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UNIVERSITY OF CALIFORNIA

Energy Analysis Program

1989 Annual Report

Applied Science Division

June 1990

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Energy Analysis Program 1989 Annual Report

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LAMP TECHNOLOGY
IMPACTS
LIGHTING CONTROLS

April 1990

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Contents

Contents (cont'd)

Introduction

Energy issues continue to be of national concern. Potential conflicts between energy and environmental goals remain important and are at the heart of policy discussions. The two key issues concerning energy and environment during the past year—global climate change and clean air—are both topics to which the expertise of the Program has been applied. In particular, our leading role in understanding the nature and determinants of energy demand and use in developing countries has contributed directly to the analysis of global energy strategies under the Intergovernmental Panel on Climate Change (IPCC). Similarly, our knowledge of costs of performance of energy efficiency measures in buildings has helped to structure the Clean Air Act amendments to encourage efficiency investments as a means of improving air quality.

One important highlight during the past year has been the Program's active contributions to the development of a National Energy Strategy (NES), a major goal of the U.S. Department of Energy (DOE). We wrote the buildings section of the NES white paper "Energy efficiency: How far can we go?" and also led the effort undertaken by six national laboratories to produce the white paper "Energy technology for developing countries: Issues for a U.S. National Energy Strategy." These were two of only five white papers produced by the labs.

The appliance standards effort is now having significant impacts. With DOE's support for appliance standards, our technical work in this project is being used to establish the costs and benefits of different levels of appliance efficiency standards. The recent decision by DOE to promulgate a standard on refrigerators—saving the nation considerable energy—relies on detailed technical studies completed by our Program.

The international efforts of the Program have seen continued growth and vitality during the past year. We have been particularly active in establishing new collaborations. An extensive network has been established to develop energy scenario analyses with participants from key developing countries. Collaboration with China, particularly to explore issues of energy efficiency, has continued. A new effort to work with Soviet energy analysts to better understand the structure of energy demand in that country has also begun. Four countries of the five within the Association of Southeast Asian Nations (ASEAN) project are using the LBL work as the technical basis for developing energy efficiency standards and guidelines. The Program is now actively engaged in supporting Pakistan in assessing opportunities to improve the energy efficiency of buildings in that country.

Research on buildings continues to be the leading element of the Program's activities. Work in this area is broad, including all building types, analysis of measured data, simulation studies, economic analyses, evaluations of conservation programs, electric utility issues, assessment of energy conservation technologies, development of analysis tools, market assessments, and related topics. In addition, we have worked hard to ensure the continuation of research on urban heat islands and on strategies for their mitigation. (At this time, DOE has not made this research a major initiative, as we believe it should be.)

Other important efforts during the past year have included drafting a report to the U.S. Congress on climate trends and greenhouse gas data; analysis of the interactive effects of climate change, air pollution, and fire on coastal sage scrub and chaparral in California; and a variety of important studies on the nature and role of bidding systems in electric utility programs to acquire demand- and supply-side resources.

We believe that most of these themes will continue to be important. In addition, we are seeking new sources of support for several areas of increasing interest: energy forecasting and scenario construction, for both the United States (in considerable depth), for other nations (especially developing countries), and for California; energy assistance for—and collaboration with—developing countries; and development of a research program on urban heat islands.

— *Building Energy Analysis* —

Workshop on Industrial Building Energy Use

H. Akbari and A. Gadgil

California has a large number of small and medium-sized industries which exert a major impact on the growth of demand on California utilities. These industries constitute an important but largely neglected fraction of total site energy use.

Industrial energy use is considered a "base load" by utility companies because it helps increase utilities' load factor. Currently, energy used for building services in the industrial sector is often reported with industrial process load. In cases where most of the energy is used for building services (with daily and seasonal load profiles that peak along with systemwide load peaks), the electric utility may, at peak power times, be selling energy below cost.

One estimate of nationwide energy use indicates that about 100 GWh—13.5% of industrial electricity use—is consumed by building services in the industrial sector. For California industries, which account for about one third of total California energy use, industrial building services represent an even larger portion of electricity use (and peak demand).

Industrial buildings are not necessarily as different from other non-residential buildings as is commonly thought. For practical reasons, many light industrial buildings are designed and built to be physically similar to retail or office structures. On the other hand, compared with other non-residential buildings, industrial buildings may have higher thermal loads,higher air-change rates, longer operating hours, and greater pollution-control or other environmental conditioning requirements and therefore may have higher intensity of energy use.

To study some of the issues posed above, the University-wide Energy Research Group and LBL jointly sponsored a one-day workshop with invited participation from researchers, the California Energy Commission (CEC), and California utilities to discuss aspects of database generation and maintenance as well as impacts of technologies on demand in our rapidly changing economic and political environment. Focusing on energy use in industrial buildings, the workshop summarized existing knowledge in the field and identified gaps in data needed for forecasting energy use and peak loads and for analyzing load-shaping and conservation strategies.

Another integral objective of the workshop was to identify the need for future research and development and to prepare detailed research plans for the California utilities, CEC, and DOE.

We hope that the proceedings of the workshop will constitute a common basis for developing a plan for further research in industrial building energy use, modeling, and assessing conservation and load-shaping potentials in California industry.

Reference

Akbari H, Gadgil A, eds. *Workshop Proceedings of the Industrial Building Energy Use.* Lawrence Berkeley Laboratory Report LBL-27658, 1988.

Workshop on Saving Energy and Reducing Atmospheric Pollution by Controlling Summer Heat Islands

H. Akbari, K. Garbesi, and P. Martien

A workshop was held at the University of California at Berkeley on the energy implications of summertime urban heat islands and the potential to control them. The workshop was sponsored by grants from the Universitywide Energy Research Group, University of California at Berkeley, the U.S. Environmental Protection Agency (EPA), and the Electric Power Research Institute (EPRI). The objective of the workshop was to coordinate a nationwide effort to study the energy and environmental implications of summer heat islands, with the ultimate goal of identifying and evaluating mitigation strategies and developing policy recommendations to promote energy-efficient site design for existing and planned urban areas.

Workshop presentations, papers, and discussions fell into four broad categories: the potential to conserve energy, to reduce atmospheric pollution, and to slow global warming by reducing summer heat islands; use of computer models to understand and simulate the heat island phenomenon; measurement of heat islands; and the design and implementation of heat island mitigation strategies.

In addition to presentations, the workshop participants attended three study groups to discuss

- microclimate modifications for saving cooling energy, reducing CO_2 emissions, and mitigating global warming;
- heat island characterization and modeling;

• an outline for a manual of strategies to reduce heat islands.

We hope the contents of the workshop proceedings will constitute a common basis for developing a plan for further research on heat island mitigation, modeling, assessing energy conservation, reducing peak power use, and improving the air quality of metropolitan areas.

Reference

Garbesi K, Akbari H, Martien P, eds. *Controlling Summer Heat Islands: Proceedings of the workshop on saving energy and reducing atmospheric pollution by controlling summer heat islands.* Lawrence Berkeley Laboratory Report LBL-27872, 1989.

Summer Heat Islands, Urban Trees, and White Surfaces

H. Akbari, A. Rosenfeld, and H. Taha

Review of temperature trends for the past 100 years in several U.S. cities shows that since about 1940, urban temperatures have steadily increased. Summer monthly averages have increased by 0.25-1°F per decade (about 1°F for larger cities such as Los Angeles, and 0.25°F for smaller cities), and we see no evidence that this rise is moderating. This long-term warming is responsible for a 1-2% increase in peak cooling loads for each degree of temperature rise, and most major cities are now about 5°F warmer than they were in the early 1900s. Therefore, we estimate that about 5-10% of current urban peak electricity use is spent to cool buildings as compensation for the heat island effect.

Because Los Angeles has warmed by about 5°F since 1940, it has incurred an increase of 375 MW or 10% of the current peak load (Figure). Other utility systems in the United States show similar trends, i.e., 1-2% increase for each degree of temperature rise. With an average cost of 10¢/kWh for electricity at peak periods, we estimate that the hourly cost of all the heat islands in the United States is about $1 million.

In addition to increasing the systemwide cooling loads, higher urban temperatures of summer heat islands increase smog. A review of smog data for Los Angeles and for 13 cities throughout Texas indicates a strong relation between smog and daily maximum temperature.

Urban trees and light-colored surfaces effectively and inexpensively reduce heat islands and create summer oases. Trees can improve the urban climate and reduce summer cooling energy use in buildings at about 1% of the capital cost of the avoided power plants and air-conditioning equipment. Light colors decrease surface absorption of short-wave radiation, thereby reducing surface temperatures and convective heating of near-surface air. On the urban scale, this results in cooler cities. External surfaces of buildings can be whitened and streets and parking lots resurfaced with white sand, thereby reducing cooling energy needs at relatively low costs.

Simulation results indicate that, in the United States, these strategies can save 0.5 quads of energy per year at a cost of saved energy of less than 1¢/kWh.

Reference

Akbari H, Rosenfeld A, Taha H. "Recent developments in heat island studies: Technical and policy." In: Garbesi K, Akbari H, Martien P, eds. *Controlling Summer Heat Islands: Proceedings of the Workshop on Saving Energy and Reducing Atmospheric Pollution by Controlling Summer Heat Islands.* Lawrence Berkeley Laboratory Report LBL-27872, 1989.

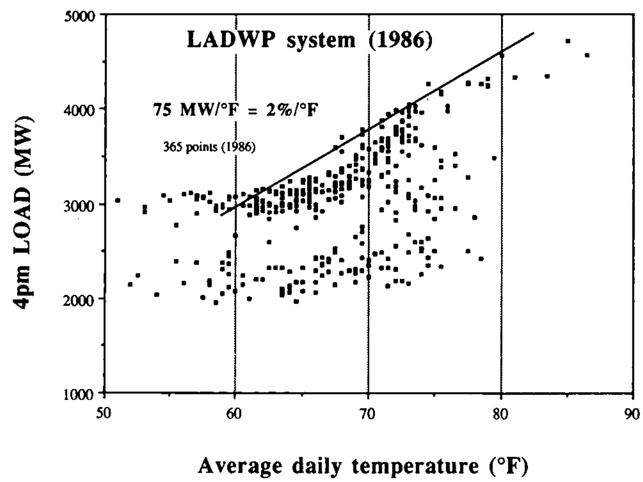

Figure. Dependence of systemwide utility load on dry-bulb temperature for downtown Los Angeles, served by the Los Angeles Department of Water and Power. (XBL 8912-4392)

Analysis of Cogeneration Potential in the Commercial Sector

Y.J. Huang, R. Ritschard, H. Akbari, and L. Rainer

One of the Gas Research Institute's (GRI) many objectives is to establish a foundation of information on the technical and sector-related factors that affect the use of natural gas in the commercial sector; this information, in turn, is intended to provide direction for continued research and development. The commercial sector holds particular appeal for potential advances in gas technologies because the sector is a relatively large energy consumer and contains a vast number of physical structures, each requiring individual systems.

To enhance its technology assessment, GRI has contracted with RCG/Hagler-Bailly, Inc. (HBI) and LBL to develop a market assessment tool for analyzing the potential of cogeneration for commercial buildings in 20 representative city markets. HBI's responsibility is to develop a microcomputer program that will allow GRI to track the potential cogeneration market depending on different institutional and technical factors. LBL's responsibility is to provide detailed characterizations of the commercial sector in the 20 city markets, including 1) estimates of current and future building stock by class type; 2) descriptions of prototypical buildings by class type, location, vintage, and equipment; and 3) DOE-2 computer simulations of hourly energy use for these prototypical buildings.

More than 400 building/location variations are being simulated. Building types simulated include hospital (Figure), secondary school, prison, hotel, motel, sit-down and fast-food restaurants, large office, supermarket, apartment, and large retail store.

One format of the output data from the simulations are three-dimensional "demand-duration" bins of thermal, air conditioning, and non-air conditioning electric loads that are incorporated into the microcomputer program developed by HBI. In addition, detailed hourly files of end-use data are provided to GRI with a computer program to reconstruct the simulated hourly energy use profiles by end use.

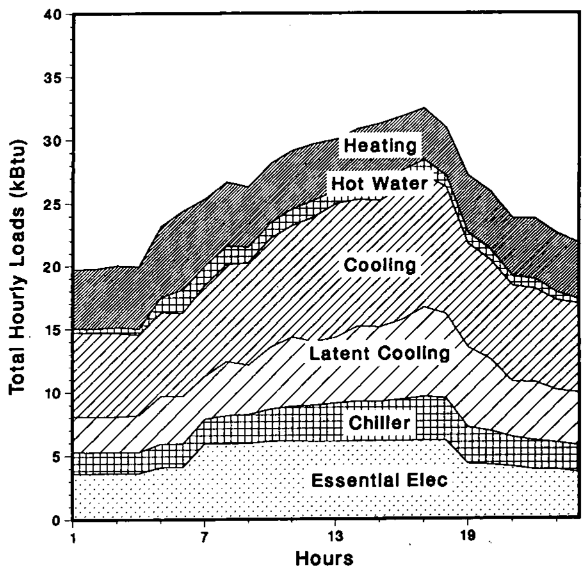

Figure. Hourly end-use energy loads for a prototypical hospital in Washington, DC, on a typical summer day. (XBL 8912-4431)

Energy Conservation Potential in Chinese Residential Buildings

Y.J. Huang

On an absolute basis, the residential building stock in China is one of the largest and fastest-growing in the world. Despite a range of climates similar to that of the United States, Chinese residential buildings are uniformly uninsulated and leaky, with thermal integrities comparable to those of pre-1940s American apartment buildings. The heating systems, if installed, have efficiencies around 50%; cooling is virtually nonexistent. The actual energy uses in these buildings, however, are limited by government mandates regulating when heating is allowed and how much coal is allowed per floor area.

