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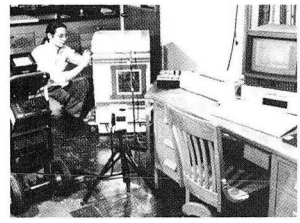
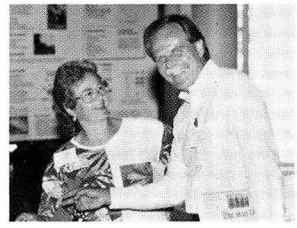
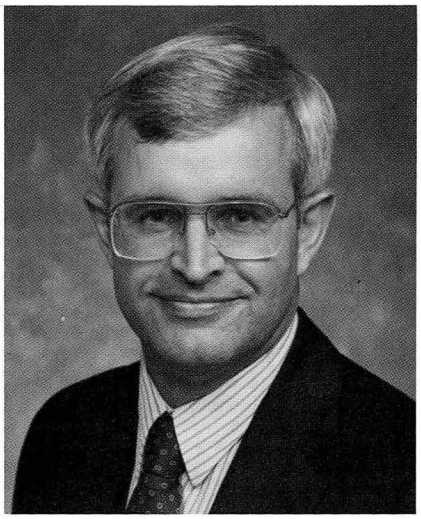
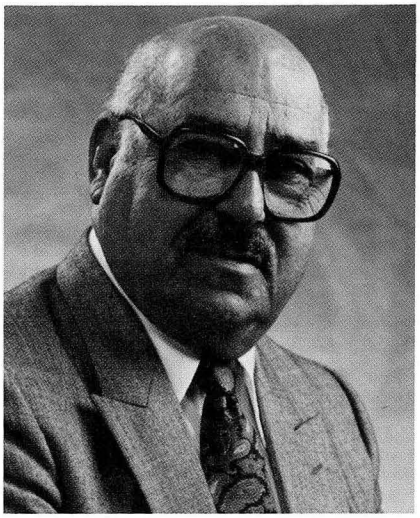






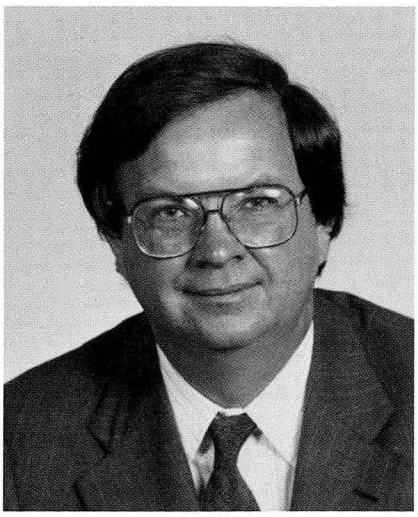
Virgil Rose
Senior Vice President and General Manager
Business Distribution Unit
Pacific Gas & Electric
1991 CIEE Research Board Chair

"I am pleased to be a part of The California Institute for Energy Efficiency. I see one of the real strengths of CIEE as being its potential to combine the creativity of researchers with the practical vision of utilities. If the utilities are to be really successful in energy efficiency, we absolutely have to build on the research work of CIEE."



Art Kevorkian
Commissioner, California Energy Commission
1991 CIEE Research Board Vice Chair

"Under the skillful guidance of Dr. Jim Cole, CIEE has really taken off in the past year. I am proud to be associated with its progress. CIEE has been very responsive to the needs of the Commission for research of energy-efficient technologies, data collection for demand forecasting, and investigation of combined energy/environmental issues. That research will directly contribute to more enlightened statewide energy policy in the years ahead."



Charles Shank
Director, Lawrence Berkeley Laboratory

"In just one and a half years CIEE has demonstrated the innovative role it can play in connecting California's best researchers with the state's utility professionals and energy policymakers. With its location at Lawrence Berkeley Laboratory, its sponsorship by investor-owned utilities, and its endorsement by energy agencies, CIEE is a real example of building the state's capability to develop and apply new energy-efficient technologies."

Director's Statement

Dr. James Cole
Director, CIEE

In 1988, a statewide collaboration of California's six largest electric and gas utilities, the California Public Utilities Commission, the California Energy Commission, the University of California, and Lawrence Berkeley Laboratory led to the creation of the California Institute for Energy Efficiency. CIEE was specifically established to respond to California's energy and environmental needs by tapping the scientific and technological capabilities of the state's universities, colleges, and university-affiliated laboratories in developing new energy-efficient technologies for buildings, industry, and transportation.

In 1990, with guidance from our sponsoring institutions and $4 million in annual funding from the utilities, CIEE began identifying, planning, and funding coordinated R&D on energy-efficient end-use technologies. The Institute has initiated a research program that includes eleven major multiyear research efforts in the fields of Building Energy Efficiency, Air Quality Impacts of Energy Efficiency, and End-Use Resource Planning. In addition, twenty-one exploratory projects were undertaken during 1990 and 1991.

Simultaneously CIEE has been building institutional capability by funding its R&D projects at California's colleges, universities, and university-affiliated laboratories, thereby cultivating strong ties between the state's academic institutions, utilities, and energy agencies. The U.S. Department of Energy (DOE) also plays a key role in allowing Lawrence Berkeley Laboratory to host CIEE's operations and in permitting CIEE to fund end-use efficiency R&D at the DOE national laboratories in California.

The innovative partnerships that created CIEE strengthen our organization's ability to accomplish effective technology transfer to California's utilities and building industry. In combination, CIEE's targeted energy-efficiency R&D, institution building activities, and technology transfer priorities form a comprehensive approach to solving the state's energy, economic, and environmental needs.

Many thanks to those who have contributed so significantly to CIEE's successes during this past year and a half. The CIEE staff and I look forward to extending the notable achievements summarized within this report through vital research in the years to come.

California's Energy Issues

Facing the Future with Innovation

CIEE's mission is to coordinate, plan, and implement a statewide program of medium to long-term (5–15 years) applied research aimed at advancing the energy efficiency and productivity of all end-use sectors in California. CIEE-sponsored research is conducted throughout the state at colleges, universities, and university-affiliated laboratories. With sponsor guidance CIEE has identified research topics in which the development of new energy-efficient technologies will yield significant energy, environmental, and economic gains for California ratepayers.

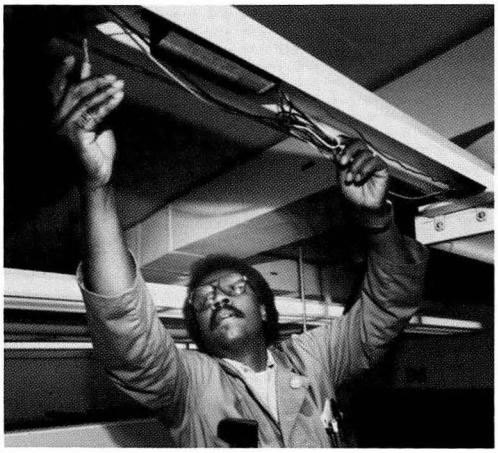
R&D Priorities

Identify, develop, and demonstrate efficient end-use energy technologies and processes that will address California's energy, environmental, and economic needs by:

- Improving building energy efficiency
- Improving air quality
- Developing new performance monitoring techniques, data, and models for end-use resource planning.

Relationship with Utilities, State Energy Agencies, and Research Institutions

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 guidance from the CIEE Research Board, technical support from CIEE's Planning Committee, and ongoing input from Project Advisory Committees 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 the rapid transfer of promising research results.



Electrician Mac Morgan is part of the solution to energy-related costs and pollution. Here he replaces an old lighting fixture with a new energy-efficient model as part of an office lighting retrofit program underway at Lawrence Berkeley Laboratory.

On California's highways and in its homes and offices, energy powers the appliances, vehicles, and equipment that provide diverse energy services. Implementing more efficient energy end uses can dramatically reduce the air pollution that results from fossil fuel combustion. CIEE R&D simultaneously emphasizes the economic and environmental benefits that can accrue to California's ratepayers from energy efficiency.

On a clear day the skyline of Los Angeles shines.

Too often, and especially in the summer, the same L.A. skyline is entirely obscured by smog from fossil fuel combustion.

A sea of electricity illuminates downtown Berkeley and distant San Francisco in a dramatic display of nighttime building electricity use.

1991 Highlights

R&D Program "Up and Running"

In 1991, CIEE planned, funded, and managed $5 million in multiyear research, exploratory research, Director's discretionary research, and technology transfer activities. The Institute's 1991 effort included $3.1 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.

The initial phases of four multiyear projects launched in early 1990 were completed in 1991. Eleven 1990 exploratory projects have been completed. Research is currently underway on eleven multiyear projects and ten 1991 exploratory projects, as well as on several Director's discretionary and scoping projects.

R&D Planning

CIEE's first Multiyear Research Plan for the period 1991-1995 was adopted by the Research Board in April 1991. The Research Plan details current multiyear projects, projects under development, and scoping activities within CIEE's three programs.

CIEE Research Projects

MULTIYEAR PROJECTS

Building Energy Efficiency Program

Alternatives to Compressor Cooling in Transition Climates

Efficient Systems for Thermal Distribution

Subprojects: Cold-Air (CoAD) Distribution Systems for Office Buildings; Improving the Energy Efficiency of Residential Air Distribution Systems; Localized Thermal Distribution Systems for Office Buildings; Reducing Losses in Hydronic Distribution Systems with Fluid Additives

Impact of Shade Trees and White Surfaces on Building Peak Loads and Cooling Energy Savings

Integrated Envelope and Lighting Technology to Reduce Electric Demand

Thermal Energy Storage

Air Quality Impacts of Energy Efficiency Program

Analysis of Energy Efficiency and Air Quality

Assessment of Natural Gas and Electric Vehicles

Subprojects: Alternative Fuels Market Study; Fleet Market Potential of Electric and Natural Gas Vehicles; Economic Incentives Study; Utility Impacts of Electric Vehicles

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

Formation of Nitrogen Oxides in Industrial Gas Burners

End-Use Resource Planning Program

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

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

Subprojects: Commercial Sector End-Use Load Shape and Energy Utilization Intensity Data; Office Equipment Energy Use, Load Profiles, Efficiency, and Trends; Residential End-Use Energy Data and Load Profiles

1990 EXPLORATORY PROJECTS

Analysis of Energy Use in Building Services of the Industrial Sector in California
An Assessment of Residential Evaporative Cooling Technologies in California
Comparative Evaluation of the Impact of Domestic Gas and Heat Pump Heating on Air Pollution in California
Customer Participation and End-Use Load Response to Voluntary DSM Programs
Flow and Energy Transfer in Enclosures
High Albedo Materials for Reducing Building Cooling Energy Use
Integrated Estimation of Commercial Load Shapes and Energy Use Intensities
Interactive Graphic Input to Superlite
Lighting Audit Tool: A Precursor to an Expert System for Specifying Energy-Efficient Lighting
Low Heat Loss, Non-CFC-Based Appliance and Building Insulation
Sensitivity Analysis of RAPRENOx

1991 EXPLORATORY PROJECTS

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

DIRECTOR'S DISCRETIONARY AND OTHER PROJECTS

A Survey of Impact Measurement Plans and Techniques in Support of Technology Performance Measurement
Commissioning of Building Control Systems
Efficiency Device for Exhaust Hoods
Evaporative Emissions from Automobiles in the South Coast Air Basin
Methane Recovery in Advanced Integrated Ponding Systems
Non-CFC-Based Appliance and Building Insulation: Initial Prototype Development
Peak Power and Cooling Energy Savings of White Surfaces and Shade Trees
Survey and Forecast of Market Demand and Supply of Energy-Efficient Lighting Products
The Energy Performance of Soviet/German Modular Housing Technology

Technology Transfer

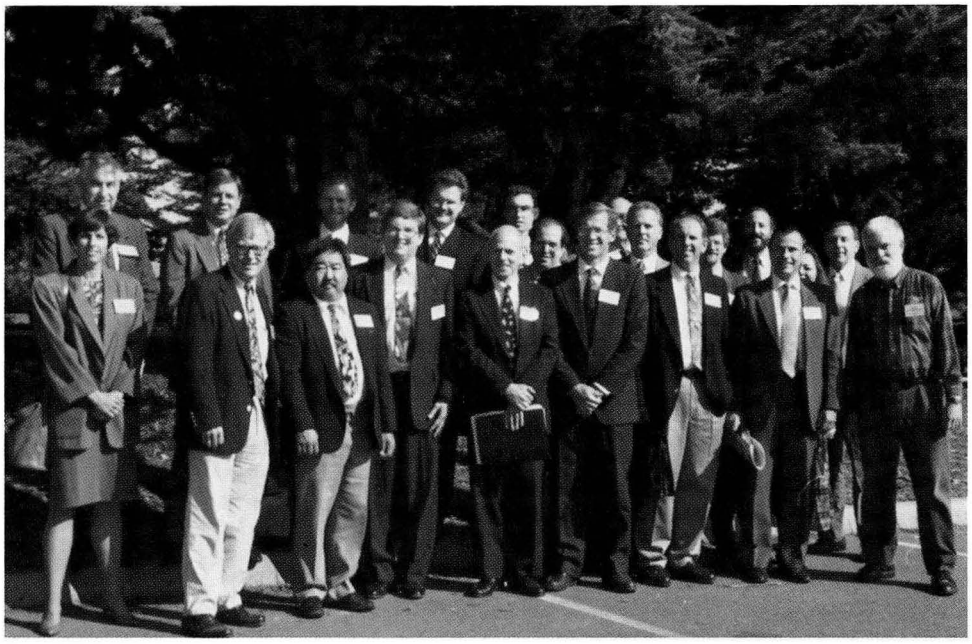
Michael Siminovich of LBL demonstrates advanced electronic ballast technology at the lighting lab as Association of State Energy Research & Technology Transfer Institutions (ASERTTI) members observe.

