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Energy Analysis Program

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APPLIED SCIENCE DIVISION ANNUAL REPORT

ENERGY ANALYSIS PROGRAM

FY 1987

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ENERGY ANALYSIS PROGRAM

INTRODUCTION

FY 1987 was an eventful year, both for energy policy and for LBL's Energy Analysis Program (EAP). One of the most discussed issues in U.S. energy policy has been the structure of the electric utility industry. The extraordinary boom in offers to construct cogenerators and other qualifying facilities under the Public Utilities Regulatory Policies Act (PURPA) during the past several years, combined with an apparent aversion by utilities to invest in power plants, has led to serious discussion about, and analysis of, utility deregulation, especially supply. This topic is of great importance both in terms of influencing future electricity supply and use and in their effects on U.S. capital markets, with the electricity industry traditionally the most capital intensive industry in the U.S. EAP has played a significant role in analyzing utility issues during the year. A major report for the Policy Office of the U.S. Department of Energy (DOE) analyzed bidding procedures (auctions) as a means of increasing the economic efficiency of PURPA purchases (see article by Rothkopf and Kahn). Such an approach is not only important for improving PURPA; it could also be an important element in a broader strategy to deregulate, or partially deregulate, utilities. The Least Cost Utility Planning Project (LCUP), supported by the Office of Buildings and Community Systems of DOE has also contributed important insights into issues shaping the electric utility industry. LCUP has delved deeply into demand-side options and programs of utilities (article by Krause) and has analyzed how such programs fit in an integrated planning framework (article by Kahn, *et al.*).

During the past year, the U.S. Congress took the first action since the 1970's in initiating a major energy conservation policy. This was the passage of the National Appliance Energy Conservation Act (NAECA). NAECA set minimum mandatory standards for major energy-using residential appliances, including furnaces and air conditioners. The Act resolved and rendered moot a Federal Appellate Court decision requiring DOE to set standards. EAP leads the overall federal appliance standards research program. EAP researchers analyzed the impacts of NAECA. The article by Ruderman, *et al.*, estimates 0.7 to 1 quad per year energy savings after the turn of the century and demonstrates substantial consumer benefits of NAECA. The Congressional Act also requires DOE to decide on standards for several products. The EAP team's analysis will constitute the major technical input to these decisions, the most controversial of which will concern standard levels for refrigerators.

A third energy policy area of intense national interest derives from the continuing low price of liquid fuels—up from 1986 but still much lower than previous years—and the energy security issues arising from anticipated future tight oil markets and heavy reliance on Middle Eastern OPEC oil. This area of concern has been dramatized by a major DOE report entitled *Energy Security: A Report to the President of the United States.* EAP research contributed directly to this report in highlighting the rapid increase in oil use in developing countries. The data collected and analyzed by the International Energy Studies (IES) Group suggested that future oil demand in developing countries is likely to be higher than commonly recognized. A major outcome of the high-level DOE review of energy vulnerability issues has been a decision to pursue a major study of alternatives to oil for transportation fuels. This project, a major new initiative of the DOE Policy Office, will be managed by EAP staff.

In addition to work directly related to key current energy policy issues, EAP continued research in a wide variety of areas, deepening our understanding of topics that have been investigated over many years. The Building Energy Analysis (BEA) Group, under Ron Ritschard, continued its analysis of energy use in public housing (an area much in need of improvements in energy efficiency), improved and extended its data base and simplified tools (including home energy rating systems) for assessing residential energy use, and gained new knowledge through several special studies (on residential foundation design, vegetative cover as a conservation strategy, and air-to-air heat exchangers). During the coming year, the group is expected to apply its capabilities to multifamily and commercial buildings.

The Energy Conservation Policy (ECP) Group, under Mark Levine, continued to focus its emphasis in three major areas: appliance standards; energy conservation research and policies for buildings in Southeast Asia; and economic studies of electric utility demand-side programs. In the first two areas, substantial progress was made in getting the research incorporated into ongoing policy processes. The utility research is evolving in two different directions: (1) broader studies of integrated utility planning issues and (2) more detailed studies of end use data relevant to residential and commercial load shapes. The latter topic is an important input into utility planning.

The International Energy Studies (IES) Group (co-led by Jayant Sathaye and Andrea Ketoff until Lee Schipper's return late in FY 1987) split its efforts between research on energy in LDC and OECD nations. The Group expanded its work to include a variety of supply issues in addition to its traditional (and continuing) strong emphasis on factors underlying energy demand. An important new initiative of the IES Group was the creation of an International Energy Roundtable. This Roundtable, involving meetings and discussions among high-level energy analysts from developing and developed countries, dealt with key international issues during the year.