An earlier study showed that under standard design conditions, building energy conservation is very attractive for China, with simple payback times in Beijing of 6 years for improved window seals and 12 years for double-glazing. Our current study investigates how actual operating conditions effect these potential energy savings. Computer simulations have determined both the increases in indoor temperature and the coal savings realized from use of conservation strategies such as insulation, double-glazing, reduced infiltration, and improved boilers.

The concept of *unmet heating degree-days* has been developed to quantify improvements in indoor comfort before any energy savings are realized. The study shows that, despite the masking effect due to current underheating, improved building and system designs can still reduce energy use by 40% while dramatically raising indoor temperatures. Economic calculations comparing energy savings to increased construction costs are skewed by unmet heating loads and by government-subsidized coal prices. From the narrow perspective of building owners and managers, building energy conservation is economically attractive in Harbin in northeast China, where the cost of conserved coal is half that of the subsidized coal price, but difficult to justify in Beijing or Shanghai. For a societal point of view—i.e., using the market price of coal—energy conservation is worthwhile in both Harbin and Beijing.

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Huang YJ. "Potentials and barriers to building energy conservation in China." Presented at the Western Economic Association International Annual Meeting, Lake Tahoe, CA, June 1989. Lawrence Berkeley Laboratory Report LBL-27664, 1989.

Multifamily Building Analysis: Comparing Simulation Results to Measured Data

R.L. Ritschard and J.W. Hanford

As part of a study for the Gas Research Institute (GRI), we compare the heating and cooling loads for 16 prototypical multifamily buildings calculated using the DOE-2.1D simulation code to available sources of measured data. Measured energy consumption was taken from two national surveys: the Residential Energy Consumption Survey (RECS)—prepared by DOE's Energy Information Administration—and the American Gas Association's (AGA) Annual Survey. We also used data from several individual multifamily buildings in the Northwest and in Minneapolis.

Several factors make it difficult to compare simulated data to measured data. For example, measured data from surveys or obtained from utilities are generally given as levels of energy consumption (e.g., billed energy usage of a furnace, water heater, or air conditioner) rather than as building loads; that is, heat requirements are given without consideration of equipment. This difference makes the comparison troublesome because of the wide range of efficiencies among individual apartments and multifamily buildings, and between different regions of the country. We addressed the issue of efficiencies by comparing the measured consumption to a range of loads that assumes efficiencies between 55% and 75% (Figure).

Despite the many difficulties of comparing simulated loads to measured energy consumption, we found that combined space- and water-heating loads from simulations agreed with measured data (within ±20%), especially from large statistical samples. Because of the lack of credible measured data from multifamily buildings, cooling loads were not evaluated. GRI and its contractors will use LBL's comprehensive database of building loads to assess new and advanced technologies. This data comparison study should provide more confidence to users of the simulation results.

Reference

Ritschard RL, Hanford JW. *Comparison of Multifamily Heating and Cooling Loads From DOE-2 Simulations with Measured Data*. Lawrence Berkeley Laboratory Report LBL-27870, 1989.

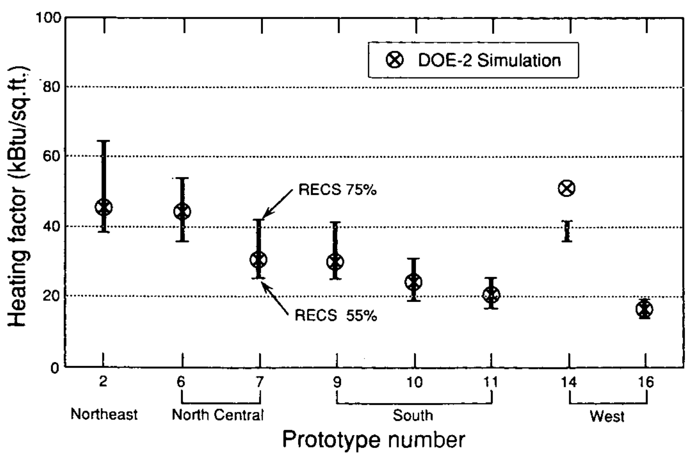

Figure. Comparison of simulated results and RECS data: prototypical multifamily buildings with individual fuel heating and domestic hot-water systems in each of four Census Regions.
(XCG 8911-4726)

Multifamily Building Analysis: Estimating Water Heating and Aggregate Electricity Loads

R.L. Ritschard and Y.J. Huang

We have extended our 1988 study, funded by the Gas Research Institute, in which we developed a comprehensive database of heating and cooling requirements for multifamily buildings in 15 cities. This database had been estimated using an hourly building energy simulation code, DOE-2.1C. Because the non-space conditioning energy requirements for water heating and aggregate electricity (i.e., lights and appliances) are not part of the normal DOE-2 output, it had become necessary to calculate them and to incorporate these calculated estimates into the total energy requirements for each of the multifamily building types.

This year, we used standard engineering procedures to calculate annual water-heating loads per apartment (Figure). These procedures were developed for the California Residential Building Energy Efficiency Standards and are mathematically identical to DOE methods. These annual water heating estimates were apportioned to monthly and hourly values by considering water-use profiles from several sources of measured data and by deriving seasonal scaling factors. The water heating estimates also provide for weekday and weekend usage patterns. Peak usage occurred in January and December; the lowest usage was seen during the summer months. Variations between summer and winter usage were found to be greatest in locations with large annual temperature swings (e.g., Minneapolis, Phoenix) and are smoother in cities with more constant temperature (e.g., San Francisco and Miami).

Two different methods were used to calculate aggregate electricity consumption. In the first method, we estimated the electricity usage of typical appliances for each prototypical building and scaled the contribution from lighting according to the floor area of the apartments. In the other method, we analyzed recent measured data from the Residential Energy Conservation Survey (RECS) to determine average usage patterns per square foot in a large sample of multifamily buildings. The two methods produced similar electricity estimates for apartments with electric cooking, but they differed for units with gas ranges. Except for those building types assumed to have gas ranges and small apartments (less than 700 ft^2), the estimates of annual aggregate electricity loads differed by less than 10%. We used the estimates from the first method and incorporated them into the whole-building database.

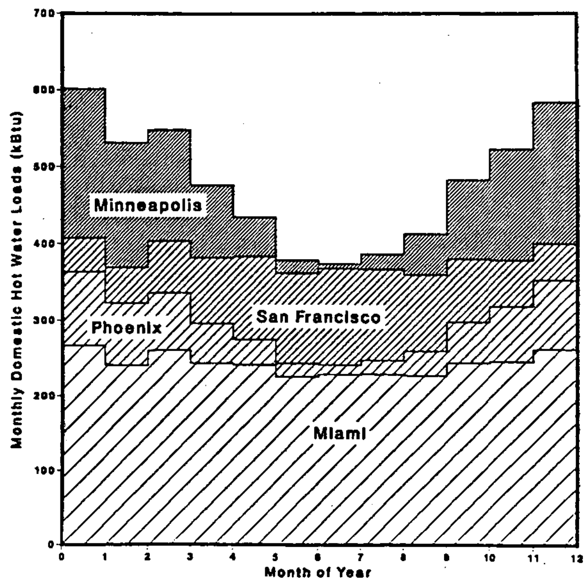

Figure. Estimated domestic hot water loads (per person) in multifamily buildings in four cities. Estimates consider seasonal variability of loads. (XBL 8912-4411)

Reference

Ritschard RL, Huang YJ. *Estimating Water Heating and Aggregate Electricity Loads in Multifamily Buildings.* Lawrence Berkeley Laboratory Report LBL-27871, 1989.

A Simplified Daylighting Design Tool For ASEAN Climates

Y.J. Huang, B. Thom, and B. Ramadan

Daylighting in commercial buildings refers to the use of electronic sensors in perimeter zones 1) to measure the availability of natural lighting through windows and skylights, and then 2) to reduce the artificial lighting intensity accordingly to maintain specified illumination levels. Daylighting is a particularly attractive energy conservation strategy in the tropics because it lowers not only lighting energy use but also air-conditioning loads by reducing unwanted heat gain from lights. Dramatic reduction in lighting energy is achievable in a high-lighting-level zone through the use of daylighting (Figure).

Effective daylighting design involves balancing the above benefits against the detrimental effects of unwanted solar heat gain through windows. These interactions can best be evaluated through parametric analysis with a detailed hourly computer simulation program. To make such information more accessible to architects and engineers, a large database has been compiled (using the DOE-2.1C program) to analyze the energy impacts of different daylighting designs on a prototypical office building in Singapore. These data are then transformed into a regression-based simplified calculation method that forms the basis of a PC-based daylighting design tool.

The daylighting design tool calculates the base-case cooling load, the cooling and fan energy, and the savings in lighting, cooling, and fan energy use when daylighting is used for an office zone, depending on orientation, office configuration, installed lighting power, required lighting level, overhang ratio, window area, and glass properties. Two parameters (base-case cooling loads and lighting energy savings) are functions of the above building characteristics and the climate. The other four (base-case cooling and fan energy, and the savings in cooling and fan energy use) are functions of the first two parameters.

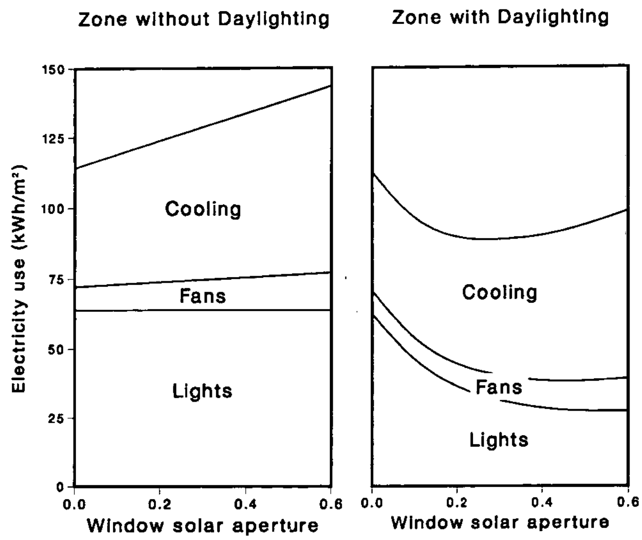

Figure. Net energy use in a middle-floor, southern zone with and without daylighting (depth, 6.1 m; lighting power, 21.5 W/m²; lighting level, 538 lux).
(XBL 8912-4412)

After the zone-level energy parameters have been determined, an extrapolation procedure is used to aggregate them into loads, energies, and energy savings for office buildings of various sizes, shapes, and shell designs.

Reference

Huang YJ, Thom B, Ramadan B. "A daylighting design tool for Singapore based on DOE-2.1C simulations." Presented at the *ASHRAE Far East Conference on Air Conditioning in Hot Climates*, Kuala Lumpur, Malaysia, October 25-28, 1989.

Analysis of Evaporative Cooler Performance in California Residences

Y.J. Huang, H.F. Wu, P.L. Chen, and H.M. Qin

The use of evaporative coolers, an energy-conserving alternative to conventional air conditioning, is particularly suited to the arid climates of California. Because evaporative coolers require power only to drive fans and pumps, these coolers consume far less electricity than do air conditioners. LBL-sponsored field tests in Arizona showed an average seasonal energy efficiency (EER) of 35.7, and 65-75% reductions in energy use for summer cooling. In addition, evaporative coolers are environmentally beneficial: they do not use chlorofluorocarbons, known to damage the ozone layer.

Despite these benefits, public acceptance of evaporative coolers has been hampered by misconceptions left over from obsolete "swamp coolers," by lack of information about its applicability to specific buildings and climates, and by concerns about comfort, health, and noise. This project, sponsored by the Universitywide Energy Group of the University of California at Berkeley, analyzes the performance and economic feasibility of evaporative coolers in California residences and small offices.

An empirical model for a direct evaporative cooler has been developed based on field measurements, and a heat- and mass-transfer model for indirect evaporative coolers developed and calibrated against manufacturer's data. The Figure shows the predicted effectiveness of plate- and tube-type indirect evaporative coolers as a function of airflow rate. The models were then incorporated into the DOE-2.1D program to permit whole-building simulation of evaporative cooler performance in various California climates.

In 1990, we will continue this work and will produce a monograph containing the results of the analysis for California residences.

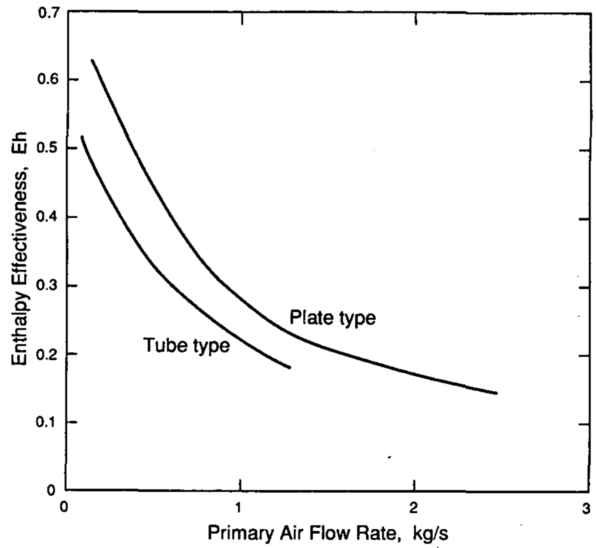

Figure. Enthalpy effectiveness of the dehumidifying process. (XCG 8912-4762)

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Chen PL, Qin HM, Huang YJ, Wu HF. *A New Heat and Mass Transfer Model for Thermal and Hydraulic Calculation of Indirect Evaporative Air Coolers.* Lawrence Berkeley Laboratory Report LBL-28201, 1989.