Strategy and Activities

The principal objective of CIEE's technology transfer effort is to communicate the objectives, scope, interim, and final results of CIEE's R&D projects to potential users such as CIEE sponsors, industry, government, and other research organizations. CIEE's technology transfer goals emphasize applying CIEE R&D, and overcoming technical and other barriers to the market adoption of new energy-efficient end-use technologies.

CIEE undertook a mix of technology transfer activities over the last year. These activities included general information dissemination (such as the CIEE Research News), report preparation and distribution, numerous workshops, Project Advisory Committee activities, and the Institute's first R&D Conference.

The close involvement of the Research Board and the Planning Committee in the formulation and management of CIEE's research guarantees that useful, achievable goals are pursued. In fact, these partnerships are one of the Institute's most efficient means of transferring research results to the private sector. A positive feedback is also established when CIEE fosters energy efficiency capabilities in the state's research community.



ASERTTI members gathered in Berkeley this fall to discuss national trends and concerns regarding energy efficiency technology transfer. Front row, left to right: Carol Gates, U.S. Department of Energy (DOE); Dave Grimsrud, Minnesota Building Research Center; Dennis Fukumoto, California Energy Commission (CEC); CIEE Director Jim Cole; Shel Feldman, Wisconsin Center for Demand Side Management; Mark Settle, Iowa Energy Center (IEC); Larry Flowers, National Renewable Energy Laboratory; Don Markle, North Carolina Alternative Energy Corp.; Carl Blumstein, UC's Universitywide Energy Resources Group. Back row: Jack White and Gunnar Walmet, New York State Energy Research and Development Authority; Karl Brown, CIEE; Dale Tiller, National Research Council of Canada (NRCC); Guy Newsham, NRCC; George Caan, Washington State Energy Office (WSEO); Pete Loux, Kansas Electric Utilities Research Program; Larry Bean, IEC; Jeffrey Harris, WSEO; Ed Vine, CIEE; Joan Blundall, IEC; and Ted Kapus, DOE.

CIEE Workshops & Forums

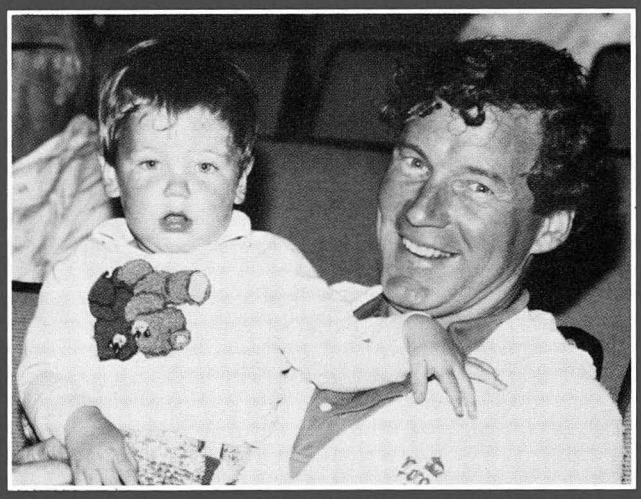
Selected events: 1990–1991

1990

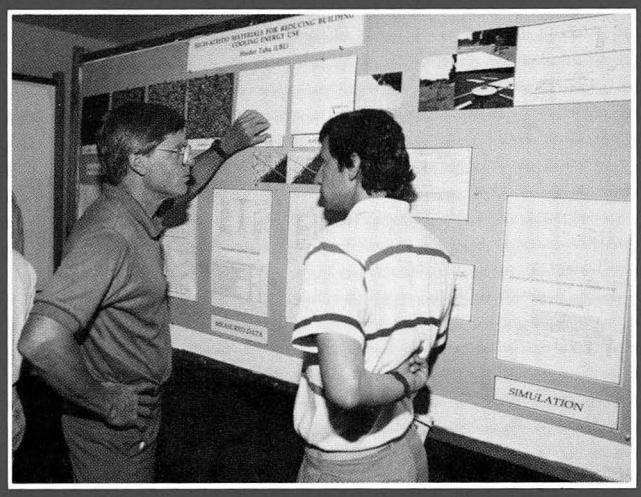
- Sixty participants attended a low-NOx combustion workshop sponsored by CIEE and the Southern California Gas Company (SCG) in Ontario, California, on June 28. The workshop helped meet CIEE's goal of obtaining industry and research community input regarding two proposals under consideration from UC Irvine and UC Berkeley.
- More than 100 people representing 40 organizations gathered at the Asilomar Conference Center in Pacific Grove, California, on July 11–13, to address issues affecting the introduction of alternative transportation fuels into the California market. Methanol, natural gas, electricity, and reformulated gasoline were the primary fuels discussed. CIEE cosponsored this conference.
- More than 40 participants gathered in Oakland in November to discuss alternatives to "the load from hell," as one utility representative termed the summer electric load from compressor-driven residential air conditioning in California (approximately 5000 megawatts occurring for only 150–200 hours annually). The Institute subsequently assembled a research team to participate in a new multiyear project.
- Pacific Gas & Electric (PG&E), with CIEE and other cosponsors, hosted an industry-utility workshop on the energy-related trends and energy efficiency potential of computers and other office equipment in San Ramon, California, on October 28-30, 1990. CIEE and PG&E also cosponsored a follow-up workshop on R&D needs and opportunities on October 7, 1991.

1991

- A workshop was held on May 15, at the Oakland Airport Hilton to discuss the findings of a scoping project that studied technology performance measurement techniques, and to receive participants' input on major measurement issues. Utility and regulatory agency representatives responsible for managing (or evaluating) demand-side management (DSM) programs and interested CIEE Planning Committee members were in attendance.
- CIEE's 1991 R&D Conference was held August 27-29 at UC San Diego, in La Jolla, California. Researchers, practitioners, and utility representatives reviewed CIEE-funded research on new energy-efficient technologies and processes of significance to California.
- CIEE hosted a two-day meeting on October 9-10, of the Association of State Energy Research & Technology Transfer Institutions (ASERTTI) in Berkeley, California. CIEE supports ASERTTI's mission to expand and enhance cooperative research and technology transfer between states and regions.



Charles Wade Christensen samples one of the numerous research presentations with his father, David Christensen of PG&E.



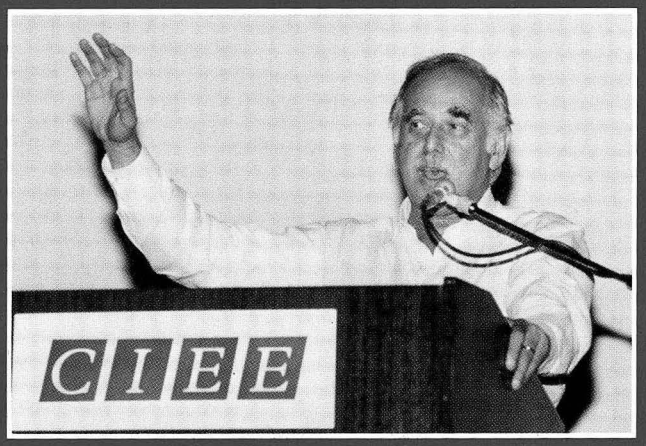
UC Berkeley's Ed Arens (left) questions Haider Taha of LBL regarding his exploratory research and poster display showing the reduction in residential energy consumption for cooling achieved by whitening surfaces.

Terraced waterfalls complement the La Jolla weather as researchers stroll across campus discussing energy efficiency. Left to right: Bill Pennington of the CEC, Max Sherman of LBL, Al Figueroa of San Diego Gas and Electric (SDG&E), Richard Shoen of UCLA, Gregg Ander of Southern California Edison (SCE), and Steve Selkowitz of LBL.

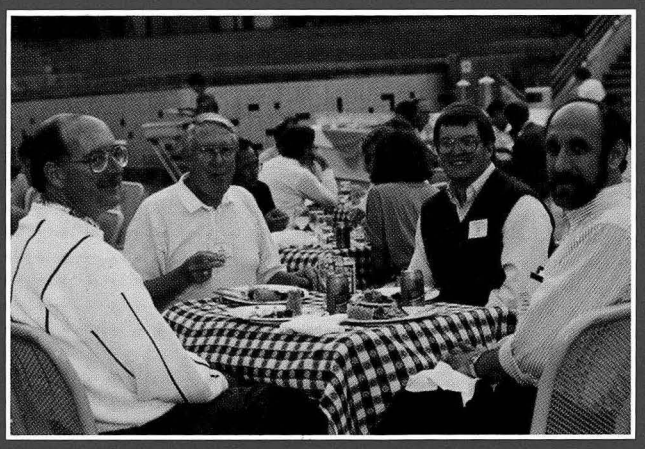
CIEE Annual Conference

In August 1991, CIEE sponsored its first Research and Development Conference at UC San Diego. For three days, more than 120 researchers, practitioners, and utility representatives from throughout the nation met for talks and presentations of CIEE-funded research on new energy-efficient technologies and processes important to California's economy and environment. The first night's barbecue was followed by an opening address from Virgil Rose, CIEE's 1991 Research Board Chair and the Senior Vice President and General Manager of PG&E's Business Distribution Unit, and a plenary talk by S. David Freeman, General Manager of Sacramento Municipal Utility District (SMUD).

The second and third days were filled with presentations of multiyear research and a poster session that communicated exploratory research results. Chosen by Conference Chair, Ed Vine, the beautiful La Jolla campus was a sun-drenched setting for days filled with both formal and informal "technology transfer." Sponsors had a chance to assess the quality and impact of CIEE's research program, and to meet researchers face to face. The gathering was a great success and will be repeated annually as a part of CIEE's technology transfer activities.



S. David Freeman, General Manager of SMUD, emphasizes the importance of energy efficiency during his opening plenary talk.