The Buildings Energy Data (BED) Group, under Jeff Harris, continued its research efforts to better characterize the energy use of buildings from measured data. In addition to improving the data bases (particularly for multifamily and new residential buildings), BED also studied several emerging energy conservation technologies (thermal energy storage, variable-speed motor drives, and energy management systems), analyzed in depth the problem of urban "heat islands", and evaluated end-use data and utility conservation programs in the Least Cost Utility Project. An important new undertaking is the application of statistical methods to BED's building-specific energy data bases to begin to draw inferences about the potential for increasing energy efficiency of the U.S. building stock.

The Resource Market Mechanisms area, under Mike Rothkopf, was actively involved in a number of key national policy issues. The major contribution, discussed earlier, was the innovative research on different bidding procedures as a means of improving the PURPA process.

A major new area for the Program was initiated during FY 1987: environmental policy analysis. Two experienced researchers in this field, Walter Westman and Paolo Ricci, have been recruited and will begin work in early FY 1988. The key areas of research emphasis have been defined to include risk assessment of environmental pollutants, effects of changes in global climate, and studies of ecological effects of environmental stressors. A dialogue has begun, both with policy and research personnel in the federal government and with researchers within the UC system, to lay the groundwork for this new activity which will contribute to research and analysis of emerging national and international environmental policy issues.

BUILDING ENERGY ANALYSIS

Overview

The Building Energy Analysis Group (BEA) conducts research and analyses on all important issues relating to the use and conservation of energy in residential buildings. The work stresses *whole buildings* rather than individual components viewed separately, in an effort to improve understanding of the tradeoffs among different approaches to achieve increased efficiency of building energy use. The research is intended for two types of use: (1) *to further knowledge* of all aspects of energy use in residential buildings and (2) *to provide research results* in a simplified format to assist builders and building operators to reduce energy use in residences. The work of the Group focuses on four areas:

- Simplified energy analysis methods,
- Energy-efficient and cost-effective cooling strategies,
- Residential building type analysis (single and multifamily), and
- Public and low-income housing.

A major accomplishment of the Group is the development of a simplified computer energy analysis tool (PEAR), which serves as the calculation procedure the Department of Energy's voluntary guidelines for new residences and the source of energy requirements for the revisions to the ASHRAE 90.2 standard. An article by Huang, Bull and Ritschard describes revisions to the residential data base used to support PEAR that were developed for Pacific Northwest Laboratories in conjunction with ASHRAE, and with support from DOE. Another part of the revised data base is described in an article by Huang and Bull and these revisions include simulating below-grade heat flows using a method developed by the University of Minnesota in conjunction with the DOE-2.1C program to determine the conservation potential of different foundation measures.

Another important research topic in support of developing simplified energy analysis tools considered existing residences and the use of home energy and labeling systems. An article by Ritschard, Vine, Barnes *et al.*, reports on the evaluation of a demonstration program sponsored by the California Energy Commission on rating and labeling existing homes in two California cities: Pasadena and Roseville. In a second article in this area, Vine, Barnes and Ritschard provide a broader evaluation of 34 home energy rating systems in 28 states.

In addition to gaining an better understanding of the energy performance of single-family residences, the BEA Group has been conducting research on the topic of existing multifamily buildings, particularly in the public housing sector. Two studies are presented for FY 1987. First, Ritschard, Greely, Goldman, Mills, and Vine provide an overview of the federally-assisted housing program that covered three activities this year in support of the overall goal of improving energy efficiency of public housing. Finally, Greely, Mills, Goldman, and Ritschard present results of a study of energy use at 91 selected public housing projects across the U.S. using both utility billing data and oil consumption data.

California Home Energy Rating and Labeling Demonstration Program: What Did We Learn?*

R. Ritschard, E. Vine, B.K. Barnes, C. Hsui, and I. Reyes

Homes built prior to California's energy efficiency standards for new residential buildings (1978) will still comprise a majority of California's housing stock by the year 2000. If homeowners were to retrofit these existing homes by increasing attic and wall insulation, improving water heating practices, and installing storm windows, setback thermostats, and other retrofit measures, the state's total residential natural gas and electricity consumption could be reduced by as much as 29%.[1] More importantly, homeowners could collectively save as much as $18 billion in the next ten years.

Many barriers exist to this type of home improvement. For example, lenders, while they may understand that greater energy efficiency leads to lower utility bills, lack a standardized method of accurately including energy efficiency in the "comparable value" of the home. One strategy for overcoming this barrier is a method for rating and labeling existing homes on the basis of their energy efficiency. By using a simple numerical scale, different sizes and types of homes can easily be compared and advertised.

To explore these benefits, the California Energy Commission (CEC) sponsored a *demonstration* program during 1985 and 1986 on rating and labeling existing homes in two California cities: Pasadena and Roseville. The goal of the project was to evaluate various delivery mechanisms that might be used in conjunction with a statewide home energy rating and labeling program. Another goal was to develop a single rating tool which could, with reasonable accuracy, rank the energy efficiency of any home within the state.