— *Building Energy Data* —

Measured Results from Single-Family Home Retrofits: BECA-B Update

S. Cohen, J. Harris, and C. Goldman

The Building Energy Use Compilation and Analysis (BECA) project at LBL addresses the need for retrofit performance data by compiling and analyzing data on the *measured* energy performance and economics of residential and commercial buildings designed or retrofitted with energy-saving features. Since issuing the previous update of the single-family (BECA-B) database in 1984, we have made two major changes. 1) results for envelope weatherization measures were expanded to include HVAC measures, and some high-quality submetered data are now available. 2) 63 data points were added, representing 16,401 houses. Data on costs and on energy savings include furnace retrofits and replacements, central air-conditioning replacement, envelope insulation, house-doctoring, warm-room zoning, and water-heating measures. Additionally, we have included some monitored end-use data on energy use and peak-power savings from electrical appliances.

Shell measures typically result in savings of 10% to 15%.* Most HVAC measures that do not involve expensive equipment replacements result in savings of approximately 5%. Flame retention burners for oil furnaces are an exception: they result in larger savings, with a payback period of five years or less. Ceiling insulation retrofits are the most cost-effective shell measures documented in the BECA database: they produce a consistent payback period of about five years. Water-heating measures often have very short paybacks—about six months to three years.

Replacement of central heating and air-conditioning units can result in a 10- to 25-year payback, depending on factors such as pre- and post-retrofit efficiency and capacity, total consumption, and fuel prices. However, the actual payback period may be less because the full cost of a new unit is attributed to energy efficiency.

The Urban Consortium's "warm rooms" project showed that zoning and weatherization of a limited area can produce large savings (about 30%) at costs similar to those of conven-

*Unless otherwise indicated, energy savings refer to the main space-heating fuel. Costs of measures are in nominal dollars. The simple payback period is based on local energy prices at the time of retrofit.

tional weatherization programs. The latter achieve 10% to 15% savings. However, zoning necessitates a change in lifestyle to achieve large savings.

Results from the weatherization programs in our database suggest that proper training, motivation, and final inspections were a key to consistent savings. Work planned in 1990 will elaborate on these initial findings, conduct additional comparative analyses, and relate BECA findings to trends in the U.S. residential stock.

Reference

Cohen SD, Harris J, Goldman C. *Update of Measured Results From Single-Family Retrofits: BECA-B Progress Report.* Lawrence Berkeley Laboratory Report LBL-28147, 1989.

Updated Results for Commercial Building Retrofits in the BECA-CR Database

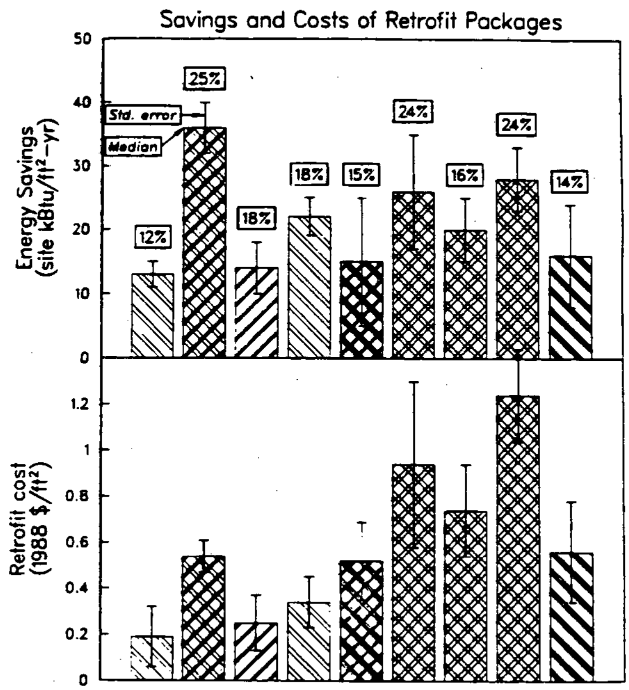
K. Greely, J. Harris, and A. Hatcher

We have updated earlier results in the BECA database on measured savings and cost effectiveness of commercial retrofit projects. The latest data cover 450 retrofit projects, representing over 1700 buildings. This update represents a 50% expansion of the initial 1984 database on commercial retrofits and addresses new issues such as individual retrofit savings, weather and occupancy normalization, electric peak demand savings, the impact of office equipment load growth, predicted vs. actual savings, and savings persistence.

Key findings (Figure):

- Median annual site energy savings amounted to 20 kBtu/ft², or 18% of whole-building usage; median retrofit cost was $0.56/ft² (1988 dollars), the median payback time was 3.1 years, and the median cost of conserved energy was $3.10/site MBtu.
- Median energy savings, retrofit costs, simple payback times, and unit costs of conserved energy (CCEs) were determined by type of retrofit measure.
- As an investment in energy conservation, the typical building owner was willing to spend the equivalent of only about eight months of energy costs.
- Retrofits installed after 1983 had lower savings, higher costs, and longer payback times than measures installed earlier, suggesting a decline in "cream-skimming" opportunities.
- Few predictions of savings came within ±20% of measured results.
- Post-retrofit data covering multiple years were available for more than half the projects; energy use continued to decrease for most of these buildings. However, in many cases, electricity use increased in each of the post-retrofit years, possibly due to growth in office equipment loads and in other miscellaneous loads.

Before retrofit, median energy intensity for buildings in the database was higher than that of the U.S. stock. Even after retrofit, the median for most building types was higher than the stock median and well above that of new, energy-efficient buildings. This suggests that considerable potential remains for saving energy in the commercial sector. Despite significant savings and short payback times for many projects, optimum savings are often not achieved. This is due to limited willingness (or financial ability) of owners to invest in all cost-effective measures, and to improper retrofit installation and/or maintenance.



	Maint.	Lights + HVAC	Lights	HVAC	Shell+ Lights	HVAC+ Wind.	HVAC+ Insul.	HVAC+ Shell	Shell
N =	88	101	31	115	10	25	33	30	18
Payback time (yrs)	1.1	1.4	2.0	2.9	4.7	5.7	6.2	6.7	8.6
CCE ($/site MBtu)	1.70	2.50	4.80	2.70	2.60	3.90	3.60	5.20	4.30
CCE ($/res. MBtu)	0.90	0.90	2.80	2.30	2.20	2.70	3.60	3.40	4.00

Figure. Energy savings, retrofit cost, median payback times (using national average energy prices), and costs of conserved energy (CCE) of various commercial retrofit strategies, from the BECA-CR database. Each project is assigned to the narrowest retrofit category that encompasses all retrofit measures. (XBL 8912-4397)

Reference

Greely KM, Harris JP, Hatcher AM. *Measured Savings and Cost-effectiveness of Conservation Retrofits in Commercial Buildings. Volume 1: Analysis and Results.* Lawrence Berkeley Laboratory Report LBL-27568, 1989.

Energy Edge Program Evaluation: Initial Performance Results

R. Diamond, J. Harris, O. de Buen, A. Hatcher, B. Nordman, and M.A. Piette

LBL is currently evaluating the 28 Energy Edge buildings as part of Bonneville Power Administration's multi-year effort to determine the conservation potential of new commercial buildings in the Pacific Northwest. Our work focuses on evaluating the energy performance of the buildings as well as the cost and savings of individual measures, comparing the Energy Edge buildings with other new buildings in the region. We are also comparing design-stage performance predictions by using simulations based on monitored data and, where possible, with direct performance measurements.

For one building, we have assembled recent estimates of individual measured performance based on a DOE-2 simulation calibrated with monitored data. This building had five Energy-Edge-funded measures: efficient lighting, extra wall and roof insulation, low-emissivity windows, vestibule entry, and occupancy sensors; the building also had non-Energy-Edge (owner-installed) measures. Estimated energy savings by measure differ—in some cases dramatically—from the original design-stage estimates (Figure). Compared with the original savings predictions, estimated savings from the "tuned" DOE-2 model were 40-60% higher for wall insulation, 50% lower for lighting, 80% lower for roof insulation, and 25% lower for low-emissivity glass. The original savings estimated for the vestibule was 3700 kWh; the tuned model estimate ranged from zero (assuming no infiltration savings) to 11,600 kWh. Direct measurement of infiltration effects from the vestibule is a high priority for the coming year.

We plan to continue this analysis on other Energy Edge buildings, looking at issues of both cost and energy savings for individual measures as well as intensities of whole-building energy use. Results from this work will be used in revising building codes and utility programs for the Pacific Northwest region.

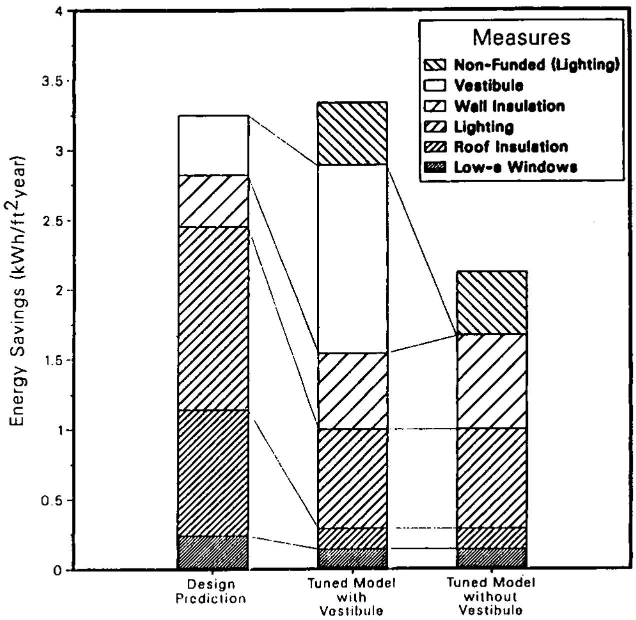


Figure. Comparisons of design-predicted savings and modeled savings based on monitored data for an Energy Edge office building. (XBL 8912-4384)

Incorporating Non-Energy Attributes into Energy Conservation Decisionmaking

E. Vine and J. Harris

Historically, the assessment of energy conservation programs has focused primarily on energy savings and costs. Because of the increased interest in global environmental issues and in the effects of energy policies on economic growth, policymakers need a methodology (as well as data) for easy, consistent comparisons of energy and non-energy impacts of a specific program, for retrospective analysis, and for planning.

In 1989, we presented the general concepts of a proposed new approach to multi-attribute analysis as an extension of the concept of supply curves for conserved energy. In their simplest form, energy conservation supply curves rank and display the savings from conservation measures in order of their cost effectiveness. This simple concept is extended to reflect multiple decision criteria and some important links between energy and non-energy policy decisions (e.g., a supply curve of reduced carbon emissions or a supply curve of net local job creation). The framework is flexible enough so that policymakers can weigh and compare each impact to reflect their concerns and to see the results in terms of program ranking. This analytic framework is simple to use, flexible, and replicable.

In displaying the results of our analysis, we compare four different approaches. The first approach compares two (or more) supply curves side-by-side: measures are first ranked by cost of conserved energy and then are separately ranked by cost of conserved carbon, for example. The second approach uses one supply curve to account for two (or more) criteria but adjusts the values of the first criterion by the impact of the second value. The third approach uses measure-specific estimates of the second impact for adjusting costs. The fourth approach uses a single supply curve but aggregates the values of the first and second (or more) attributes: a common index (e.g., dollars) is created so that the attributes can be converted into a single value.

We have outlined a conceptual approach for evaluating the energy and non-energy impacts of energy conservation programs. The difficult work ahead is in applying the framework and in determining its usefulness to decisionmakers.

Reference

Vine E, Harris J. Evaluating energy and non-energy impacts of energy conservation programs: a supply curve framework of analysis. *Energy* (in press, 1989); also published as Lawrence Berkeley Laboratory Report LBL-27275, 1989.

Extrapolating Measured Performance of Individual Buildings to Estimate National Energy Conservation Potential

A. Meier, C. Goldman, K. Greely, and J. Harris

The first estimates of aggregate energy conservation potential appeared in the mid-1970s. The initial estimating procedures have not changed substantially, although assumptions are now more thoroughly researched and documented. The estimation is based on prototype units with specified physical characteristics. Engineering calculations or computer simulations are used to estimate savings from one or more energy conservation measures. The savings for that prototype are then multiplied by a weighting factor to represent its fraction of the building stock.

A major drawback of the prototype-based procedure is its reliance on engineering calculations and on simulation; we are given no assurance that real houses, appliances, or equipment use as much energy as calculated. The increased availability of monitored-performance data now permits an alternative approach to estimating conservation potential, based on extrapolating measured savings from documented case studies. We have tested this new procedure by estimating the nationwide potential for energy-efficient space heating in existing multifamily buildings and in new, electrically-heated homes.

Results from the BECA-B database for multifamily buildings provided monitored space-heating savings for more than 200 projects representing 20,000 apartment units. The BECA-B database overrepresented larger multifamily buildings in the stock, buildings in cold climates, electrically heated buildings, and those with high initial consumption. The Residential Energy Consumption Survey (RECS) was used to calibrate BECA results to reflect national stock and characteristics of energy use. After making these adjustments, we found that typical space-heating retrofits of multifamily buildings could save about 0.2 quads per year nationwide and that intensive retrofits could save 0.5 quads. Both estimates involve considerable uncertainty.

We also estimated the potential space heating savings in new, electrically heated homes. The data were from Bonneville Power Administration's Residential Standards Demonstration Program (RSDP), an unusually large, diverse data set which included a control group. Using procedures developed for BECA, savings for 400 homes were normalized for weather and for occupancy. Average space-heating savings were about 45% (2500 kWh). Four adjustments were made to this initial estimate to account for differences from the U.S. electrically-heated stock in terms of heating system type, floor area, climate, and initial energy consumption. We found that applying building standards equivalent to RSDP could save as much as 0.32 quads/year nationwide after a decade.