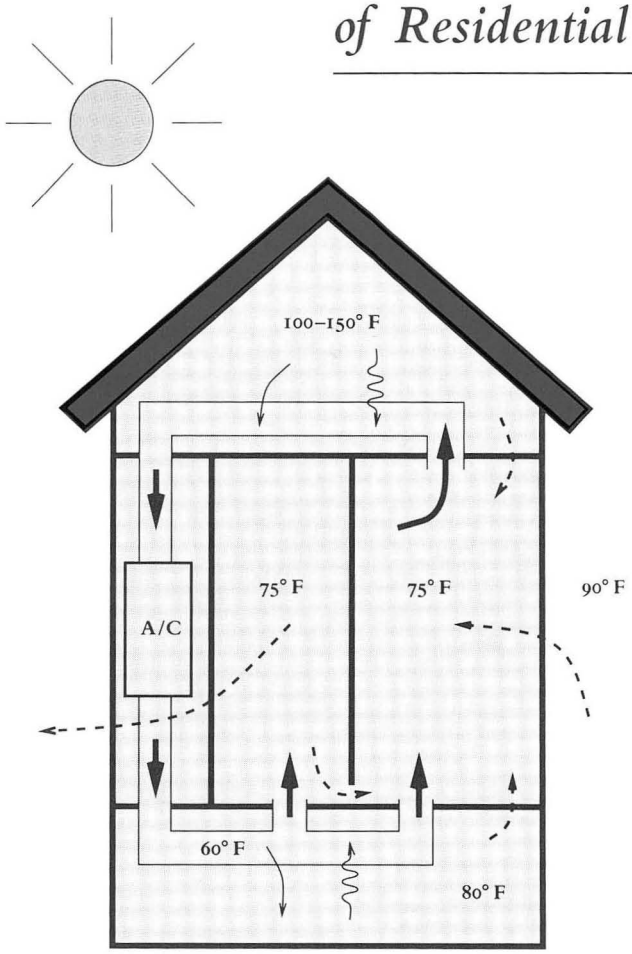


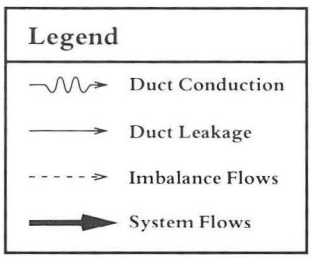
Left to right: Malcolm Lewis of Bein Frost & Associates; Al Gough, President of the Lighting Research Institute; CIEE Director Jim Cole; and Steve Selkowitz of LBL enjoy the first night's barbecue dinner in UC San Diego's Price Center pavilion.

SUBPROJECT HIGHLIGHT

BUILDING ENERGY EFFICIENCY

Improving the Energy Efficiency of Residential Air Distribution Systems





Schematic representation of the loss mechanisms associated with residential air distribution systems in unconditioned spaces.

Background

Each year in California, massive amounts of energy pour through building air distribution systems to heat and cool homes and offices. Metal ducts, flexible ducts, and fiberglass ducts link heating and cooling equipment to the areas in buildings that require space conditioning. On a peak summer day, 4 gigawatts of air conditioning power flows through 100,000 miles of ductwork to cool California homes.

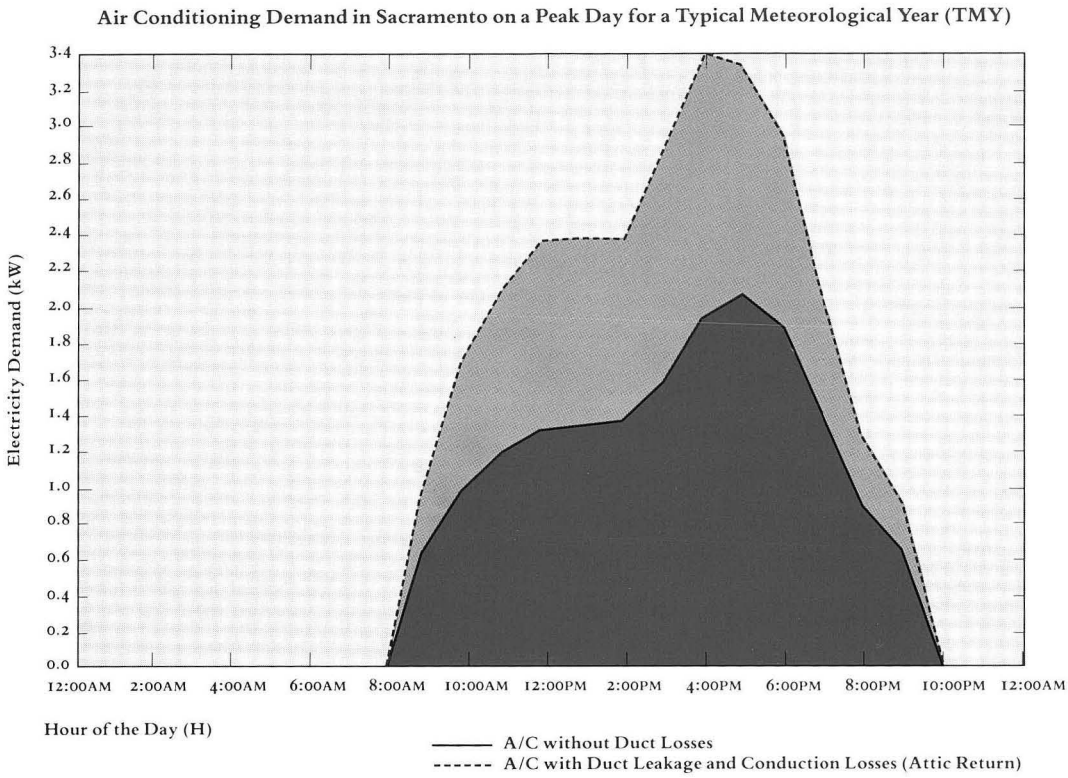
Research Challenge

As part of a broader investigation into thermal distribution in buildings, Mark Modera and a team of researchers at Lawrence Berkeley Laboratory (LBL) launched a three-year effort focusing on the performance of air distribution systems in California's homes. This year, the team quantified the impacts of the following weaknesses in residential air distribution systems:

- leakage between ducts and surrounding areas
- excessive infiltration of outside air and uneven temperatures caused by supply- and return-air flow rates that are not in balance
- heat conduction through the ducts.

Accomplishments

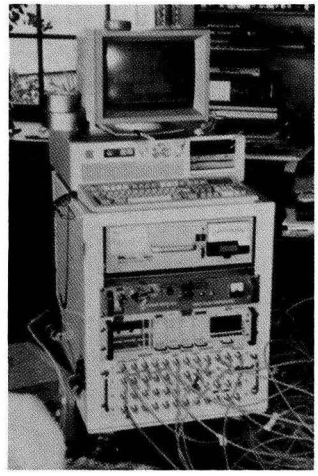
1. A survey of heating, ventilating, and air conditioning (HVAC) contractors investigated the types, locations, and costs of ducts installed in California homes, the sealing techniques used in their installation, and the viability of alternative approaches.
2. A Field Study measured and analyzed the performance of air distribution systems in 31 homes (nine in San Diego, four in Sacramento, and 18 in the San Francisco Bay Area).
3. A simulation tool modeled duct system interactions with the building shell and equipment of a typical ranch-style house in Sacramento.



Graph showing the differences in electric power demand between cooling a house with room air conditioners and a conventional air distribution system on the peak day in Sacramento. Note the significant difference at peak hours.

Findings

The project team found that a typical ranch house in a moderate California climate wastes an astonishing 33% of all heating energy, between 23% and 40% of all air conditioning energy, and 1 kilowatt of peak power because of losses from air distribution systems. Project findings indicate that removing half of the inefficiencies of residential air distribution systems could save California ratepayers more than $300 million in avoided power bills.



Automated field monitoring equipment used for the 31-house residential air distribution characterization study.

Future Directions

Next year the team will perform more simulation work and apply their findings to modify retrofit and new building construction policies, including California's Title-24 building standards. They will also develop new technologies (including "internal access" duct-sealing technology) and examine zone-conditioning systems.

Localized Thermal Distribution for Office Buildings

Background

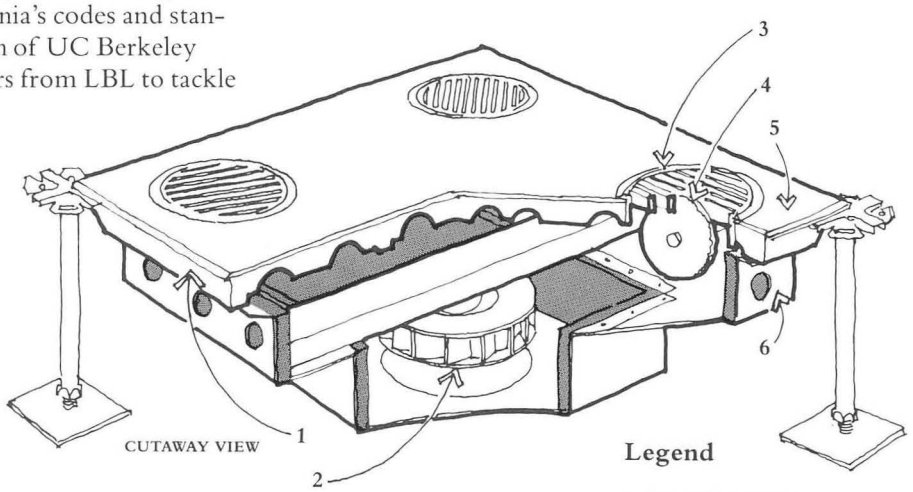
It has become increasingly difficult for conventional centralized HVAC systems to satisfy the environmental preferences of individual office workers. A growing awareness of the importance of comfort and health to the productivity of workers has led to the development of localized thermal distribution (LTD) systems that are under the direct control of workstation occupants and introduce supply air close to workers.

Research Challenge

The comfort and energy use characteristics of LTD systems are at present poorly understood. The objectives of this project are: to provide technical information to industry and design professionals that encourages energy-efficient product development and design approaches, to assist utilities in projecting future energy use trends resulting from such systems, and to recommend appropriate approaches to regulating LTD systems through California's codes and standards. Ed Arens and Fred Bauman of UC Berkeley (UCB) teamed up with researchers from LBL to tackle these issues.

Accomplishments

1. A series of tests to determine the thermal and ventilation performance of LTD systems (designed for floor and desk-level air supply) were completed by UCB and LBL working together in UCB's Controlled Environment Chamber. The two LTD systems were the Task Air Module floor supply system, manufactured by Tate Access Floors, Inc., and the Personal Environments Module desk-level supply system, manufactured by Johnson Controls Corp.
2. A plan for field study of such systems in open plan offices was developed to determine the impact of LTD technology on building energy consumption and the thermal comfort of occupants.
3. The influence of LTDs on building energy consumption was evaluated by computer simulation, to determine optimum ways of designing and operating such systems in the future.

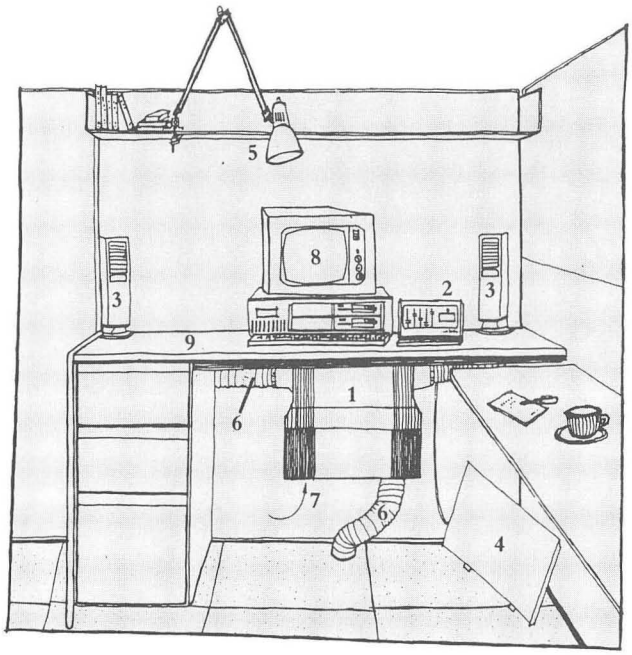


Panel measures 24" long × 24" wide × 8" deep

Legend

1. Access floor panel
2. Electric fan
3. Air discharge grille
4. Speed control
5. Hard surface covering
6. Acoustical housing

The floor supply module is installed as a component of a raised access floor system; typically, one module is located near each office worker. A variable speed fan draws fresh air from below the raised floor and delivers it to the room through four discharge grilles. Office workers can control both the direction and the quantity of air supplied from the module.



The desk-mounted supply system provides even greater convenience and control than the floor supply module. Fresh air is supplied through nozzles located at desk-level, and a desktop control panel handles supply air volume and temperature, a radiant heating panel under the desk, the task light, and a white noise generator. An occupancy sensor is also included.