This extrapolation method may give a more believable estimate of aggregate energy savings because it is based on monitored savings. The method still has limitations, however, and these relate mainly to data availability; the extrapolation method can provide only measures that have been implemented and well documented. Moreover, it may require both physical and demographic data not normally compiled either in retrofit projects or in stock surveys. As better data become available (e.g., on measure-specific savings), the case-study extrapolation approach will merit further attention.

— *Energy Conservation Policy* —

Analysis of Federal Appliance Efficiency Standards

J.E McMahon, D.B. Berman, P. Chan, T. Chan, J. Koomey, B. Lebot, M.D. Levine, S. Stoft, and I. Turiel

As amended by the National Energy Conservation Policy Act, by the National Appliance Energy Conservation Act of 1987, and by the National Appliance Energy Conservation Amendments of 1988, the Energy Policy and Conservation Act provides energy conservation standards for 14 types of consumer products* and authorizes the Secretary of Energy to prescribe amended or new energy standards.

LBL's assessment since 1979 of proposed standards evaluates their economic impacts according to legislated criteria (Figure). The economic impact analysis is performed in four major areas:

- An *engineering analysis*, which establishes the technical feasibility and product attributes including costs of design options to improve appliance efficiency.
- A *consumer analysis*, which forecasts appliance sales, efficiencies, energy use, and consumer expenditures to the year 2015.
- A *manufacturer analysis*, which provides an estimate of manufacturers' responses to the proposed standards. Their responses are quantified by changes in several measures of financial performance.
- An *impact analysis*, which provides an integrating framework for assessing the costs and benefits of appliance standards. The impact analysis includes a consumer *life-cycle cost analysis*, a *utility analysis*, an aggregate *cost-benefit analysis*, and an *industry impact analysis*.

In 1989, we analyzed the impacts of proposed updated standards for refrigerators, refrigerator-freezers, freezers, small gas furnaces, dishwashers, clothes washers, and clothes dryers. We demonstrated potential energy savings for these products and identified standards levels projected to save energy and to save money for consumers without undermining the financial health of the appliance industry.

A substantial effort was dedicated to projecting the impacts of the expected elimination of chlorofluorocarbons from new household refrigerators and freezers in the 1990s.

In 1990, we will analyze proposed energy efficiency standards for the aforementioned products except refrigerators, refrigerator-freezers, freezers, central air conditioners, and heat pumps.

*The fourteen products covered are refrigerators, refrigerator-freezers, and freezers; room air conditioners; central air conditioners and heat pumps; water heaters; furnaces; dishwashers; clothes washers; clothes dryers; direct heating equipment; kitchen ranges and ovens; pool heaters; television sets; fluorescent lamp ballasts; and any other product so classified by the Secretary of Energy.

References

U.S. Department of Energy, Assistant Secretary, Conservation and Renewable Energy, Buildings Equipment Division. *Energy Conservation Standards for Consumer Products: Refrigerators, Furnaces, and Televisions Sets.* Technical Support Document DOE/CE-0239, November 1988.

U.S. Department of Energy, Assistant Secretary, Conservation and Renewable Energy, Buildings Equipment Division. *Energy Conservation Standards for Consumer Products: Dishwashers, Clothes Washers, and Clothes Dryers.* Technical Support Document DOE/CE-0267, July 1989.

U.S. Department of Energy, Assistant Secretary, Conservation and Renewable Energy, Buildings Equipment Division. *Energy Conservation Standards for Consumer Products: Refrigerators and furnaces.* Technical Support Document DOE/CE-0277, November 1989.

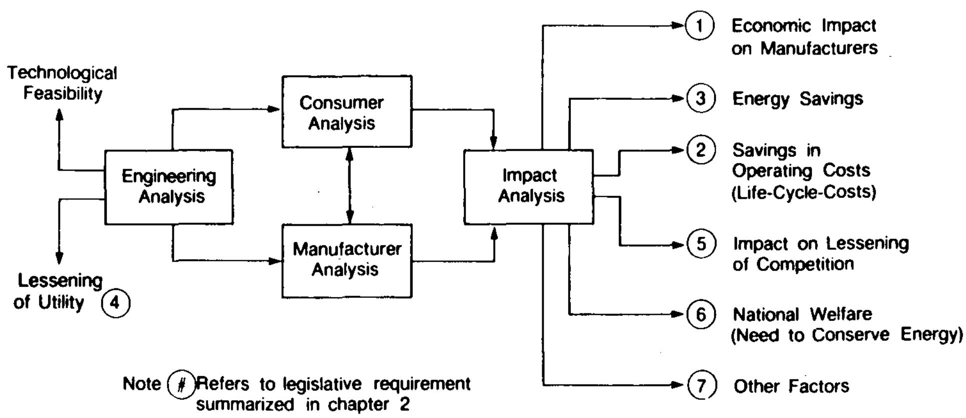


Figure. Satisfaction of legislative requirements through the analysis process. (XBL 856-8918)

Engineering Analyses of Appliance Efficiency Improvements

I. Turiel, A. Heydari, and B. Lebot

The economic impacts of appliance efficiency standards depend largely on the relation between cost and energy consumption of a consumer product. Our engineering analysis seeks primarily to identify this cost-consumption relation for selected appliances. In 1989, we analyzed refrigerators, freezers, dishwashers, clothes washers, clothes dryers, and small gas furnaces. Two legislative requirements were addressed: estimating the maximum technologically feasible design options, and ensuring that new designs do not lessen consumer utility.

Our analysis selects appliance classes, baseline units, and design options; determines maximum technologically feasible designs and the efficiency improvement provided by each option; develops cost estimates; and generates cost-efficiency relationships. Data are obtained through contacts with trade organizations and manufacturers, from computer simulations, and from suppliers of purchased parts and materials. Public comments on a previous notice of proposed rulemaking (NOPR) for refrigerators, freezers, small gas furnaces, and televisions were reviewed, and a reanalysis was performed for refrigerators and freezers. The reanalysis assumed that the use of chlorofluorocarbons (CFCs) would be phased out by the mid 1990s; therefore, substitutes for CFC-11 (used in insulation) and CFC-12 (a refrigerant) were evaluated. The analyses were used in the final notice of rulemaking published by DOE in November of 1989.

Our engineering analysis of dishwashers, clothes washers, and clothes dryers, was used by DOE for a NOPR concerning these three products. Public comments for these three products have been received and are under review.

In 1990, we plan to modify the engineering analysis for dishwashers, clothes washers, and clothes dryers based on the comments received on the NOPR. Responses to public comments on these three products will be prepared. We also plan to perform new analyses for eight products: water heaters, pool heaters, direct heating equipment, mobile-home heaters, fluorescent ballasts, room air conditioners, ranges/ovens, and televisions.

References

Federal Register, November 17, 1989; 54:221:47916-47945.
Federal Register, August 9, 1989; 54:152:32744-32767.

Assessing the Impact of Appliance Standards on Manufacturers

S. Stoft, T. Chan, and P. Cunliffe

The Manufacturer Analysis assesses the impact of appliance standards on the the profitability and competitiveness of various appliance manufacturing industries, i.e., those to be affected by mandatory energy-efficiency standards. The primary tool used for our evaluation is the Manufacturer Impact Model (LBL-MIM). LBL-MIM uses engineering cost and efficiency estimates as well as economic and financial data for the analysis. Output includes price, rate of profit, shipments, revenue, net income, and the standard errors for these estimates. LBL-MIM also estimates retail prices used by the Residential Energy Model (LBL-REM) and by our life-cycle cost analysis.

In 1989, we used LBL-MIM to prepare a final analysis of refrigerators, freezers, and small gas furnaces, as well as to prepare a Technical Support Document (TSD). In addition to the analysis of standards, a regulatory impact analysis for the case of more costly chlorofluorocarbons (CFCs) was done. We also generated estimated retail prices for CFCs. We also completed an initial analysis and a TSD for dishwashers, clothes washers, and clothes dryers.

Our results continue to indicate that, contrary to industry assertions, federal energy-efficiency standards are not likely to exert a drastic impact on profitability because industry can use markups to pass on variable costs.

Planned enhancements and activities regarding LBL-MIM include revising the model to include specification of a discount rate which will allow LBL-MIM to better use data from LBL-REM. LBL-MIM will be reviewed by an external panel of representatives from industry, academia, and the Environmental Protection Agency. The review panel will review LBL-MIM's modeling approach and economic assumptions to identify strengths and areas for improvement. We also plan to integrate more fully LBL-MIM's demand modeling with LBL-REM.

Reference

Stoft S, Chan T, Hobart. *A Method for Assessing the Impact of Federal Efficiency Standards on the Manufacturers of Home Appliances.* Lawrence Berkeley Laboratory Report LBL-28237, 1989.

Forecasting Residential Energy Demand

J..E McMahon, D.B Berman, and P. Chan

The LBL Residential Energy Model (LBL-REM) estimates the consumer impacts of federal policies regarding energy consumption by home appliances, including furnaces and air conditioners. LBL-REM combines engineering estimates of possible appliance designs with simulation of market behavior (including fuel choice, efficiency choice, and usage behavior) involved in the purchase of appliances (Figure).

LBL-REM has been improved this year: we have explicitly modeled the elimination of chlorofluorocarbons (CFCs) from household refrigerators, refrigerator-freezers, and freezers in the 1990s; we have added the capability to project household consumption of water and of hot water—and water and sewage costs—as a function of ownership and characteristics of clothes washers and dishwashers; and we have conducted a preliminary analysis of uncertainty arising from key variables, including projected energy prices and purchase prices of efficient appliances.

The model was used to analyze the impact of federal policies on consumers and on national energy consumption. These policies include DOE's promulgation of more stringent standards for refrigerators, refrigerator-freezers, freezers, and small gas furnaces; and proposed new standards for dishwashers, clothes washers, and clothes dryers.

In addition, LBL-REM results were used to analyze impacts on manufacturers, electric utilities, and the environment.

We plan to continue modeling the impacts of any proposed federal conservation standards. For example, we will incorporate into LBL-REM any new data arising from public comments on the proposed rules for dishwashers, clothes washers, and clothes dryers. Analysis of room air conditioners, water heaters, direct-heating equipment, and pool heaters will be performed on a regional basis. We will develop new projections of energy consumption for televisions, mobile-home furnaces, fluorescent-lamp ballasts, and ranges and ovens. We will continue to improve the consumer analysis and forecasting capabilities of LBL-REM and will continue to enhance its capability to analyze uncertainty.

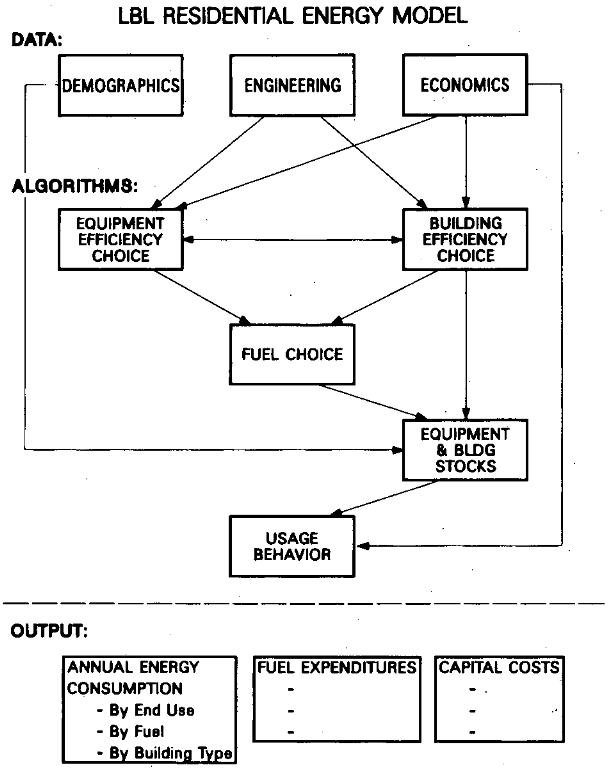


Figure. Logic diagram showing major components of LBL Residential Energy Model. (XCG 8412-13510)

Energy-Efficient Refrigeration and the Reduction of Chlorofluorocarbon Use

I. Turiel and M.D. Levine

Two recent actions by the U.S. Congress–passage of the National Appliance Energy Conservation Act (NAECA) and ratification of the Montreal Protocol on Substances that Deplete the Ozone Layer–have profoundly affected several large industries in the United States. Under NAECA, manufacturers of residential appliances must meet minimum energy-efficiency standards by specified dates. According to the Montreal Protocol, producers of chlorofluorocarbons (CFCs) must reduce the amount of CFCs that they manufacture, as CFCs have been identified as a cause of ozone depletion in the stratosphere. Because CFCs are used as blowing agents in polyurethane foam insulation to improve the efficiency of refrigerators and freezers, a potential conflict exists between the goals of reducing CFC use and improving energy efficiency. CFCs are also used as the heat-transfer fluid in the refrigeration system of refrigerators and freezers.

We have evaluated CFC use, ozone depletion, energy efficiency, and global climate change as these issues relate to residential refrigerators and freezers. Refrigerators and freezers use large quantities of CFC-11 and CFC-12 and consume a significant amount of electricity (7% of total U.S. electricity use). We also analyzed the cost and energy-use impacts of using substitutes for the present refrigerant and insulation. Evacuated panel insulation, which could substitute for foam insulation, was assessed as a promising alternative for the mid- to late 1990s. In addition, we discuss policy alternatives such as reclamation and recycling of CFCs, as well as the impacts of various strategies on global warming.

The Potential for Cost-Effective Buildings by the Year 2010

J.E. McMahon, D.B. Berman, P. Chan, J. Eto, and J. Koomey

The buildings sector—residential and commercial combined—accounted for 65% of U.S. electricity consumption and 48% of U.S. natural gas consumption in 1988. Buildings have accounted for an increasing share of national energy consumption, rising from 32.7% to 36.3% between 1979 and 1985. In 1985, total costs for construction and energy amounted to 13.2% of GNP.

Future U.S. energy consumption in buildings will depend on population growth, economic conditions, energy prices, and the choices we make. From 1990 to 2010, the number of households is expected to increase by 32%, and commercial floorspace is expected to increase by 47%. Based on current decisionmaking processes, total residential energy consumption is expected to increase by about 18%; total commercial energy consumption, by about 44%. The fraction of total primary energy consumed in the buildings sector and supplied by electricity is expected to increase from 63% in 1990 to 76% by 2010.

A large database of technological improvements already available to buildings provides the basis for characterizing an alternative future. In this scenario, decisions about equipment efficiency and the penetration of energy-saving designs in buildings are driven by life-cycle economic considerations. Equipment and building purchasers are modeled as if they consider the sum of life-cycle operating expenses (discounted at 7% real) along with the first costs when choosing energy-consuming products. Investments having minimum life-cycle costs are preferred; in effect, energy-efficiency improvements are made as good investments.

This scenario does not attempt to maximize energy savings with best available technology, but instead is driven by sound investment criteria only. Because historical purchasing decisions regarding equipment and building shells have typically not used such investment criteria consistently, this scenario results in greater investment in energy efficiency and significant energy savings over projections based on current decisionmaking. Overall growth in primary energy consumption in buildings (residential and commercial combined) is reduced by more than half, i.e., from 30% to 12%.

We expect to expand the technology database and to analyze potential policies for achieving widespread adoption of the cost-effective measures.

Reference

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—*Global Energy/Environmental Issues*—

Research and Policy Studies to Promote Energy Efficiency in Southeast Asian Buildings

M.D. Levine, J.J. Deringer, J.F. Busch, Y.J. Huang, and K.H. Olson

The purpose of this project is to assist five ASEAN countries* to identify appropriate government policy options for conservation of building energy, to enhance their policy analysis capabilities, and to implement policy initiatives.

Several ongoing tasks have continued through 1989. First, technical assistance has been provided to several countries in their development of energy conservation standards for new commercial buildings. Indonesia, Malaysia, the Philippines, and Thailand are all in the process of adopting new building standards for implementation; Singapore is currently upgrading its 1979 standard. Second, we created a database of more than 800 DOE-2 simulations on the potential energy savings of using natural daylighting in Singapore office buildings, and we developed a simplified methodology for extrapolating these data to office buildings of different configurations. Third, we consolidated the results of in-country surveys of commercial buildings into an ASEAN-wide database and conducted a comparative analysis of electricity use by building type.

The most important new achievement of the project has been the progress made toward completion of research projects on building energy conservation in each of the ASEAN countries:

- Indonesia has performed research on air conditioning systems, has conducted energy audits, and is developing a national policy to promote energy-efficient new buildings.
- In Malaysia, a case-study analysis has been performed to understand the impacts on the Malaysian electric utility of the widespread application of thermal energy storage (TES) systems for air-conditioning large commercial buildings.
- The Philippines have conducted detailed surveys of more than 50 buildings to identify their building characteristics, energy systems, and energy consumption. The data gathered are being used in drafting requirements for energy efficiency in commercial buildings.
- Singapore researchers have used DOE-2 computer program results as a basis for developing a simplified method for implementing standards.
- Using an existing database on energy use in Thai buildings and local climate data, Thailand has drafted an energy performance standard for commercial buildings.

These research activities, as they progress in each of the countries, will yield a deeper understanding of energy use in ASEAN buildings. This in turn will provide a sound technical basis for developing effective policies to reduce energy use in buildings.

*Indonesia, Malaysia, the Philippines, Singapore, and Thailand.

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Energy Issues in China

M.D. Levine, F. Liu, X. Liu, and M. Ross

The objective of this project has been to study energy issues in the People's Republic of China related to global climate change. The historically rapid growth of energy use in China, combined with the high proportion of coal use in the energy economy and the immense population of China, has made China a major contributor to global release of greenhouse gases (Figure).

This project involves close collaboration with Chinese researchers, particularly at the Energy Research Institute of the State Planning Commission. Work has concentrated on four topics: 1) compilation of statistical data describing the evolution of the Chinese energy system; 2) review and analysis of energy conservation programs in China; 3) analysis of factors contributing to overall reductions in energy intensity in China over the past decade; and 4) assessment of the energy performance of the Chinese steel industry.

Some key findings of the research to date:

- Extremely rapid economic growth in China has led to rapid increase in energy consumption.
- Despite the rapid growth in energy supply, China has persistent shortages of energy, particularly electricity and, more recently, coal.
- Because its energy supply has not kept pace with its growing economy, China has devoted considerable effort to improving the efficiency of energy use.
- Energy use remains very inefficient in China. However, care must be taken in making comparisons between China and industrialized countries. In the steel industry, for example, raw data suggest that the energy required to produce a ton of steel in China is twice that required in the United States. A more careful analysis, in which corrections are made for accounting differences, differing products, and the like, reveals that the average intensity of Chinese steel plants is about 40% greater that U.S. plants.

Continuing work includes additional research in all four areas of the project as well as preparation of a monograph on critical energy issues facing China.

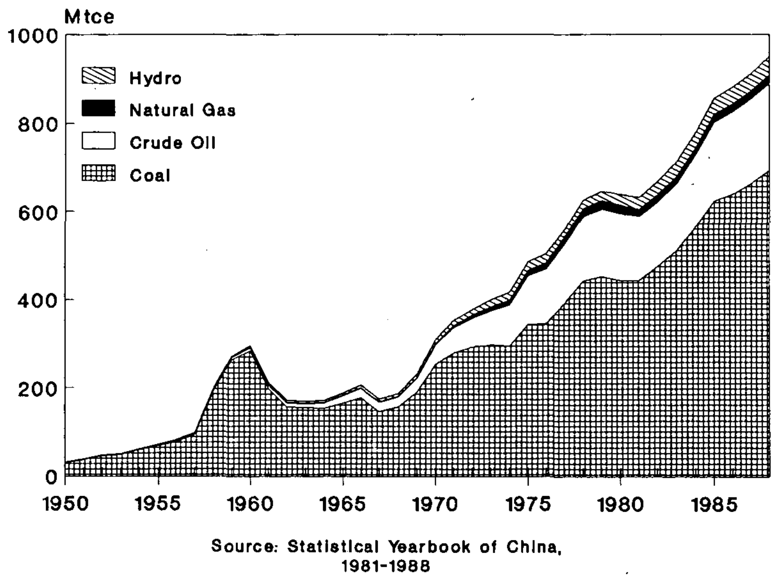

Figure. Commercial energy production in China. Mtce = million tons coal equivalent. (XBL 8912-4398)

Tropical Deforestation and Species Endangerment*

W.E. Westman

This research seeks ways to quantify the pattern and extent of deforestation in the tropics as well as the effect of this forest clearing on native species populations. We are using satellite remote sensing to quantify rates and patterns of tropical deforestation and are using field data and predictive models to link this information to predictions of species endangerment. Current efforts are focused on tropical rainforest regions in southern Uganda and northeastern Australia.

Using LANDSAT multispectral scanner (MSS) data, work in Uganda revealed that levels of forest disturbance could be discerned, but types of closed forest dominated by different species could not. Information derived at the fine scale of MSS was compared to coarser spatial scale imagery from the Advanced Very High Resolution Radiometer aboard the NOAA-9 satellite. In examining edge/area relations of the forests at changing scales of spatial resolution, we found that a constant fractal dimension characterized edge/area relations in two separate rainforest fragments.

For Queensland, we have developed a simulation model of gene flow between isolated populations of centipede in 17 forests fragments on the Atherton Tableland. Botanical work characterized differences in structural and dispersal characteristics of edge vs. interior forest species.

Future work will involve use of shuttle-imaging radar to discriminate forest structural types, and botanical work will characterize changes in forest structure and species distributions in a rainforest watershed. The site of these studies will be the Luquillo Experimental Forest in Puerto Rico.

The policy implications of tropical deforestation and climate change on biodiversity were also examined.

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*Collaborators: Laurence Strong, Christine Hlavka (NASA Ames Research Center); CJ Tucker (NASA Goddard Space Flight Center); Hank Shugart, John Weishampel (University of Virginia); Bruce Wilcox (Institute for Sustainable Development); and Mary Beth Buechner (University of California, Davis). This work was sponsored by the National Science Foundation and the NASA Earth Sciences Division.

Effects of Climate Change on Pacific Coastal Shrublands

W.E. Westman

The interactive effects of climate change, air pollution, and fire on species composition is being studied in two major shrubland types of the Pacific Coast of North America: coastal sage scrub and chaparral. Coastal sage scrub is a drought deciduous type that is a major source of ignition fuel for wildfires, particularly in Southern California. Chaparral is important both for control of soil erosion and for watershed protection on mountainsides throughout the West Coast; it is also an important source of fuel to sustain wildfires.

By combining field data with simulation models, we have found that the interactive effect of projected climatic changes with effects of climate change on ozone concentrations and fire frequency and intensity can produce more severe ecosystem effects than the direct effects of climate change on plant growth alone would imply.

In order to build a simulation model of chaparral to complement the existing model for coastal sage scrub, baseline data in a chaparral-clad watershed in the Santa Monica Mountains of Southern California were collected in anticipation of a controlled burn in the watershed in 1990. In addition, species distribution maps of 17 chaparral and sage species, made by field survey in the 1930s, were overlayed on climatic maps, using a geographic information system. This permitted derivation of climatic response functions for the species (Figure) that will be used in simulation modeling.

We plan to combine the chaparral and coastal sage scrub models to examine competitive behavior of species in the two communities under a range of climate scenarios.

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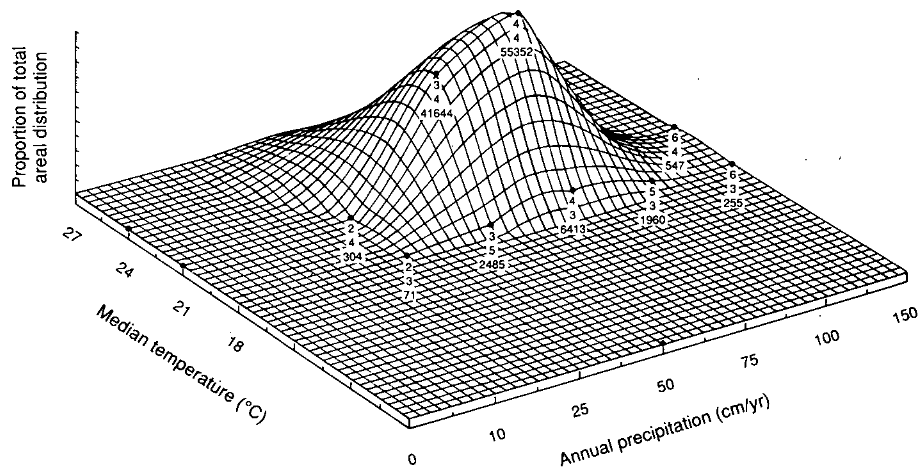

Figure. *Adenostema fasciculatum* versus precipitation (X) and hottest-month temperature (Y)
(XBL 8912-7342)

Global Climate Trends and Greenhouse Gas Data: Report to The U.S. Congress

R.L. Ritschard and W.E. Westman

This report, prepared for DOE, examines current and emerging federal efforts to collect, manage, and disseminate data on the emissions of greenhouse gases, their atmospheric concentrations, and trends in Earth's climate. The objective of the report is to review how data are used to estimate and project emissions, to infer climate trends, and to support assessment and policy analysis functions. It also examines coordination of federal data activities among agencies. The report recommends strengthening data collection and management in light of anticipated large increases in collection and demand for such data over the next decade.

Federal data centers, databases, and data directories are surveyed and are also described in greater detail in three appendices. We also describe anthropogenic and biogenic emission factors including available databases, emission models, and climatic feedbacks. We present the data collected on each major greenhouse gas (e.g., carbon dioxide, methane, nitrous oxide, halocarbons, and ozone), including information on ambient concentrations and trends in concentration. We discuss available data sources and data needs of several important climatic and geophysical variables such as surface temperature, stratospheric temperature, precipitation, cloud cover, fires, sea surface temperature, interior ocean properties, sea level change, and ocean chemistry. The roles of climate models and paleoclimatic research are also described. The remainder of the report covers the major issues of coordination, management, and dissemination of data. These issues are identified and summarized in light of both existing data sources and emerging data management concepts.

A set of findings and recommendations are provided in the full report under the major categories of data coordination, data management, and data collection. The most significant issue facing the global climate-change program is how to integrate the existing federal data management system in an era of expanding data collection from both land-based and satellite systems. In an effort to address this issue, we propose a global-change data and information network that improves coordination among national and world data centers and increases the ability to produce data and information for different users, including scientists, policymakers, and the public.

Reference

Ritschard RL, Westman WE. *Global Climate Trends and Green-House Gas Data: A Report to Congress on Federal Activities in Data Collection, Archiving, and Dissemination.* Washington, D.C.: U.S. Department of Energy, Office of Environmental Analysis, 1989.

Energy Technology for Developing Countries: Issues for the U.S. National Energy Strategy

M.D. Levine (editor)

This work is one of five reports prepared by the U.S. National Laboratories as a part of DOE's development of a National Energy Strategy. Under the leadership of LBL, contributions to this report were made by six other laboratories: Argonne, Battelle-Pacific, Los Alamos, Oak Ridge, Sandia, and the Solar Energy Research Institute.