Legend

1. Desk-level supply module
2. Desk-level control panel
3. Desk-level supply nozzle
4. Radiant heating panel
5. Task light
6. Flexible supply duct
7. Recirculated room air
8. Personal computer
9. Desk

4. Applicable California building codes and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards were reviewed for compatibility with LTD technology. Changes were recommended and adopted in the new version of ASHRAE Standard 55-81 which, when applied to LTDs, will reduce the energy required to condition workspaces.

Findings

LTD systems can be controlled over a wide range of thermal conditions. They perform well at meeting non-uniform thermal loads in offices, maintaining thermal comfort in workstations, and providing effective ventilation. Use of LTD systems can provide better optimization of building HVAC systems, although energy use can increase or decrease in comparison with conventional systems depending on LTD design and operation characteristics.

Preliminary analyses show that energy use is minimized for LTDs with the following characteristics:

- higher supply- and return-air temperatures
- minimum possible local fan loads
- occupancy sensors
- reduced central fan static pressure
- an economizer cycle.

UCB and LBL Research Team. Seated (left to right): Gail Brager, David Faulkner, Kristin Heinemeier, Manny Kin. Standing (left to right): Pleas McNeel, Zhang Hui, Doug Sullivan, Cris Benton, Ed Arens, Bill Fisk, and Fred Bauman.

Future Directions

Next year, field studies will be carried out in two office buildings with operational LTD systems. Additional laboratory and simulation experiments will continue to provide more details about LTD system performance and energy use, and will investigate issues related to local occupant sensors, worker productivity, and energy demand.

Thermal Energy Storage

Background

Properly designed, equipped, and installed thermal energy storage (TES) systems can shift a significant portion of daytime building cooling loads to off-peak hours, reducing the need for less efficient and more polluting power generation equipment and costly new power plants. Properly applying TES technology is mutually beneficial to building owners, ratepayers, and electric utilities.

Some installed TES systems, however, are failing to deliver the expected load shift. This failure is of concern to facility owners, the TES industry, and electric utilities that have committed ratepayer funds to pay incentives for installing TES systems.

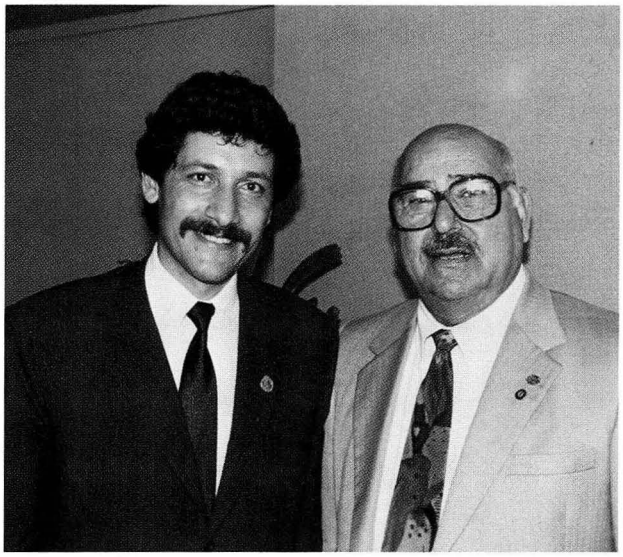
Research Challenge

A team of researchers at San Diego State University (SDSU) led by Halil Guven and Preston Lowrey, and participating faculty members of SDSU's Energy Engineering Institute, initiated a 3-year effort beginning in 1990 to:

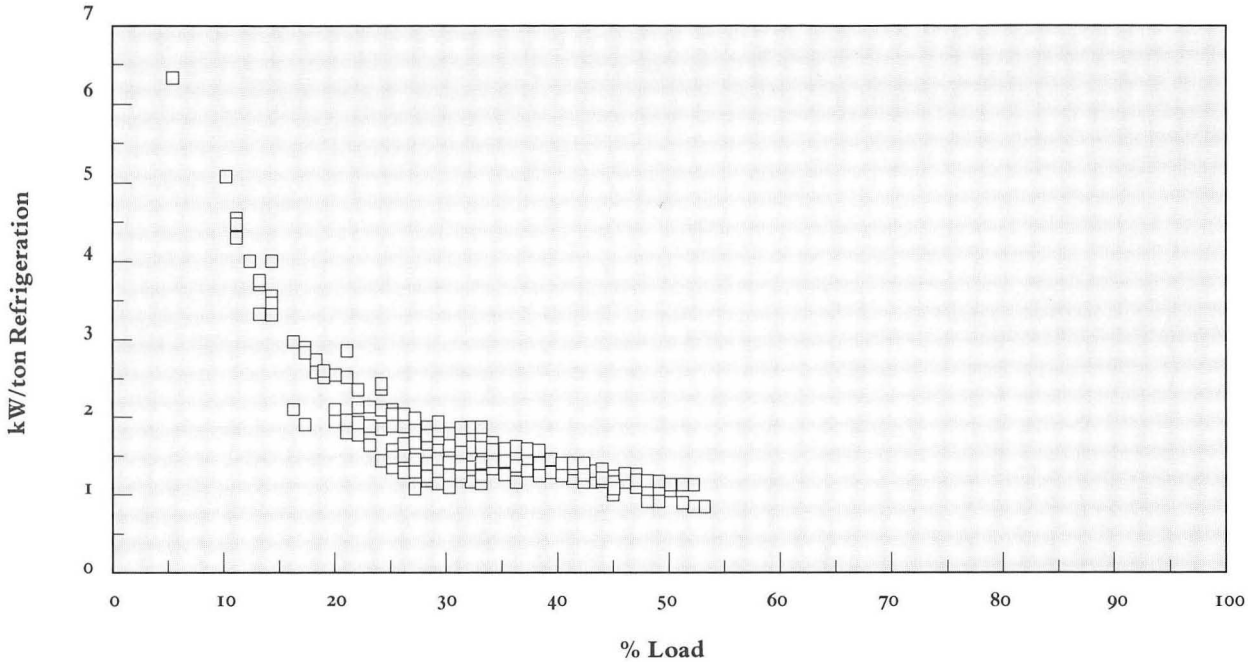
1. Evaluate the performance of installed TES systems in California and elsewhere in the United States in order to identify and categorize problems.
2. Compare the field performance of TES systems to that of conventional HVAC systems.
3. Develop field performance verification (commissioning) guidelines and procedures for TES systems.

Accomplishments

1. A field performance survey of 49 conventional and 37 installed TES systems was completed.
2. Nearly 100 leading authorities on TES attended a workshop on TES commissioning procedures conducted by the Energy Engineering Institute in San Diego on February 11–12, 1991. Participants from throughout the U.S. grappled with common problems during three panel presentations and extensive round table discussions.
3. Draft TES Start-up, Testing, and Commissioning Guidelines (Version 1.0) were developed and distributed to members of the TES industry for comment prior to field testing. The guidelines outline the roles of the nine participants in the design, construction, commissioning, and certification phases of TES projects.



Dr. Hal Guven (left) introduces Art Kevorkian as a keynote speaker at the TES Commissioning Workshop in San Diego on February 11–12, 1991. Guven chaired the workshop sponsored by SDSU's Energy Engineering Institute. Kevorkian, a Commissioner with the California Energy Commission and the 1991 CIEE Board Vice Chair, spoke on the CEC's energy R&D programs.



This load curve is for a water-cooled centrifugal chiller analyzed in the field study of conventional chiller performance. The study showed that many conventional chillers typically operate at very low load levels of about 30%.

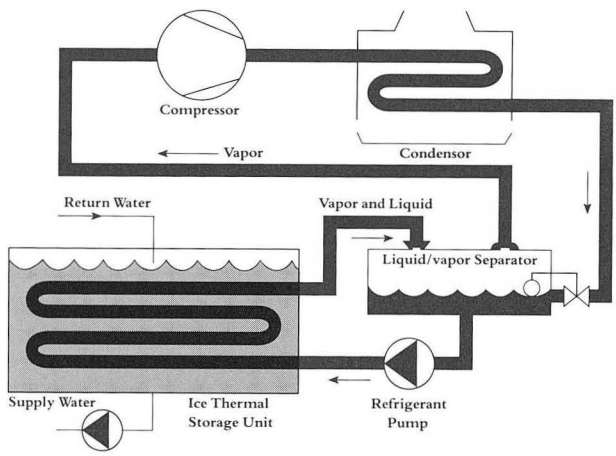
Findings

Failed TES systems identified in the performance survey appeared to suffer from inadequate procedures in TES system design, equipment selection and integration, installation, and operation.

Significant oversizing of the conventional chillers surveyed frequently caused them to operate at inefficient load levels (in the 20%–40% range). Below 40% load, chiller efficiency dropped severely. With further study, more effective cooling load profiles and chiller sizing methodologies could be developed.

Future Directions

During the project's second year, the Draft Commissioning Guidelines will be refined and are expected to be tested on several new representative TES projects. They will be made available to the TES industry, and their applicability, usability, relevance, and cost effectiveness will be documented.



Schematic of a TES system as shown on the cover of the "Draft Thermal Energy Storage Commissioning Guidelines" distributed at the February workshop. Development of the guidelines is still in progress and they will be tested on several systems to be installed in 1992.

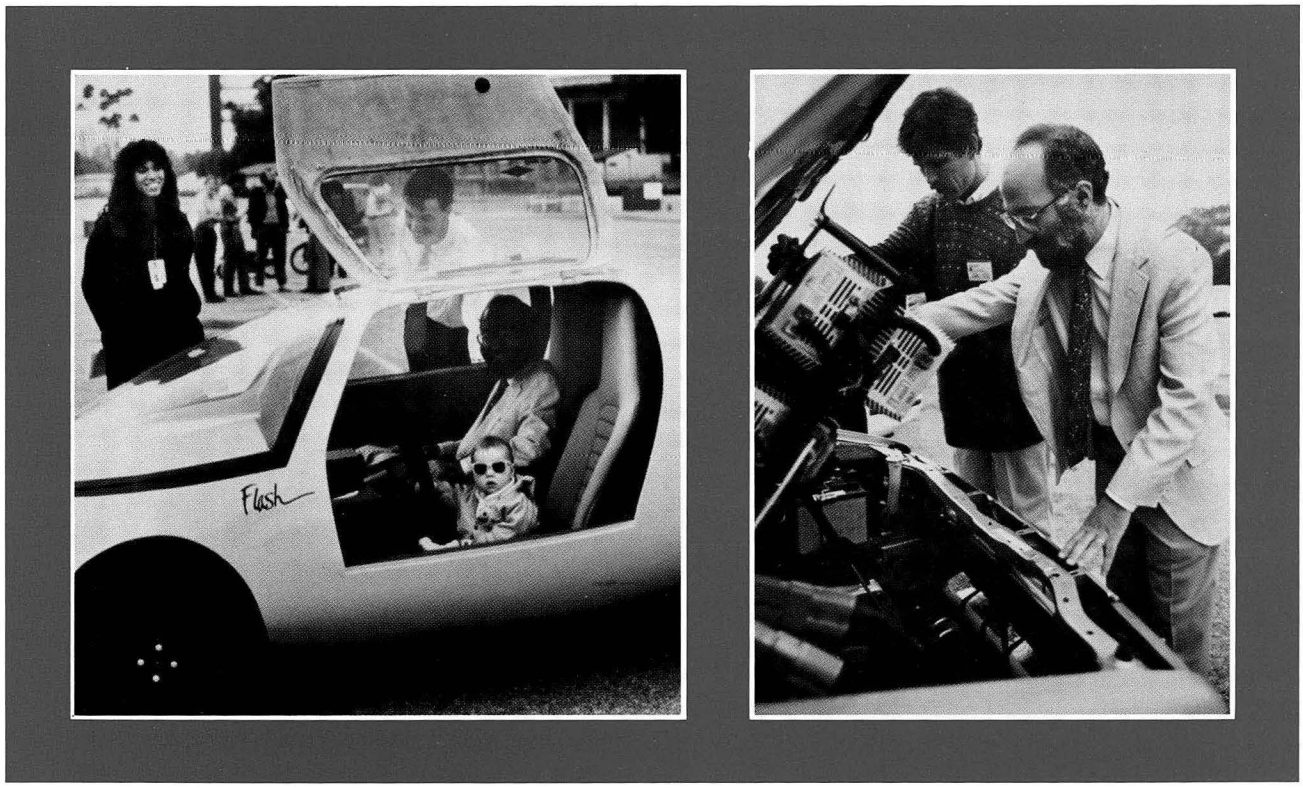
PROJECT HIGHLIGHT

AIR QUALITY IMPACTS OF ENERGY EFFICIENCY

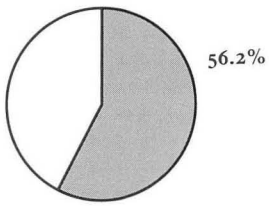
Assessment of Natural Gas and Electric Vehicles

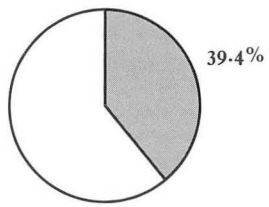
Background

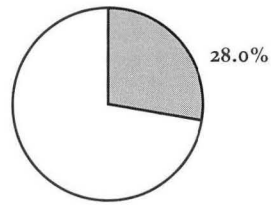
Motor vehicles account for about half the hydrocarbon and nitrogen oxide emissions, about 30% of the greenhouse gases, over 80% of the carbon monoxide, and over half the petroleum consumed in California. Natural Gas Vehicles (NGVs) and Electric Vehicles (EVs) have the potential to replace a large share of petroleum-powered vehicles and substantially reduce urban air pollution, reliance on imported oil, and greenhouse gases at reasonable costs. Consumer and fleet owner adoption is critical to achieving these significant benefits.