The project reviews current issues involving energy in developing countries in order to identify prospects and needs to develop improved energy technologies and to speed their adoption. Review of the energy situation in developing countries reveals the relatively rapid past growth and the anticipated high future growth of energy in these countries. Assessment of existing energy loans and assistance to developing countries indicates that levels of support are inadequate to improve energy performance in most of the countries.

Against this background, the project explores opportunities for energy technology research, development, and demonstration (RD&D) and technology transfer to developing countries. We conclude that

- a variety of enhanced energy technology RD&D is needed;
- creation of desirable energy choices and adoption of improved energy technologies require broad, integrated programs;
- opportunities exist for greater efforts to promote use of technologies for more efficient end-use, non-fossil fuel supply, and more energy-efficient, environmentally acceptable conversion of fossil fuels;
- DOE has important capabilities to contribute to such programs.

— International Energy Studies —

A Long-Term Perspective on Norwegian Energy Use

L. Schipper, R. Howarth, and D. Wilson

Our analysis of long-term trends in energy use in the Norwegian economy (sponsored by Oslo Lysvaerker and the Norwegian Oil and Energy Department) shows that low electricity prices and the income generated by the development of North Sea petroleum resources have permitted Norwegians to largely escape the impacts of the energy shocks of the 1970s.

Between 1950 and 1986, the structure of the Norwegian economy evolved toward a progressively more energy-intensive mix of activities in manufacturing, transportation, and households. Although some improvements in energy efficiency were realized in the years following the energy shocks, these improvements were smaller than those observed in other nations and were largely offset by growth in energy-consuming activities. Automobile fuel economy has improved by about 10% since 1973, but the number of cars has increased by more than 50% over the same period. The thermal transmittance of building shells was reduced, but heated floor area and the energy intensity of space heating continued to rise even after 1973. In the manufacturing sector, most industry groups achieved modest reductions in energy intensity, but the share of output generated by energy-intensive industries grew steadily over time.

Although for the most part, the energy intensities of each major end-use sector remained constant or increased over the period of analysis, the ratio of energy use to Gross Domestic Product (GDP) fell by 25% between 1973 and 1986 because of changes in the structure of the Norwegian economy. The implication is that both efficiency improvements and structural change may exert pronounced impacts on the long-term evolution of energy use so that aggregate indicators such as the energy/GDP ratio may be misleading indicators of energy efficiency.

Reference

Schipper L, Howarth R, Wilson D. *A Long-Term Perspective on Norwegian Energy Use.* Lawrence Berkeley Laboratory Report LBL-27295, 1989.

Use of Oil and Energy by the Manufacturing Sector in Seven OECD Countries: A Review of Recent Trends

R.B. Howarth, L. Schipper, and P.A. Duerr

This project monitors the energy used by manufacturing in seven industrialized nations: the United States, Japan, the Federal Republic of Germany, France, the United Kingdom, Sweden, and Norway. Results indicate that sectoral energy use in these nations fell from 29.5 EJ in 1973 to 22.9 EJ in 1985—a reduction of 22%. Oil use fell by 57%—from 9.5 to 4.0 EJ—over the same period. At the same time, manufacturing output (as measured by real value added) increased by 26%. Manufacturing energy use was thus essentially decoupled from output during the 1970s and 1980s through reduced energy intensities in the industry groups that constitute manufacturing and through shifts in the structure or mix of output away from energy-intensive industries.

Of these two factors, reduced energy intensity was more important. Between 1973 and 1985, intensity reductions would have reduced sectoral energy use by 30% if the level and composition of output had remained constant; this estimate compares with the 22% reduction that actually occurred. Structural change—or shifts in the mix of products produced—also had a significant impact on energy use. The share of manufacturing output generated by five energy-intensive industry groups—iron and steel; non-ferrous metals; paper and pulp; industrial chemicals; and stone, clay, and glass—fell from 22% (in 1973) to 19% (in 1985). This change would have reduced energy use by 12% if the total level of output and the energy intensities of each industry group had remained constant. The 1973 and 1979 increases in the price of oil caused manufacturing oil intensity to fall by 66% between 1973 and 1985. Although the substitution of electricity and non-oil fuels was one factor behind this trend, direct efforts to conserve oil were probably more important. Our analysis shows that the intensity of electricity use was roughly constant, even after correcting for changes in the mix of products.

Although the reduction in total energy intensity appears to be permanent, oil use in Norway increased rapidly in 1986 and 1987 as the price of oil declined in international markets. Whether this trend will extend to other nations remains uncertain.

Reference

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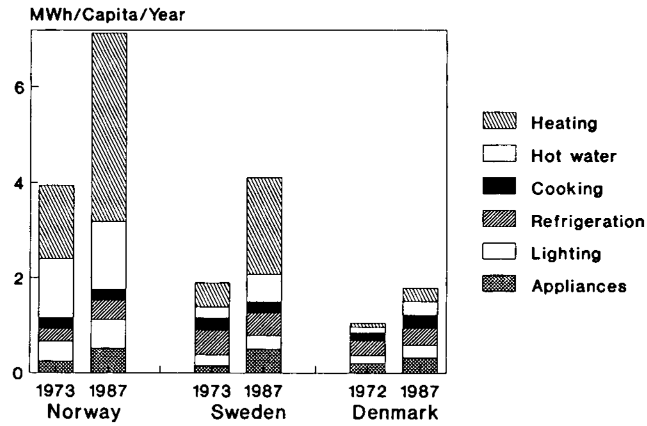
Dynamics of Electricity Use in Scandinavian Households

S. Tyler and L. Schipper

We have compared changes in the structure of residential electricity use in Denmark, Norway, and Sweden since the early 1970s. Substantial differences exist in per capita electricity use averaged over all purposes (Figure). We have noted that a major distinguishing feature among these countries has been the consistent differences in the average price of residential electricity.



We have reached three important conclusions: 1) when the saturation of household appliances reaches maturity, only changes in the use of electricity for space heating and for water heating can significantly change the intensity of electricity use in the residential sector; 2) efficiency of household electricity use is strongly influenced both by domestic technologies and policies (e.g., housing standards) and by international manufacturers (e.g., of lighting equipment, windows, and household appliances); 3) behavior of household occupants plays a key role in determining the intensity of electricity use, both through their demand for the services electricity provides and through their choices of equipment. Relative electricity prices have strongly influenced the choices of policymakers, consumers, and equipment manufacturers in this sector. Our conclusions suggest that pricing policies and improved technology offer potential for reducing residential electricity use in Scandinavia through greater efficiency and fuel substitution.

Reference

Tyler S, Schipper L. *Residential Electricity Use: A Scandinavian* Heating *Comparison*. Lawrence Berkeley Laboratory Report LBL-27276, 1989.

Figure. Residential electricity use in 1973 and 1987, normalized to population and corrected to normal climate; hot water includes clothes- and dishwashers. (XBL 8912-4395)

Urban Energy Use: Saturation and Fuel Transition in the Developing Countries

J. Sathaye and S. Tyler

This project studies the transition in household fuel use in cities of the developing countries from traditional biomass fuels to fossil fuels and electricity. Household energy consumption in several cities is being surveyed by each of five research teams at institutes in India, China, the Philippines, Hong Kong, and Thailand. The objective of the research is to relate patterns of fuel use to differences in household characteristics such as income, size, location, and access to fuels. In addition, a limited sample of indoor and outdoor air-quality measurements will help show the relative exposures of different types of households (differentiated by fuel use, income, and other characteristics) to airborne combustion products.

Most of the activities are sponsored by the International Development Research Center in Ottawa, Canada. LBL has been responsible for project development, provision of technical advice and support to the Asia-based research teams, and overall project coordination. LBL held principal responsibility for organizing an initial research workshop held in February 1989 and for developing a standard set of core survey questions to be included by each research group in its survey instrument. LBL will also conduct cross-national comparative analysis of survey findings as they become available.

The project is expected to add to the understanding of 1) household fuel use patterns, 2) changes in these patterns across incomes and countries, and 3) the degree of exposure to combustion-related indoor air pollution in cities of developing countries.

A workshop scheduled to be held in mid-1990 will allow participating research groups to present their results and to assess the policy implications of their findings.

Energy Demand in the Soviet Union: A First Appraisal

L. Schipper and R.C. Cooper

One of the most interesting developments of 1989 was the addition of the Soviet Union to the wide range of countries whose energy systems we have been examining. Energy consumption in the Soviet Union is extremely important to the Soviet economy. In the past, most work in this area was focused specifically on oil production and exports, because of Soviet hard-currency requirements. However, recent economic constraints in the Soviet Union have placed much more emphasis on energy efficiency in order to reduce the large share of investment claimed by the energy sector and to shift these funds towards additional consumer goods. The environmental aspect of fuel consumption and production is receiving significant attention in the press. As the Soviet Union is the world's second largest consumer of fossil fuels, that country's energy consumption plays a large role in global emissions. Our work in this area is proceeding in cooperation with the Soviet Academy of Sciences.

When we combine our preliminary observations of both the structure and intensity of Soviet energy use, we reach several tentative conclusions. First, the opportunities for energy conservation in the Soviet Union are truly enormous. The problems in obtaining increased efficiencies are, however, more institutional than technical: the Soviet Union has had little economic incentive to invest in more efficient energy use, although Soviet authorities are working hard to change that situation. Industrial development in the Soviet Union is based on large, energy-intensive industries whose emphasis has been on gross output of products without consideration of raw-material inputs. Energy prices are determined by a central pricing authority and have not kept pace with world energy prices or with the costs of domestic energy production. Technologies for monitoring energy consumption are not widely available, and many consumers pay for energy on an allocated basis (e.g., by square feet of floor space) rather than by actual consumption.

Our second conclusion is that some planned and implied structural changes might act to increase energy use, whereas other changes will decrease it.

Finally, we discovered that although not all of the theory of glasnost and perestroika has penetrated the energy sector of the Soviet Union at this time, the experts we have met have largely agreed that these concepts will have to impact all energy decisionmaking, lest the high cost of wasting energy bankrupt the process of perestroika.

Biomass Fuels in Developing Countries

S. Meyers and G. Leach

Reliance on biomass fuels (biofuels) is gradually giving way to use of kerosene and LPG in many cities of the developing countries, but biofuels still provide much of the basic energy used in rural areas and by the urban poor. Biofuels are also used by rural industries and commercial enterprises in towns.

We have reviewed the supply and consumption of biofuels in developing countries. Surveys show that in rural areas, use of crop residues and animal dung is more common in Asia, whereas wood tends to be more available in Africa and Latin America because of historically lower population density. In urban areas of Africa, charcoal use is very important. Fuelwood is common in many Asian cities, while biofuels are less significant in urban Latin America and in China. In rural areas, per capita consumption of biofuels is higher in the warmer regions of sub-Saharan Africa and Latin America compared with North Africa, the Middle East, and Asia, reflecting more abundant biomass resources. The lower proportion of biomass in total household energy use in Latin America—50% to 65%, versus 80% to 95% in most of rural Asia and Africa—results from higher rural incomes and from access to modern fuels. The importance of biofuels declines gradually from rural to urban settlements, with no rigid rural/urban distinction.

Variation in use of biofuels is shaped primarily by biofuel availability, by modern fuel availability, and by household income. Increasing scarcity of more desirable types of wood in rural areas typically leads to greater use of lower-quality wood, crop residues, and animal dung. As income allows, people move away from biofuels for reasons of convenience and cleanliness. Anecdotal information and sales of kerosene and LPG indicate that transition to modern fuels is occurring in cities, but the pace of change is uncertain. The cost of modern fuel stoves and lack of reliable fuel supplies are the most important barriers to change; relative fuel prices are less important.

In 1990, we will continue to monitor consumption of biofuels in developing countries.

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Impact of Energy Conservation in OECD Homes, 1973-1987

L. Schipper and A. Ketoff

Previously, we reviewed the energy conservation policies and programs of major Organization for Economic Cooperation and Development (OECD) countries. The goal of our 1989 work was to quantify energy saved by households in major OECD countries, in order to set the overall context in which these programs operated. Although it is difficult to measure the amount of conservation *caused* by individual programs, it is possible to compare the total change in energy demand caused by changes in the components of demand (e.g., number and size of homes and households, characteristics of homes and equipment) with changes expected from major energy conservation programs.

Our present work has analyzed the components of changes in household energy use since 1973, drawing on our extensive database covering the structure of energy use in homes in Japan, North America, and most countries of Western Europe. Between 1972 and 1986, the household energy intensity* in major OECD countries declined by as much as 26%, strong evidence of energy conservation. At the same time, the size of homes, the comfort levels attained (as indicated by significant increases in central heating in Britain and Central Europe), and the number and size of electric appliances all increased. Taken separately, these *structural* changes would have increased the energy use per household by as much as 25% in some countries; indeed, household energy intensity in Japan was fully 38% higher in 1986 than in 1972. Even in Japan, however, the energy efficiency of space heating and of appliances improved. The real impact of energy conservation was thus greater than the percentage figures imply.