Left: A potential future "green" vehicle driver, Rhiannon Sperling, tests an alternatively fueled vehicle at the auto clinic held at the Rose Bowl in Pasadena. Right: During the auto clinic, Tom Turrentine of UC Davis, and Dan Sperling "look under the hood" at the inner workings of a prototype EV.







Criteria for EV Ownership. The following criteria narrow the potential market for EVs: 1) potential purchasers must own their residence; 2) they must have a carport or garage; 3) they must have two vehicles, one of which is not used to commute daily more than 70 miles round trip, and one of which is capable of long distance trips.

Research Challenge

Dan Sperling and Cathy Kling at UC Davis, and Andy Ford at the University of Southern California (USC) initiated multiyear research in 1990 on: 1) the consumer market potential of EVs and NGVs in the Los Angeles region, 2) economic incentives for EVs and NGVs to reduce mobile source emissions, 3) the impacts on utilities of EVs and NGVs.

Accomplishments

1. A test clinic was conducted at the Rose Bowl in which 250 randomly selected individuals test drove a selection of EVs, NGVs, and methanol vehicles. The clinic was preceded and followed by surveys and focus group interviews. National survey data of household infrastructure and driving distance was evaluated.
2. Incentive-based strategies for encouraging the production and market penetration of alternative vehicles were evaluated, including "marketable credits" schemes for manufacturers which allow manufacturers to sell and trade production allowances for categories of inefficient and efficient vehicles. The costs and benefits of regulatory approaches were investigated in part through a workshop "Roads to Alternative Fuels."
3. The impacts on Southern California Edison Company (SCE) of extensive use of EVs in southern California were analyzed.

Findings

1. While a large part of the population desires a "green" car, few people appear to be willing to pay a large premium for an alternatively fueled vehicle. While the target market for NGVs is quite large due to broad range and refueling characteristics, the target market for EVs is smaller, at only about 30% of households.
2. Preliminary analyses suggest that there may be large cost saving advantages from using marketable credit systems to promote the production of EVs and NGVs.
3. Analyses of various scenarios show that SCE can accommodate a large number of EVs in its service territory without adding new resources to its existing electricity supply and utilization plan.

Future Directions

UC Davis will continue to develop economic incentive strategies and consumer market potential models. It will also examine how fleet managers determine whether to purchase EVs and NGVs. The USC effort will consider the impact on SCE of various EV "charging" strategies, and explore ways to transfer the impact analysis techniques to the Los Angeles Department of Water and Power (LADWP), San Diego Gas & Electric Company (SDG&E), PG&E, and other utilities.

Gas-Filled Panels: High Performance, Non-CFC-Based Thermal Insulation

Background

Gas-Filled Panels (GFPs) are an alternative non-chlorofluorocarbon (CFC) high performance insulating material for appliance (refrigerator/freezer), building, and transportation applications. Alternative insulations are in high demand due to the phase-out of CFCs and increasing energy-efficiency standards. GFPs evolved from applying manufacturing techniques for highly insulating windows to the production of an opaque insulation. The panels consist of infrared-reflecting (low-emissivity) multilayer baffles surrounded by a sealed barrier filled with a low-conductivity gas or air at atmospheric pressure.

Research Challenge

During their one year exploratory research project, Steve Selkowitz, Dariush Arasteh, and Brent Griffith of LBL worked to develop self-supporting GFPs using readily available materials, and to demonstrate their performance potential.

Accomplishments

Over 100 prototypes were designed, built, and tested before two designs yielded the expected thermal performance values.

Findings

GFP samples were independently tested at Oak Ridge National Laboratory (ORNL) and predicted thermal performance values were supported. ("R-values" refer to insulation performance per unit of thickness. Fiberglass has an R-value of 2.5 to 3.7, and CFC-blown foams have an R-value of 7.2.) Air-filled panels performed as well as styrene foam. Argon-filled panels performed as well as CFC-blown foams (at a level twice that of fiberglass), and krypton-filled panels offered much higher performance levels than any commercial insulation currently available. Projected performance levels for second generation prototypes are even higher.

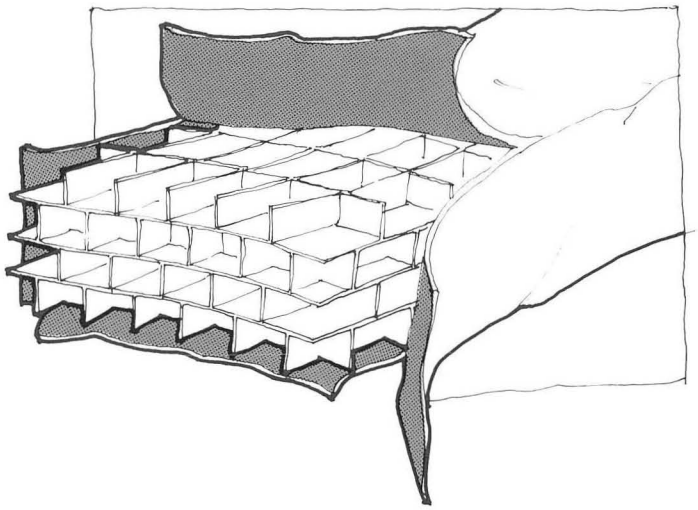
Research into possible manufacturing techniques shows that GFPs are relatively easy to manufacture and can be produced at a low to moderate cost. GFPs can be assembled from roll stock polymer films using raw materials and equipment from the packaging industry.

Energy-efficient building walls, especially in manufactured housing, can include low cost flexible GFPs to improve overall wall thermal resistance without increasing wall thickness. The GFPs' R-values are so high that they would eliminate the need for 2″×6″ construction in moderate climates such as found in California's central valley.

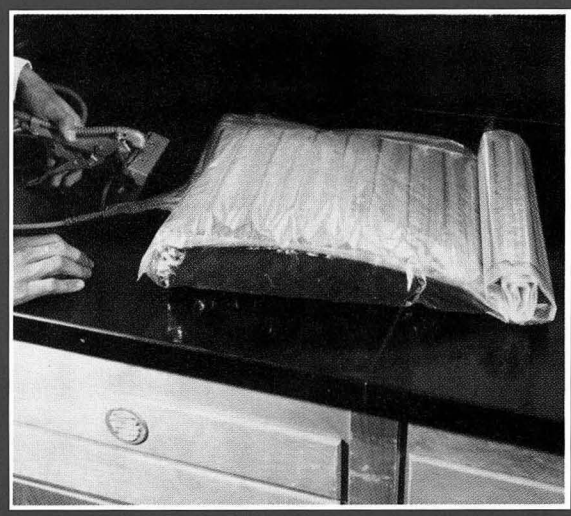
Future Directions

In the near term, appliances could be manufactured with composite insulations consisting of GFPs foamed-in-place with non-CFC foams. In the long run, advanced plastics and processing techniques, used in conjunction with GFP technology, may achieve high performance appliance components without the use of any foam. Current research is aimed at developing GFPs for both of these applications and for investigating GFP application in manufactured housing.

1991 BEST NEW PRODUCT AWARD WINNER IN POPULAR SCIENCE MAGAZINE'S "HOME TECHNOLOGY" CATEGORY.



Cross-section of a gas-filled panel made of two specialized components: an envelope containing a gas or gas mixture, and a baffle consisting of multiple, low-emissivity, coated, nonpermeable layers that eliminate radiative and convective heat transfer, allowing conductive transfer through the gas and baffle.



Close-up of a GFP being filled with gas or a gas mixture.

Photo of the research team holding a GFP. Left to right: Brent Griffith, Steve Selkowitz, and Dariush Arasteh of LBL.

** See cover for thermogram of a stud wall fitted with GFP insulation. Description is on inside back cover.*

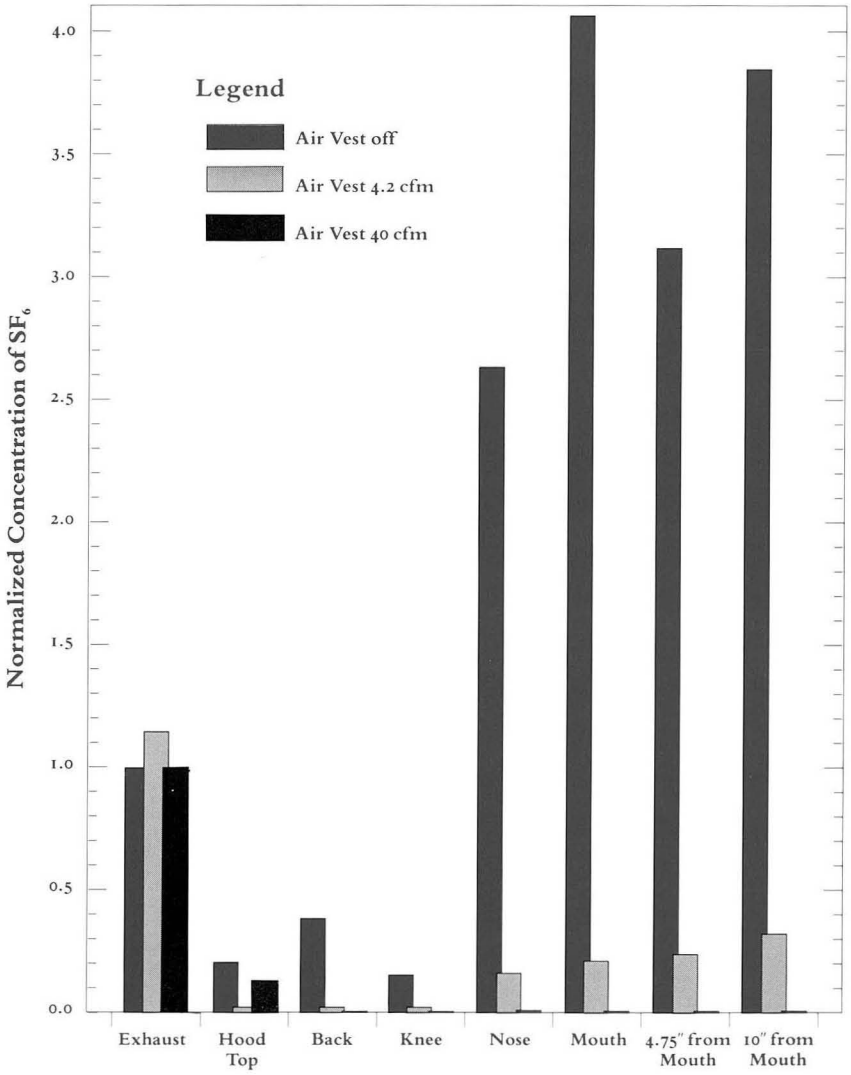
A New Energy-Efficient Device for Exhaust Hoods

Background

Exhaust hoods (also called spray-booths when used with spraying operations) are widely used to protect workers from fumes or aerosols generated during industrial processes. Unfortunately, when a worker stands in front of the open (face) area of an exhaust hood, air flow is partially blocked and a back-eddy is created that draws some of the harmful material from the process area toward the face of the worker. Increasing the design face velocity to counter this effect strengthens the back-eddy almost in proportion.