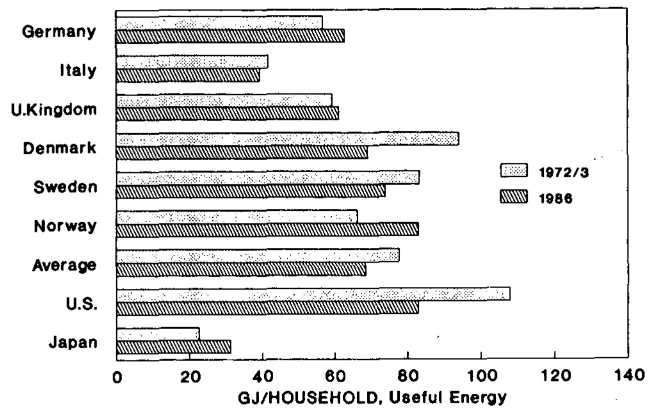

Figure. Changes in household energy use in the United States, Japan, and Europe. (XBL 8912-4396)

The U.S. reduction in household energy use—23%—was greater than the average for Europe, and second only to that of Denmark among all countries studied (Figure).† Space heating intensity (adjusting for increased home size over the study period) also fell more in Denmark than anywhere else; the U.S. decrease—29%—was second largest. At the same time, levels of equipment ownership in Europe and Japan grew more than in the United States, where consumers already had a high indoor standard in 1973. Thus, the overall U.S. performance, measured as reduced household energy intensity, was approximately as good as—or slightly better than—that of most countries in Europe.‡

We are studying closely the evolution of household energy use in each country since 1983, when real oil prices were at their highest *real level.* Preliminary results indicate that the rate of energy saving has declined or even reversed. Have consumers reached an efficiency plateau? Our work in 1990 will attempt to answer this question.

*Measured in useful energy per household, excluding 33% of the energy contained in oil and gas and 45% of that in solids to reflect combustion losses.

†Danish households had the highest unit consumption and very high oil dependence in 1972 in relatively inefficient homes; they then faced the steepest price increases, boosted by the highest energy taxes. With the help of an aggressive conservation program, Danes achieved the greatest energy savings of any OECD country

‡Nevertheless, overall U.S. heating efficiency still remains somewhat lower than that of homes in Scandinavia, and efficiency of U.S. appliances still lags behind those of appliances made in Europe or Japan.

Plans for the Power Sector in 13 Major Developing Countries

S. Meyers, J. Sathaye, O. Masera, and A. Ketoff

Demand for electricity is growing rapidly in many developing countries, and their use of fossil fuels for generating electricity is becoming increasingly significant in the global energy picture. We have studied plans for the power sector in the 1990s in 13 major developing countries in Asia and Latin America. Planned or estimated future rates of growth in installed electric-power capacity for the years 1987-2000 vary considerably among the 13 countries, from a high of 9.8% per year (in Pakistan) to a low of 2.8% per year (in Argentina and Venezuela). Planned future growth is markedly lower than that recorded for the 1979-1987 period in seven of the 13 countries; in most of the others, the planned growth is about the same as was achieved in the 1979-1987 period. For the 13 countries as a group, the future average growth of 6.3% per year is less than the 7.5% rate recorded for 1979-1987. Reasons for lower future growth include slower expected economic growth, rapid past expansion of capacity, and difficulties in expanding power capacity.

According to power-sector plans, the share of total energy capacity from coal-fired power plants is expected to increase substantially in Indonesia, Malaysia, Pakistan, the Philippines, South Korea, Taiwan, Thailand, and Mexico. The relative contribution of hydropower will decrease in many of the 13 countries, whereas natural gas will become more important in India, Indonesia, Malaysia, Taiwan, and Argentina. For the 13 countries as a group, the share of coal-fired plants is expected to increase from 35% of total installed capacity to 41% in 2000, whereas the share of hydropower will decline slightly from 39% to 38%. The share of natural gas will increase from only 6% to 7%, as growth in some countries is partly balanced by decline in others. The share of oil-fired plants will decline from 16% to 9%, and the share of nuclear power will grow from 4% to 5%.

Because of difficulties in constructing planned nuclear and hydropower plants, the move toward coal may turn out to be stronger than the plans indicate; however, environmental problems associated with coal could limit its role as well. Financial, institutional, and environmental challenges to conventional expansion of the electrical supply are provoking increasing interest in new approaches for the power sector. These approaches include improving the efficiency of generation, transmission, and distribution of electricity; cogeneration and other private power generation options; and programs to increase end-use efficiency.

Reference

Meyers S, Sathaye J, Masera O, Ketoff A. *Plans for the Power Sector in 13 Major Developing Countries.* Lawrence Berkeley Laboratory Report LBL-27764, 1989.

Transport Fuel Use: A Statistical Analysis

J. Sathaye and S. Stoft

The single largest contributor to the greenhouse effect is the CO_2 produced by the burning of fossil fuels for energy. Over the next 20 years, most of the growth in energy demand will come from the developing countries (LDCs); by 2010, these countries will be consuming fuels at approximately the same rate as the developed countries.

To date, relatively little effort has been expended on forecasting LDC energy demand. We have begun to remedy this oversight by analyzing the demand for transportation energy in 12 LDCs from 1970 through 1986.* Demand for various fuel types within the transportation sector have also been estimated.

We have modeled per capita demand for transportation energy as a function of income, price, and an unspecified country-specific factor. The country-specific factor is multiplicative and varies by more that a factor of two between India (which has the highest factor) and South Korea and Indonesia (which have the lowest factors). These factors tend to remain fairly constant throughout the time period of our study, indicating that they can be used in long-range forecasts.

In modeling the elasticity of energy demand as depending on income, we found that the poorer countries are generally more elastic with respect to both income and price. In very poor countries, short-run income elasticity is as high as 0.6, and long-run elasticity is as high as 1.8. Elasticity with respect to price was found to have less than half the magnitude of the income elasticity. Both elasticities were found to drop dramatically as income increased, but we do not yet have sufficient data to estimate the elasticities of the wealthiest LDCs in our sample.

During 1990, we will extend this model, developed for the transportation sector, to the commercial and industrial sectors and will extend our estimates to higher income levels, thus allowing longer-range forecasts for LDCs.

*Countries studied: Argentina, Brazil, India, Indonesia, Malaysia, Mexico, Pakistan, Philippines, South Korea, Taiwan, Thailand, and Venezuela.

Reference

International Energy Studies Group, LBL. *Energy Use in the Developing Countries: A Statistical Analysis: Focus on Transportation.* Progress report to the U.S. Department of Energy, 1989.

Residential Energy Use and Conservation in Venezuela

A. Ketoff and O. Masera

We have been conducting a study in Venezuela on residential energy use and conservation. In its first phase, the project consists of a survey and analysis of household energy use for the city of Caracas (4 million inhabitants). In its second phase, the project will extend to four more cities and, by doing so, will account for almost 50% of Venezuela's urban population. Our goal is to provide recommendations for energy conservation and fuel-switching programs that will reduce household energy demand and increase the market share for residential gas in Venezuela.

Results of the Caracas survey show that basic usages of electricity—i.e., for lighting, television, and refrigeration—are diffused in almost all households and that clothes washers are found in over 75% of the city's dwellings (Figure). The use of electricity for water heating is also rapidly diffusing as a result of low electricity prices and the limited extension of the natural gas grid. Fewer than 2% of the households surveyed use gas water heaters.

Other results indicate that the intensity—i.e., unit consumption—of energy use for refrigeration and ford heating water is high compared with the consumption in other cities of the developing countries and is even higher than in several European countries. This appears to be a consequence of the quality and size of the appliances in the country: most available devices are oversized, old, and of obsolete design.

This study permits us to examine viable policy options for increasing the market penetration of natural gas and for improving the efficiency of appliances, although the extremely low energy prices in Venezuela (among the lowest in the world) are a major obstacle to policy implementation. A program of rebates might be necessary to encourage successful diffusion of efficient energy-consuming devices in an environment of low energy prices.

The results of the survey in Caracas were compared with similar studies performed in nine other Latin American countries. We found that inefficient use of electricity in households is common for most countries in the region. However, important structural and cultural differences between countries, regions, social groups—as well as between urban and rural areas—lead us to conclude that no common set of efficiency measures can be applied to the whole region.

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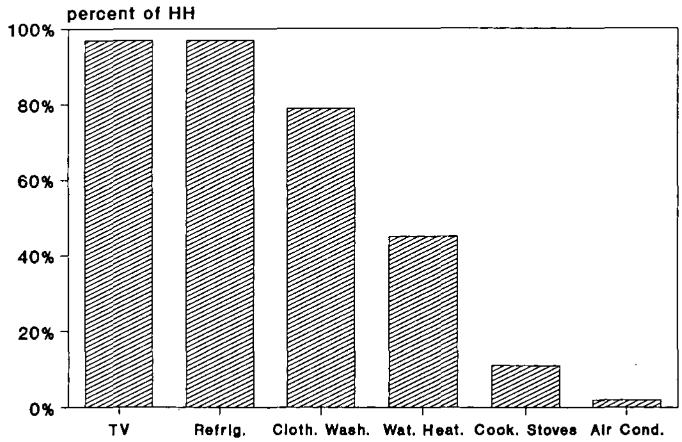

Figure. Ownership of electric appliances in Caracas, Venezuela, in 1988. (XBL 8912-4413).

Long-Term Energy Scenarios for the Developing Countries

J. Sathaye, A. Ketoff, and S. Meyers

This project is intended to construct long-term energy scenarios for developing countries (LDCs). These scenarios will help estimate the emissions of greenhouse gases and the trend toward global climate change. The scenarios will also provide a context in which to implement the energy strategies most effective for reducing emissions.

The first phase of the project began in 1988 and focused on an end-use approach to developing long-term energy demand scenarios for the developing countries.

The second phase of the project was initiated in early 1989, expanding the efforts to

- Establish a network of analysts from institutions in several of the largest energy-consuming developing countries;
- Establish a common methodology and develop scenarios of long-term energy use for each country in order to project greenhouse-gas emissions;
- Design and analyze country-specific and global policies to reduce these emissions;
- Disseminate results through workshops and dialogue with government decisionmakers.

In June of 1989, a workshop organized at LBL was attended by analysts from Brazil, China, India, Indonesia, Korea, Mexico, Quatar, Sierra Leone, Venezuela, and Zimbabwe. Sector experts were invited to provide technical details about energy technologies and their potential for energy savings. The workshop helped to familiarize participants with approaches to modeling global climate change.

LBL has begun planning the third phase of the project. This phase will add countries to the project. Potential additional countries include Pakistan, Thailand, the Philippines, Malaysia, Argentina, Colombia, Saudi Arabia, Nigeria, Sri Lanka, Kenya, Costa Rica, Peru, and Ecuador. In this phase of the project, we will also expand the policy implementation aspect. The second phase focused largely on developing scenarios and on analyzing barriers to policy implementation; the third phase will focus on detailed studies of projects which, when implemented, will lead to more rational use of energy and will have a major effect on reducing greenhouse-gas emissions.

— *Utility Planning and Policy* —

Incorporating Demand-Side Options into Competitive Bidding Programs

C. Goldman

Actual experience with demand-side management (DSM) bidding is quite limited, although bidding programs are proliferating rapidly. Initial experience suggests that DSM bidding programs may have a limited role in a utility's overall demand-side management strategy. This limited role reflects the level of development of the energy-services industry, the high transaction costs in certain sectors, and the inappropriateness of bidding mechanisms for various types of programs, e.g., informational design assistance for new construction.

A few New England utilities have conducted pilot bidding programs for DSM resources, whereas integrated bidding processes—including DSM resources—are being planned or implemented by utilities in New York, New Jersey, and Washington. These programs are the subject of an ongoing study being conducted jointly by LBL and Oak Ridge National Laboratory.

Utility Experience with DSM Bidding: Some Examples

Central Maine Power (CMP) and New England Electric System (NEES) are two utilities that are relatively advanced in terms of actual experience implementing a DSM bidding program. CMP's Power Partners Program is a pilot integrated-bidding program in which demand-side options compete with small power producers. CMP received 13 DSM bids from energy-service companies (ESCOs) and customers in response to a December 1987 solicitation; CMP eventually signed six contracts representing about 16 MW of savings. Bid prices ranged from 3¢/kWh to 5¢/kWh, about 85-95% of the utility's avoided cost of new supplies. CMP's experience suggests that bidding might be an attractive option for industrial customers seeking to develop energy-efficient process improvements.

NEES's Performance Contracting Program relies on ESCOs to develop demand-reduction proposals for geographic groups of large commercial/industrial customers. ESCOs guaranteed savings of 9 MW at bid prices ranging from $700/kW to 750/kW. Based on the results of a recent customer survey, NEES found that customers are quite satisfied with the program; however, the utility believes that its own custom rebate programs have achieved demand reduction goals at a lower cost.

Bid Evaluation Criteria for DSM Projects

A basic difference among utilities is found in their approach to bid evaluation. Some utilities, such as Jersey Central Power & Light and Orange & Rockland Utilities (NY), rely on point systems in which bidders score their projects based on explicit evaluation criteria provided by the utility (Table). The utility selects winning bidders principally on the basis of highest scores. In contrast, other utilities such as Puget Power reveal bid evaluation criteria in qualitative terms only (shown by an X in the Table). In these systems, the utility has information about the evaluation process that bidders do not have, and the selection criteria are not transparent to bidders prior to bid preparation. This approach emphasizes flexibility for the utility.

Our future work in this area will focus on evaluating selected DSM bidding programs in several states.

Reference

Goldman C, Hirst E. *Key Issues in Designing Demand-Side Bidding Programs.* Lawrence Berkeley Laboratory Report LBL-27748, 1989.