Research Challenge

Mitigating the drawbacks of fume hood operation is conventionally achieved at high energy costs with high volume air flow rates that require substantial make-up air to be conditioned and introduced into the process building. Future air pollution abatement regulations may exacerbate these already high costs by requiring exhaust hoods to trap pollutants. Ashok Gadgil of LBL decided to investigate alternatives with discretionary funding from CIEE's Director.



A histogram representing measured concentrations of sulfur hydrochloride (SF_6) at various points, with a hood face velocity of 56 feet per minute and air ejection rates from the airvest of 0, 4.2, and 40 cubic feet per minute (cfm). The measurements are averaged concentrations of SF_6 over 15 minute intervals. Pure SF_6, to simulate a pollutant, was released at a rate of 80 cc/min., at the height of the mannequin's elbow about seven inches in front of its stomach (the approximate work station location). Similar results were found at higher hood face velocities.

Accomplishments

1. An innovative "airvest" to be worn by workers was designed to draw air from behind and expel it in front of the worker.
2. A prototype airvest was developed and tested in LBL laboratory experiments.
3. A patent application for the airvest was filed.

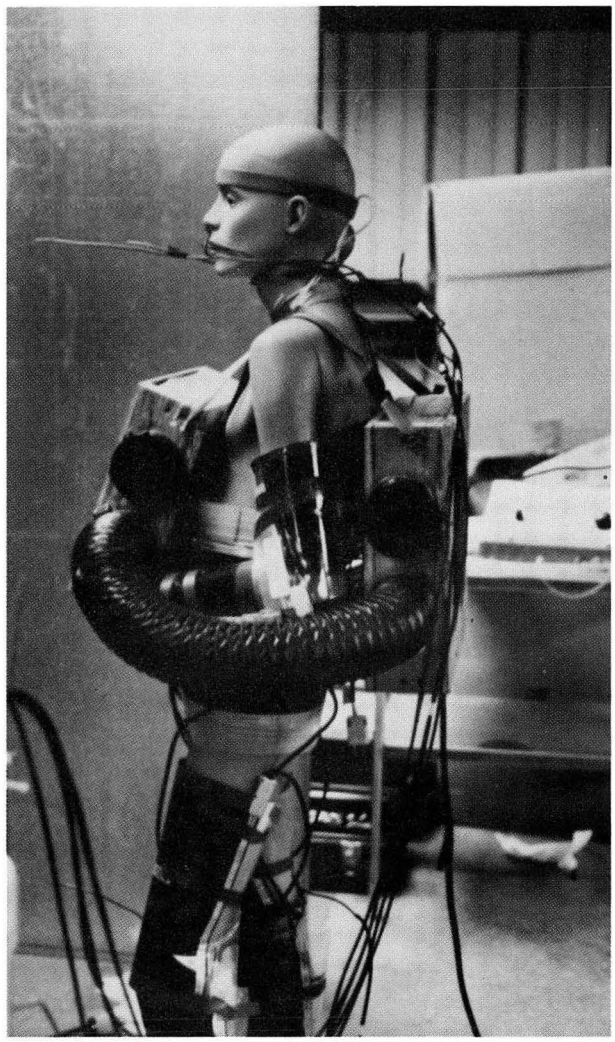
Findings

Gadgil found that the airvest allows exhaust hoods to operate efficiently by making workers essentially "transparent" to the flow of air into the exhaust hood. Under ideally matched flow conditions, the resulting air flow pattern was identical to that found with no worker present: no back-eddy developed, and pollutant removal and transport was as effective as with an unobstructed exhaust hood. Under conditions of imperfect matching, the hood performance was still improved by the airvest.

In laboratory experiments, the prototype airvest reduced worker exposure to pollutants (measured in the nose and mouth breathing zone of a mannequin wearing the airvest) by factors of 100 to 800, while simultaneously achieving a modest reduction in fan energy consumption of about 20%. Energy savings from conditioning less make-up air would be substantial. For example, during the winter in Chicago, it is projected that heating costs would be reduced between $1,000 and $3,000 per device per shift.

Future Directions

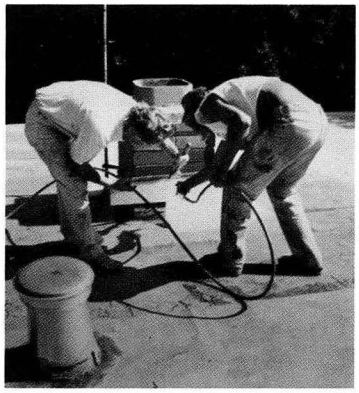
Optimization of the airvest design will be pursued by Gadgil, perhaps with support from industrial collaborators to speed its development for the market.

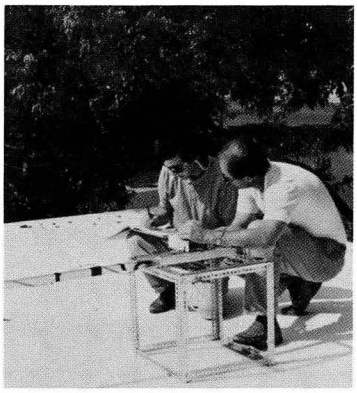


A side view of the mannequin. Note the intake and ejection box hung with straps from its neck. Black heater foils are taped to its legs, thighs, arms, and waist. The brown band on its head is also a heater. The heaters are used to create a thermal plume similar to that from the body heat of a worker. Note the copper tubing at the mannequin's mouth used for sampling tracer concentrations in the breathing zone.

BUILDING ENERGY EFFICIENCY

Impact of Shade Trees and White Surfaces on Building Peak Power and Cooling Energy Savings





Top: Workmen are painting a roof white to increase its albedo. Middle: Haider Taha of LBL and Wim Bos of SMUD measure the albedo of the newly whitened roof. Bottom: Preliminary analyses indicate that savings in cooling energy use from shade trees may reach 20%–40%. In this photograph, shade trees placed on the south side of a house in Sacramento saved about 25% in cooling energy when the outside air temperature reached 104°F. Larger savings may be realized when bigger and denser trees are planted to cast larger shadows and to cool the ambient air by evapotranspiration.

Background

In many cities, human changes to the city landscape have inadvertently created "summer urban heat islands" that are from 5° to 9°F hotter than the countryside. This "heat island" effect increases air conditioning loads and adds to discomfort. The leading factors contributing to heat islands are the loss of vegetation in cities, and the reduction in the albedo of city surfaces (their ability to reflect solar radiation) due to the use of dark road and roofing materials.

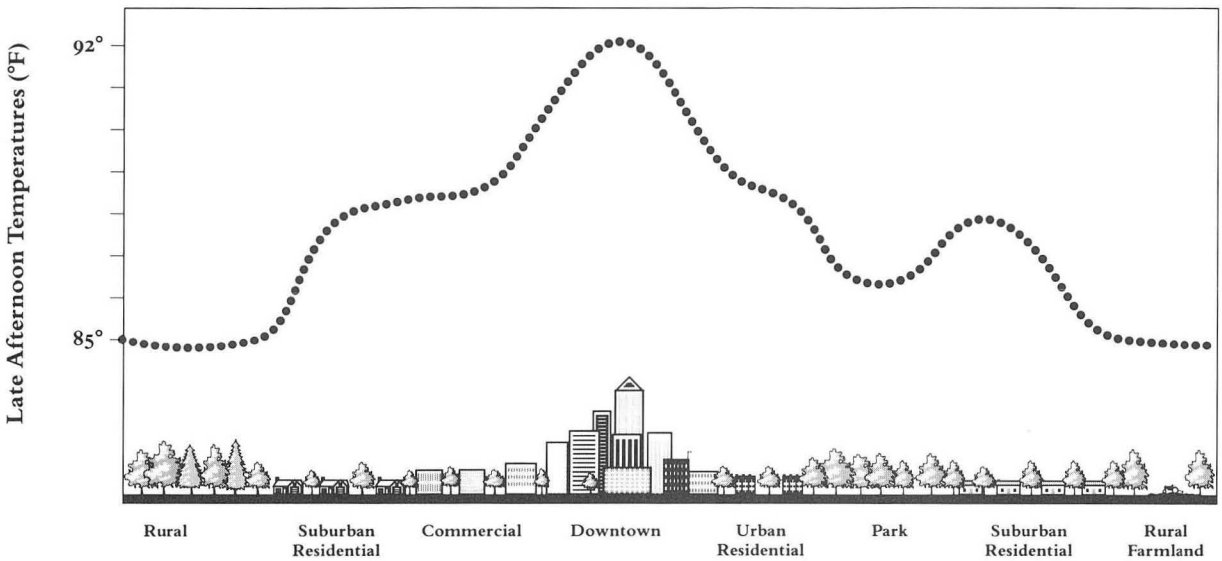
Research Challenge

A multiyear collaborative effort between the Sacramento Municipal Utilities District (SMUD) and an LBL project team was launched to assess, monitor, and document the direct effects and energy saving benefits of shade trees and light-colored surfaces on selected residences and public buildings in Sacramento. The LBL project team consisting of researchers Hashem Akbari, Art Rosenfeld, Joe Huang, Haider Taha, and David Sailor is responsible for providing technical guidance to the monitoring effort and for analyzing data and conducting computer simulations. The SMUD engineering staff is responsible for installing monitoring equipment and gathering data.

Accomplishments

1. Six single-family residences and two bungalows at public schools were selected as candidate monitoring sites.
2. The project team and the SMUD engineering staff specified and procured monitoring equipment and finalized monitoring protocols and agreements with occupants and staff of the prospective sites.

Sketch of an Urban Heat-Island Profile



Graph shows the temperature changes in degrees Fahrenheit as the density of development and trees changes.

3. Preparations were undertaken to temporarily modify existing conditions by adding trees and painting existing roofs with light-colored high-albedo materials that were identified in the CIEE-sponsored 1990 Exploratory project.
4. Pre- and post-retrofit data were collected.

Findings

Preliminary results suggest that nearly half of the cooling energy use in the school bungalows and all of the cooling energy use in one of the houses were eliminated by changing their roof color to white. The impact of shade trees was also impressive; by shading the south and west side windows and walls with small (eight foot) trees, cooling energy was reduced by 25%–40%.

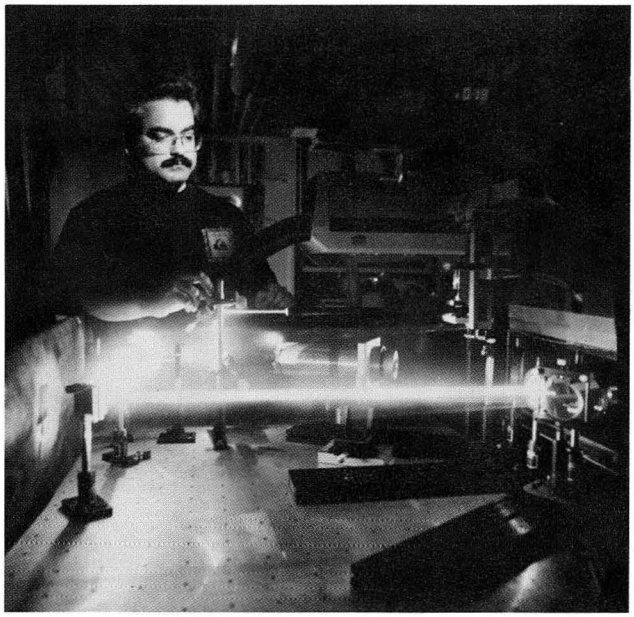
Future Directions

SMUD's heat island mitigation program includes planting 500,000 shade trees around homes, schools, and businesses in Sacramento over the next ten years. SMUD estimates a savings in peak residential cooling energy use of about 600 megawatts at a cost of about $150 per kilowatt. During the next two years, collaborative research between SMUD and LBL will focus on investigating the direct effects of shade trees and white surfaces, designing a project to quantify the neighborhood cooling effects of white surfaces, and assisting SMUD to develop and implement a program for white surfaces for certain neighborhoods in Sacramento.

PROJECT HIGHLIGHT

AIR QUALITY IMPACTS OF ENERGY EFFICIENCY

Formation of Nitrogen Oxides in Industrial Natural Gas Burners



As shown on the cover, student David Moyeda is adjusting the laser diagnostics on the subscale burner test stand at the UC Irvine Combustion Laboratory.

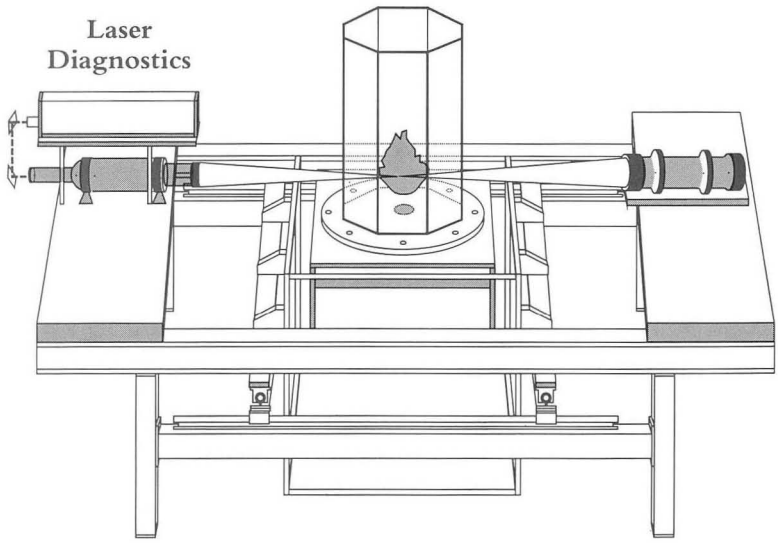
Background

In recent years, air-quality emission regulations have resulted in a substantial reduction in the emission of nitrogen oxides from industrial natural gas–fired burners. Empirical, "input/output" methods have been successfully employed by burner manufacturers and combustion modification specialists to develop a large and varied population of "low-NOx" burners.

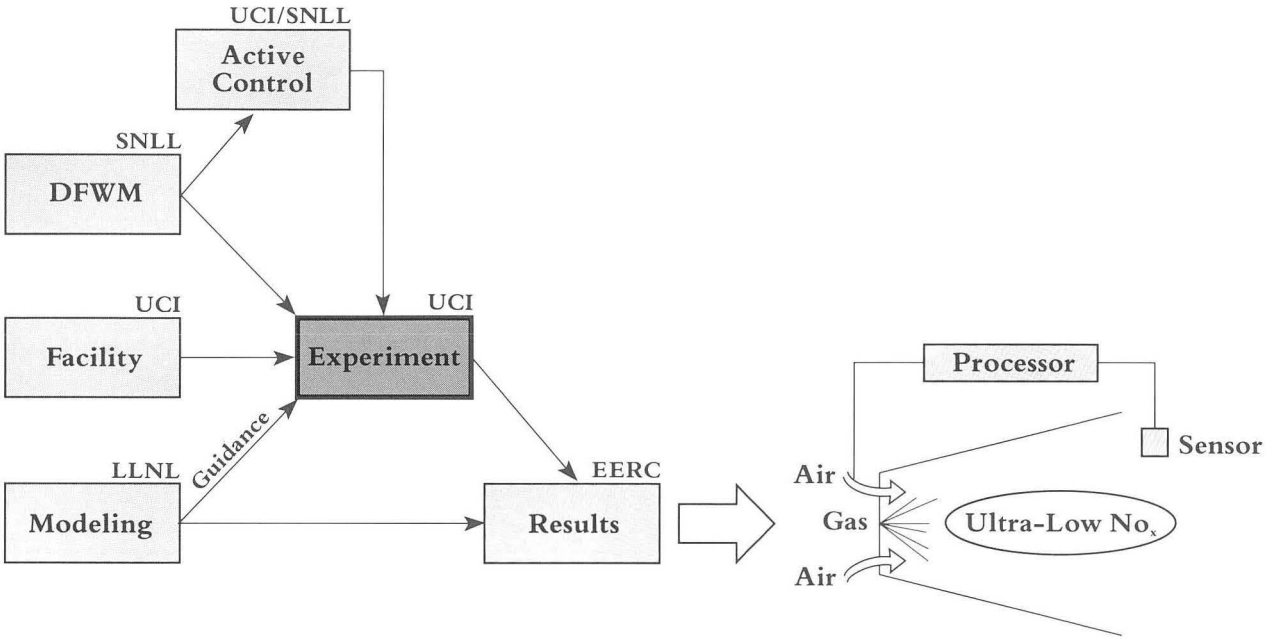
Demands to further improve air quality have led to a broadened population of industrial sources required to utilize low-NOx burners, and an additional requirement to develop "ultra low-NOx" burners.

Research Challenge

The research challenge is to develop design criteria for ultra low-NOx burners while maintaining or enhancing both burner combustion efficiency and overall system energy efficiency. Comprehensive modeling, and detailed in situ measurements of the velocity, temperature, and species concentrations fields within burners are required.



Schematic of the experiment.



Schematic of the technical approach showing the coordination of participating institutions.

A participatory approach was adopted by investigators at the UC Irvine Combustion Laboratory (UCICL), Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories-Livermore (SNLL), and the Energy and Environmental Research Corporation (EERC) in Irvine. G. Scott Samuelsen of UCICL is the lead investigator.

Accomplishments

The research, cofunded by the Southern California Gas Company, was initiated on June 1, 1991. The comprehensive modeling, design of the burners, construction of the experimental facility, development of the active control methodology, and adaptation of Degenerate Four Wave Mixing (DFWM) for in situ measurement of NO and NO2 are underway. A full day meeting was held with the Project Advisory Committee to review and comment on the project's technical and organizational approaches.

Findings

Early analyses suggest that tailoring the mixture of natural gas and combustion air under overall "lean" conditions is a key to achieving ultra-low emissions of NOx while preserving combustion and (possibly improving) energy efficiency.

Future Directions

Design, fabrication, operation, and verification will be completed in the first year for the facilities, laboratory burner instrumentation, and comprehensive modeling. Second-year research will focus on screening and parametric studies, and third-year research will be dedicated to optimization experiments and the demonstration of active control.

Envelope and Lighting Technologies to Reduce Electric Demand

Background

The greatest contributors to peak electric demand for cooling and lighting in most California commercial buildings are the fenestration (the arrangement of windows and doors in a building) and illumination systems. The performance of lighting and building envelope systems has improved in recent years, but new technologies are typically applied in a piecemeal fashion that yields less than optimal results. In addition, these technologies are presented to the building community without consideration for the various constraints and priorities influencing design decisions.

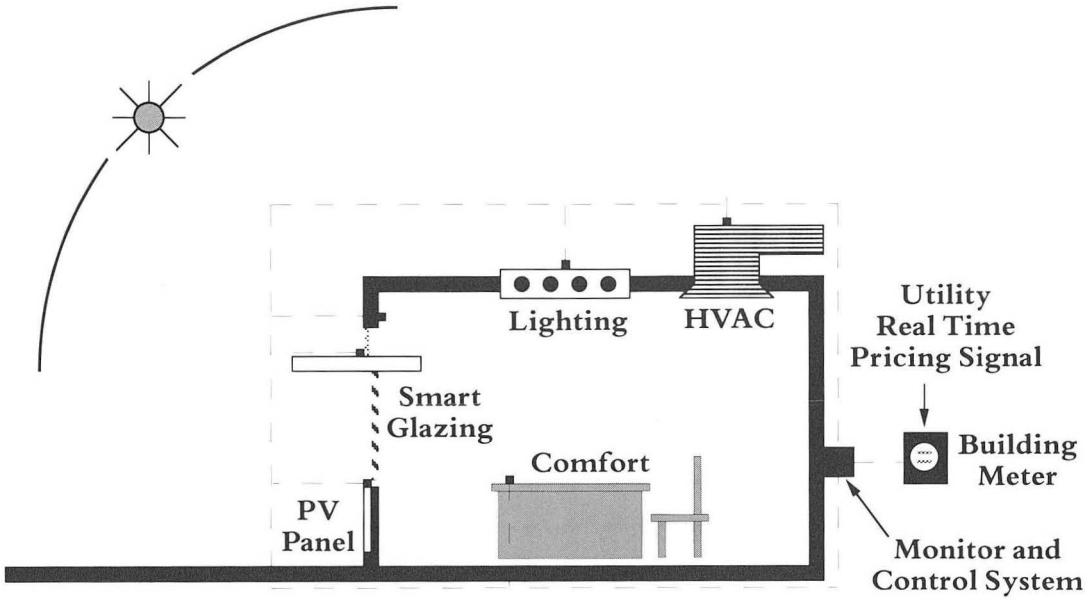
Technologies designed and packaged as integrated systems (supported by tools to assist in design, specification, and assurance of performance) would promote building industry adoption and commercialization, and architectural and engineering specification.

There is significant missed potential for improving the energy efficiency of "standard practice" commercial design for building envelope and lighting systems. The interior perimeter office above illustrates the significant role of windows and lighting.

Research Challenge

The goal of this multiyear project is to develop integrated building envelope/lighting systems that enhance worker comfort and productivity while significantly reducing energy use and peak demand. Steve Selkowitz of LBL heads the project team consisting of Jennifer Schuman and other researchers at LBL, and a group led by Dick Schoen at the Graduate School of Architecture and Urban Planning at UCLA. LBL's technology focus is supported by UCLA's design and construction expertise.

Left to right: Werner Osterhaus of LBL and Adam Jackaway of UCB prepare a light shelf model using reflective film coating. The model is used to test the impact of light shelves on interior illumination.



Schematic room section with optimum HVAC, lighting, envelope, and controls integration.

Accomplishments

1. Developing an initial utility impact assessment of the energy performance potential of new and emerging technologies.
2. Reviewing technology options in several envelope and lighting categories of systems and hardware, and reviewing design tools and utility design assistance programs.
3. Examining varied market, industry, and design concerns.
4. Developing building prototypes based on common architectural practice.
5. Creating algorithms for computer analysis of integrated control systems for shading and lighting, as well as for other new systems not previously analyzed or modeled.
6. Developing initial designs for integrated systems and performing initial analyses for each building prototype.
7. Conducting a technology assessment study that produced a 200+ page compendium identifying a large number of unexploited individual technologies.
8. Deriving optimal building performance "targets" for the years 1995 and 2005.
9. Developing relationships with several potential building industry and utility partners who participated in designing what will probably become several short-term demonstration opportunities.

Findings

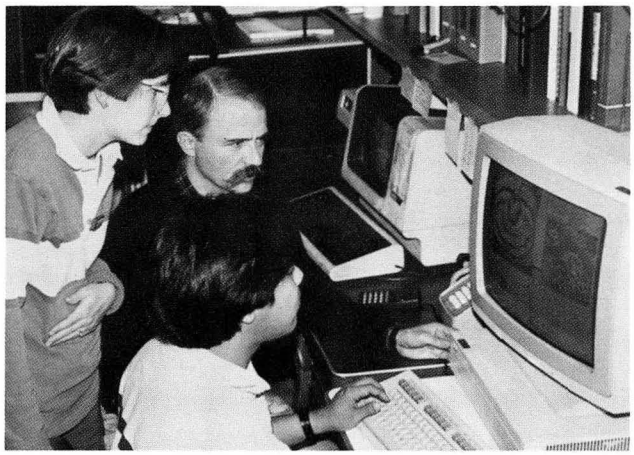
A preliminary analysis of the expanded use of advanced building technologies indicates that a potential 38% reduction in lighting and cooling by 1995 and a 73% reduction by 2005 can be achieved. Peak demand could be reduced by 22% in 1995 and by 40% in 2005.

Future Directions

First-year research only focused on current technologies for new office building construction. Second-year research will investigate emerging technologies, other building types, and retrofit applications. Options for assisting utilities will be explored including providing technology and case study databases, developing design tools, and helping to improve or develop more effective design assistance programs.