Table. Bid Evaluation Criteria for Demand-Side Management Projects

Category	Jersey Central	Orange & Rockland	Puget Power	Central Maine
Economic Factors				
Price	53	50	X	X
Front-load Security	2		X	16-23
Project Status/Viability				35
Developer Experience	6	4	X	
Tech/Market Assessment	9	8	X	
Longevity (O&M)	3	2		
Financial Viability/Security	7	6	X	4-10
Metered Savings	X	X	X	17-28
Supply-related Factors		8.5		
System Optimization				
Load Shaping Need	10		X	7-17
Dispatchability		1.5		
Other (e.g., bid size, location)	10	3		2-5
Environmental Factors		15		
Fuel Choice		2		

Least-Cost Utility Planning: Progress and Challenges

C.A. Goldman, J.H. Eto, F. Krause, M.D. Levine, and A.H. Rosenfeld

In recent years, a growing number of utilities and public utility commissions (PUCs) have adopted a new approach to integrated resource planning, aimed at providing customers with least-cost energy services through the balanced development of supply-side and demand-side resources. Technological advances and regulatory reforms have opened up new supply-side options, including renovation of older plants, cogeneration, and power purchases from independent producers. On the customer side of the meter, utilities—often at the urging of PUCs—are testing new ways to meet customer needs for comfort, heat, light, and power by using more efficient end-use technologies. Utility and customer costs can also be reduced by shifting some loads off peak. Least-cost utility planning (LCUP) also poses new analytic challenges, i.e., to reliably quantify demand-side management (DSM) resources in ways that can be compared with conventional supply-side resources and to develop integrated utility resource plans that balance economic objectives with environmental and other policy goals.

In response to a Congressional mandate, DOE supports a broad R&D program on least-cost utility planning. During the past year, DOE asked LBL and Oak Ridge National Laboratory to review recent progress in least-cost planning and to identify the need for additional work. We found that significant advances have occurred since the inception of the DOE program in 1986. For example, LCUP processes are underway in most states, and many utilities have prepared long-term resource plans in response to state legislation or regulation. In some regions (such as the Pacific Northwest, Nevada, Wisconsin, and Maine), LCUP is a mature process within commissions as well as utilities. Utilities and PUCs in other regions are also aggressively pursuing LCUP. This effort is motivated in some cases by anticipated capacity shortfalls (as in New England) and in other cases by "rate shock" (as in several Midwestern states).

Although substantial progress has been made, much remains to be accomplished to achieve the benefits of improved long-term resource planning. On the basis of our assessment, we suggest several foci for long-term LCUP efforts nationwide:

- Assess regulatory alternatives that reward utilities for successfully implementing least-cost plans.
- Expand training, networking, and other technical-support activities that share planning successes, analytical tools, and innovative regulatory strategies among public utility commissions and utilities.
- Encourage and document successful institutional arrangements for resource planning and implementation.
- Develop information on the performance and costs of demand-side technologies and programs to help balance the information available on demand and supply options.
- Incorporate environmental and other social factors into resource planning.

Current rate-of-return regulation as practiced in most states rewards utilities for short-term sales and discourages optimal use of DSM options. These disincentives have caused various state PUCs to initiate proceedings on ratemaking reforms. Proponents of LCUP argue that it is likely to be successful only if ways are found to align the financial interest of the utility with the goals of integrated resource planning.

Expanded technical support is needed, particularly for PUCs and small utilities as they confront difficult technical and analytic problems in preparing and reviewing LCUP plans (e.g., proper choice and use of models to screen and develop attractive resource portfolios; treatment of uncertainty; and integration of DSM resources into the integrated resource plan). Documenting and sharing examples of successes and failures of different utilities and PUCs is also important if LCUP is to mature in an efficient manner, e.g., by successful institutional arrangements such as collaborative processes.

The quality of data used in integrated planning models needs to be significantly improved, especially on the demand side. Reviews of utility plans reveal important deficiencies such as lack of data for certain end uses and sectors, and limited experience in screening and interpreting DSM data. Improved DSM data are needed with respect to baseline energy use (e.g., end-use load shapes and demographic and economic data), DSM technologies, and participation in utility DSM programs (e.g., penetration by market segment).

Failure to consider external factors is an important shortcoming of current LCUP practices. Significant differences exist in the environmental effects (e.g., air quality, water quality, and land use) of various electricity supply options. Ultimately, the specter of global warming may lead to dramatic changes in integrated resource planning practices. For example, future utility planners may be required to develop resource plans that achieve specific targets in reducing carbon dioxide emissions.

Future projects will focus on four priorities: evaluation and monitoring of innovative ratemaking incentive strategies; utility and regional case studies that assess alternative methods of incorporating environmental externalities into the resource planning process; training courses on key LCUP issues for PUC staff; and continued technical assistance to PUCs and utilities in reviewing LCUP plans and DSM technologies and programs.

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Competitive Bidding for Wholesale Power Contracts

E. Kahn

Competitive bidding provides an increasingly important option for securing new electric power resources from independent producers. The procedures adopted by utilities differ widely and will have very different impacts on potential suppliers. Some bidding systems appear biased against capital-intensive technologies. The most critical design features that distinguish methods currently used by utilities are the amount of information made available to bidders, the treatment of front-loaded prices, and the indicators used to assess project viability.

Although most utility bidding Requests for Proposal (RFPs) specify weights for various price and non-price factors (Table), the real influence of a particular factor depends on whether it differentiates among bidders. An analysis of eight generic bids in a hypothetical auction showed that the systems proposed by Niagara Mohawk and Orange & Rockland, which purport to rank price factors with 70% and 50% of the total weight, actually evaluated bids almost entirely on price considerations alone. This is due to the relative ease with which bidders met the criteria defining non-price considerations.

A major area of controversy surrounds the role of front-loading in price offers. Front-loading refers to a situation in which a bidder asks for payments in excess of a utility's estimates of avoided cost during the initial years of a contract. To be economical over the long run, these bidders must more

Table. Summary of Bid Evaluation Systems of Four Utilities*

Category	Virginia Power	Boston Edison (RFP #2)	Niagara Mohawk	Orange & Rockland
Price	70%	40%	70.8%	50%
Supplier Assurance	10%			
Development Longevity		20% 8%	5.3% 1.7%	23% 1%
Fuel Choice and Flexibility	10%	4%	1.5%	4%
Environmental Factors			9.2%	7%
System Optimization	10%			
Dispatchability	Virtually Required	4%	4.6%	4%
Other			0.5%	3%
Front-Loading	**Capacity Only**	20%	6.3%	**20% for Oil & Gas, 35% for Solid Fuels**
Contract Length	**25 years preferred**	**20 years maximum**	**>5 years; 15 preferred**	5%
Maximum Bid Size		**25% of Block Size**		

* Percentages appearing in plain type reflect relative valuation weights; those in boldface type reflect minimum constraints.

than compensate with low prices. Some utilities are concerned, however, that front-loading imposes short-run risks to ratepayers. Analysis of penalty schemes proposed in these cases shows some examples where the penalties seem unduly severe. A technique called the "equivalent loan" method is used to compute implicit interest rates embedded in the utility's evaluation of the front-loaded bids. In some examples, the implicit interest rate can range from 25% to 65%. Even for the risks involved, this is too high; the penalties hurt the competitive position of capital-intensive technologies, whose financing requirements create a need for some front-loading.

Dispatchability is a particularly important but difficult attribute to evaluate. Utilities often need operational flexibility from independent suppliers. Valuing offers along this dimension is interactive when many bidders are involved, because the value of one project depends on the nature of other offers. In the 1988 Virginia Power solicitation, for example, where the utility emphasized dispatchability, 95 bidders responded to the RFP and offered 14,000 MW to the utility. Virginia Power eventually decided to contract with 17 projects offering over 2,000 MW. Our study shows how optimization methods can be used to evaluate bids in this type of situation.

In the Virginia Power RFP, bidders were given relatively little information about the evaluation process. Virginia Power was vague about how it treated price and non-price factors. This approach gives considerable negotiating power to the utility. In many jurisdictions, regulators are not comfortable with so much delegation of authority; utilities in these states usually propose or use "self-scoring" systems in which the bidder knows how many points will be awarded for each attribute.

Current methods used to evaluate the viability of projects need to be improved. Utilities seek viable projects but have not identified consistent, reliable indicators. Moreover, some criteria are contradictory: for example, bidders who have high levels of debt service coverage may be awarded additional points while being severely penalized for seeking the front-loaded bid prices necessary to produce these coverage ratios.

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Energy-Efficient Commercial Lighting: Technology Assessment

M.A. Piette, F. Krause, and R. Verderber

About one fifth to one fourth of total U.S. electricity consumption is consumed by lighting, 40%-50% (about 260 BkWh) being used for commercial sector lighting. The past decade has seen many technical developments in lighting equipment that could greatly reduce use of lighting energy; unfortunately, these products are slow to be incorporated into lighting systems. A major barrier to achieving significant market penetration of energy-efficient lighting technologies is the lack of adequate information regarding their performance characteristics and economic potential. We have examined cost and performance issues related to energy-efficient lighting technologies, with special emphasis on commercial sector applications and on technologies typically sponsored in utility demand-side management programs.

Our major findings:

- Commercial energy-efficient lighting technologies currently include improved incandescent lamps, compact fluorescent lamps, improved fluorescent tubes, high-intensity discharge lamps, improved core-coil ballasts, dedicated and tunable electronic ballasts, parabolic fixtures, specular reflectors, occupancy controls, daylighting sensors, timing devices, communications-based controls, new daylighting techniques, and improved maintenance practices.
- If the best commercial technologies are carefully combined to optimize cumulative gains in efficacy, energy savings can be very large. In standard fluorescent fixtures, for example, these gains can exceed 70%.
- Energy-efficient technologies for common lighting retrofits and new construction options yield a very favorable cost of conserved energy. Under most conditions, this value would range from about 0.5¢/kWh to about 3¢/kWh. Payback periods range from a few months to less than three years.
- In new construction as well as retrofit projects, where lighting systems can be designed (or redesigned) to fully exploit the efficiency improvement from electronic ballasts, these ballasts are often more cost-effective than improved core-coil ballasts.
- A number of improved lighting technologies are in the prototype or laboratory stage and could greatly boost the efficacy and other performance characteristics of current technology. These technologies include electrodeless fluorescent and high-intensity discharge lamps with 50-100% higher efficiencies than current versions, more sophisticated controls of the thermal environment in which lamps operate, and full exploitation of tunable electronic ballasts and communications hardware to allow the control of individual fixtures. These new technologies would allow routine energy savings of more than 80% compared with today's lighting systems.

- Demonstration projects, lighting mock-up facilities, and specialized software are needed to familiarize designers, installers, and other lighting professionals with currently available energy-efficient options.
- Energy savings from lighting-system investments should be more broadly verified in field tests that account for the influence of occupant behavior, interactions between lighting and heating, cooling, and air conditioning demands, and optimization of controls.

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Piette MA, Krause F, Verderber R. *Technology Assessment: Energy-Efficient Commercial Lighting.* Lawrence Berkeley Laboratory Report LBL-27032, 1989.

Analysis of Hourly End-Use Electricity Load Shapes in California Residences

H. Ruderman, J. Eto, A. Golan, and D. Berman

The impact of demand-side management programs on future utility-load profiles is a major issue for the development of integrated resource plans. Current end-use hourly and peak-demand models to assist in utility planning are constrained primarily by the lack of reliable hourly load data. Moreover, these data are difficult to obtain because of the high cost of metering end-use energy. With support from the California Energy Commission Demand Forecasting Office and from the Department of Energy Least-Cost Utility Planning project, LBL researchers address this information gap by summarizing the results of major residential end-use metering programs in California in a format suitable for use in forecasting models.

Sub-metered end-use load data were analyzed for more than 700 Pacific Gas and Electric (PG&E), 300 Southern California Edison, and 50 San Diego Gas and Electric residential customers to develop representative daily hourly load shapes by season. The analysis included load data for refrigerators, freezers, cooking equipment, clothes dryers, dishwashers, and clothes washers. Central and room air-conditioning loads were represented graphically by a matrix relating energy use to the hour of the day and to the weather occurring during that hour; a unique matrix position defines energy use for each hour and observed weather condition (Figure). The matrices were generated using a novel fitting procedure, developed by LBL, by which observed data is represented by an analytical relationship. Efforts to validate this procedure will form the basis for ongoing work in this project area.

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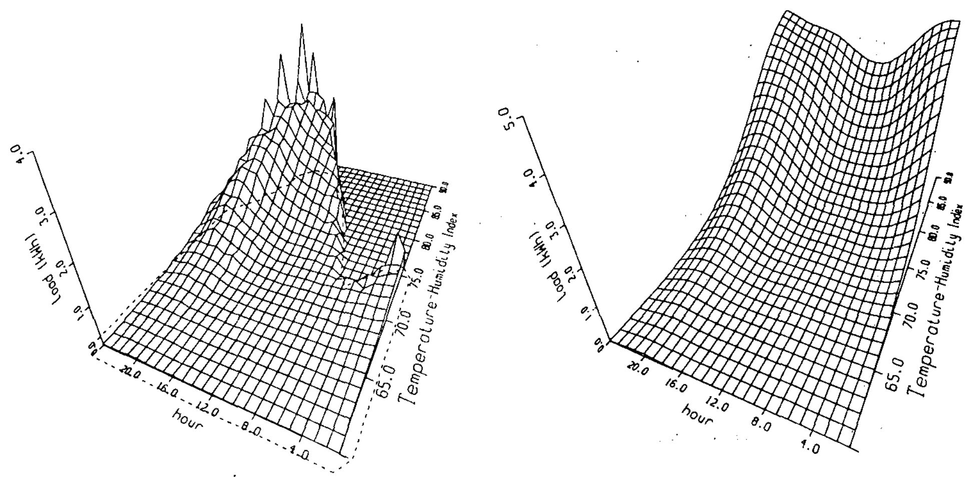

Figure. PG&E central air conditioning time-temperature matrix—raw and fitted data. Central air-conditioning energy use is represented by a matrix that relates energy use (z-axis) to time of day (x-axis) and to weather conditions in a given hour (y-axis). Plotting the metered data from PG&E's Appliance Metering Project (at left) yields an irregular surface with significant missing data. Application of the LBL fitting procedure produced the figure at right. (XBL 8912-4394)

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