END-USE RESOURCE PLANNING

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



Office information processing equipment is widely believed to be the fastest growing energy end-use in the fastest growing commercial sector. These machines also produce unwanted heat, resulting in increased cooling requirements in many commercial buildings.

Background

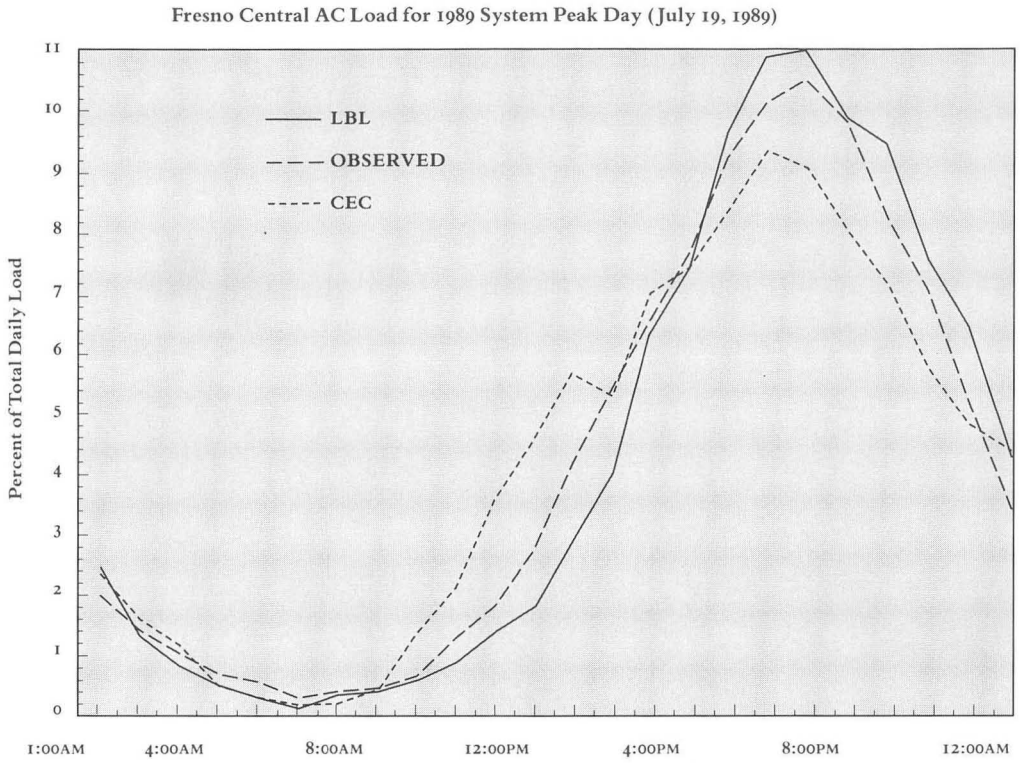
The models used by California utilities and the California Energy Commission (CEC) to forecast peak electricity demand, require more detailed analyses of electricity consumption by specific end-use technology over the hours of the year. California's utilities and the CEC have already begun collecting the data needed to improve important forecasting models used to verify energy efficiency policy interventions.

Research Challenge

During the first year of this multiyear project, Joe Eto, Hashem Akbari, and Mary Ann Piette of LBL conducted research in three subprojects aimed at analyzing existing data to develop information for common use by PG&E and CEC energy demand forecasters.

Accomplishments

1. Five years of end-use metered data was collected by PG&E from over 700 households. It was analyzed and new inputs for CEC and PG&E residential peak demand models were developed.
2. A spreadsheet model that forecasts energy use for seven categories of office information equipment in eleven commercial building types was created.
3. The major data sets required to apply LBL estimation techniques to commercial buildings were prepared from extensive on-site surveys, load research accounts, mail survey responses, and weather data. Load shape profiles and end-use energy intensities (EUIs) were analyzed for four of the twelve building types used by PG&E and CEC forecasters.



Comparison of Results for LBL Central Air Conditioning Load Shape Analysis. Central air conditioning loads recorded on the PG&E system peak day in 1989 in the vicinity of Fresno are compared to predictions of these loads formulated with LBL's analysis of metered end-use data and the existing CEC forecasting method. LBL's analysis predicts a load shape that peaks at the same time, but is slightly higher than recorded loads. The CEC prediction peaks an hour early at a significantly lower level than recorded.

Findings

1. Preliminary analyses of metered residential end-use data suggest that LBL can greatly improve the accuracy of California residential peak demand forecasts.
2. LBL's forecast of office information equipment energy use indicates that while energy use grew dramatically in the 1980's, this growth will slow somewhat in the 1990's. Nevertheless, LBL estimates that office information equipment will account for nearly 10% of PG&E's commercial sector electricity use by the year 2010 (up from about 6% in 1990).
3. The load shapes and EUIs estimated for large and small office and retail buildings clearly demonstrate the improved accuracy of the LBL estimation method (which includes metered whole-building load shapes) over previous methods, which relied exclusively on engineering simulations.

Future Directions

In the second year, space-conditioning load shapes developed for PG&E and the CEC will be compared to those generated by the Electric Power Research Institute's (EPRI's) load shape forecasting model, HELM. The office information equipment model will probably be enhanced by promising sources of data that have been identified. And finally, the analyses of four building types in the first year will be extended to the eight additional building types used in PG&E and CEC forecasts of commercial sector energy use.

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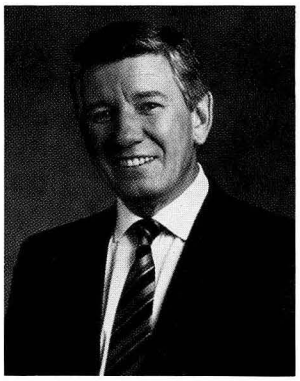

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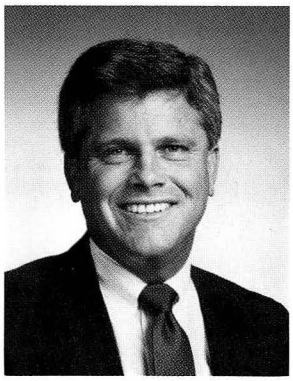

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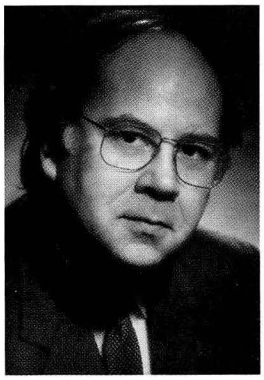

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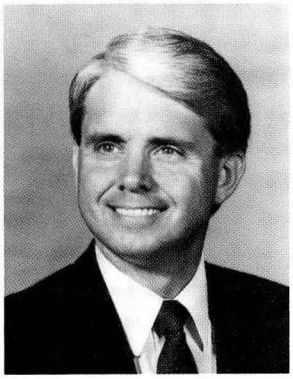

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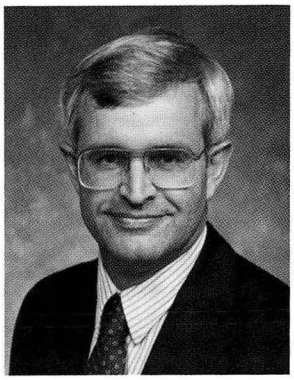

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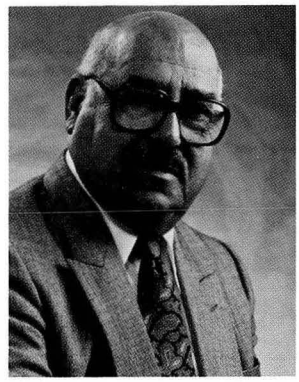

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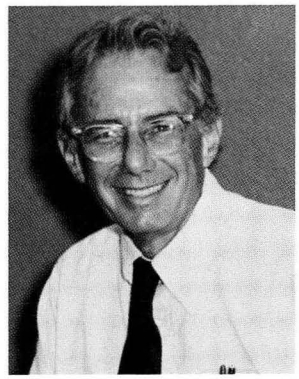

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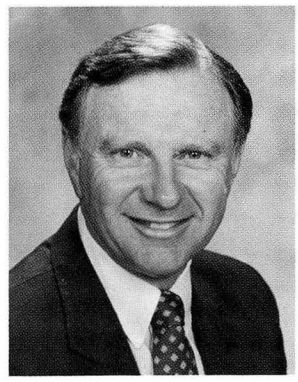

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CIEE Planning Committee. *Front row, left to right: Betsy Krieg, PG&E; Richard Chogyoji, LADWP; Barry Olsan, SCE; Al Figueroa, SDG&E; Carl Blumstein, UC. Back row: Mike Batham, CEC; CIEE Director Jim Cole; Mike Jaske, CEC; Clark Gellings, EPRI; George Mosinskis, Southern California Gas Company (SCG); David Christensen, PG&E; and Bruce Vincent, SMUD. Not shown are Tony Fung, SCE; Mike Lederer, UCB; Chuck Montoya, LADWP; Ken Olsen, SCG; William Pennington, CEC; Robert Sawyer, UCB; Elena Schmid, CEC; Don Schulz, CPUC; Ted Turner, SDG&E; Carl Weinberg, PG&E; and James Loewen, CPUC.*

Statement of Income, Expenditures, and Retained Research Funds

(Dollars in Thousands)

Income	**Year 1990**	**Year 1991**
Sponsor Funding		
California Energy Commission	95	—
Los Angeles Department of Water & Power	300	300
Pacific Gas & Electric	1693	1530
Sacramento Municipal Utility District	160	151
San Diego Gas & Electric	225	350
Southern California Edison	1000	1218
Southern California Gas	700	600
Total Sponsor Funding	4173	4149
LBL Cost-Sharing[A]	225	189
Interest Income[B]	41	117
Total Income	4439	4455
Expenditures[C]		
Multiyear Research Program		
Building Energy Efficiency	1344	1176
Air Quality Impacts of Energy Efficiency	773	1027
End-Use Resource Planning	293	40
Total Multiyear Research	2410	2243
Exploratory Research Program	527	695
Director's Discretionary Projects	103	156
Supplemental Projects	95	115
Technology Transfer[D]	112	180
Research Contracting Expenses[E]	64	86
Staff and Operating Expenses	603	848
Total Expenditures	3914	4323
Balance of Current-Year Funds	525	132
Carryover from Prior Year	221	746
Carryover to Following Year[F]	746	878

Financial Notes

[A] Lawrence Berkeley Laboratory provided partial cost-sharing of CIEE staff and other operating costs during 1990 and 1991.

[B] Funds for the Base Program are placed in an interest-bearing account until committed to a specific approved research project or activity.

[C] Expenditures for research projects are funding commitments.

[D] Amount includes expenses involved in publishing and distributing CIEE technical reports, Newsletter, Multiyear Research Plan, and other special publications, and for conducting workshops and technical meetings.

[E] Includes procurement burden for contracting research projects.

[F] These funds will be used to support planned research in future years.

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Special thanks to CIEE's sponsors and supporters, to the researchers and to the CIEE staff, especially Ellen Ward and Scott Coleman.

On the Cover

Top Photo: *David Moyeda adjusting the laser diagnostics on the subscale burner test stand at the UC Irvine Combustion Laboratory.*

Middle Photo: *Infrared image of a stud wall, the upper half of which was insulated with fiberglass (3.5 in.) and the lower half of which was retrofitted with an argon gas-filled panel (3.5 in.). In this figure, warmer surface temperatures are redder in shade and colder temperatures are bluer. A temperature color-scale is shown at the bottom of the figure. Since surface temperatures correspond to heat loss rates, a higher warm-side temperature implies a lower heat loss rate. The infrared photo shows a significant difference between the two insulations and indicates that GFPs perform almost twice as effectively as fiberglass.*

Bottom Photo: *At CIEE's 1991 R&D Conference, Marc Schiler of USC demonstrates an interactive graphic input based on the Computer-Aided Architectural Design (CAAD) program for use in calculating natural light levels in buildings. Left to right: Zed Jawdat of UCSD, Malcolm Lewis of Bein, Frost & Associates, Yang Lin of SDSU, Helmut Feustel of LBL, and Bruce Vincent of SMUD.*

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