ACCOMPLISHMENTS DURING FY 1987

A major element of the CEC's Demonstration Program was the Rating Tool developed previously by LBL.[2] The primary intent of the tool was to provide accurate estimates of each building component's contribution to the overall energy use of the house in a simplified manner. The tool used a slide rule format to provide a simple and easy-to-understand way for translating the house characteristics into an energy rating. The final calculated values from the slide rule were compared to a rating scale, which was a normalized scale from 1 (least energy efficient) to 6 (most energy efficient). The scale was set using the estimated energy budget for a house that met California's 1978 new building standard as a "3", and a current Title 24 house as a "5". The ratings were scaled linearly from these two benchmarks so that the estimated incremental savings are the same between any two ratings.

The Cities of Pasadena and Roseville were selected by the CEC to test two different delivery mechanisms. Pasadena, as the model for a *government-focused* delivery mechanism, used city building officials to certify a home's rating and provide labels. Roseville was selected to implement a *utility-focused* program in which the city, as an electric utility, offered a home rating and labeling service. In both Pasadena and Roseville, the ratings were provided by trained energy auditors. Pasadena was to have had a second program using building inspectors, but there was a potential conflict of interest: building inspectors are obliged to report building code violations, and this obligation may compromise the program by threatening the homeowner in reporting violations and adding certain liability problems for building officials in guaranteeing the ratings.

Both Pasadena and Roseville projects involved raters whose job it was to audit houses and provide information to homeowners about improving the energy efficiency of their homes. The Pasadena project used two auditors who independently rated 25 city employee's houses during June and July 1986. In Roseville, a single auditor (RCS-trained) rated 68 houses between December 1985 and September 1986. The Roseville ratings were performed as part of the energy audit mandated by a city ordinance requiring that all houses built prior to July 1978 be audited upon resale.

LBL evaluated the rater's experience with the Rating Tool and the delivery systems used in each demonstration project by addressing three principal questions:[3]

(1) Does the Rating Tool work?
(2) Who should do the rating?
(3) How can the effectiveness of the rating process be improved?

In addition to reviewing evaluation reports submitted by the two cities, we collected data on the

*This work was supported by the Conservation Division of the California Energy Commission under Contract No. 400-84-002 through the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

demonstration programs by interviewing homeowners, real estate agents, raters, and program managers. The interviews were conducted by telephone, and a structured questionnaire containing open-ended and closed-ended questions was used. We found that the testing of the Rating Tool itself became the focus of the demonstration programs; the development of a comprehensive delivery mechanism received little attention.

The raters in both cities were generally very favorable to the Rating Tool; they thought it was easy to understand and simple to use, comprehensive, provided a rating in a reasonably short time period, and could be a great boon to their profession. Some technical problems were encountered with the tool itself such as, accounting for window air-conditioners, and developing additional efficiency level for heat pumps.

Other problems were encountered that were more subjective in nature, but which could be treated in a consistent manner with guidelines and proper training of raters (e.g., determining infiltration levels, and estimating the area of shaded windows). After confronting these problems and arriving at tentative solutions, the raters were able to continue to use the tool and perform the rating calculations. Moreover, based on program reports by the two cities and on our interviews with raters and program coordinators, there appeared to be *no* insurmountable problems associated with the continued use of the Rating Tool in these communities.

Based on the responses of the project coordinators in Pasadena and Roseville, the experience of the raters, real estate agents, and homeowners, and pulling together conclusions from our own investigation of HERS, on a national basis, (see Annual Report article by Vine, *et al.*), we make several recommendations.

First, the CEC/LBL Home Energy Rating Tool worked but it can be improved with some technical modifications and with supporting documentation. Second, comprehensive delivery systems are necessary for successful implementation of home energy rating systems (HERS). The target of home energy rating programs (homeowners or builders) must be provided with both technical and financial assistance in order to facilitate energy-efficiency improvements as well as to motivate their investment decision. Third, raters should be trained auditors with sufficient knowledge and understanding of how homeowners make decisions on improving the energy efficiency of their home. Finally, the homeowner *must* be viewed as an active participant in the rating process rather than as a passive recipient of a HERS label. One of the key measures of the success of a home energy rating program is how much energy is saved as a result of the homeowner's implementation of energy-saving measures. It is further recommended that a rating or certification form be provided to the homeowner as a record of the rating process.

PLANNED ACTIVITIES FOR FY 1988

This research has been concluded and no further activities are planned.

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2. Ritschard, R., Huang, Y.J., and Hsui, C. (1986), "California Rating Tool: Assumptions and Methodology," LBL-20772.
3. Ritschard, R., Vine, E., Barnes, B.K., Hsui, C., and Reyes, I. (1987), "Evaluation of the California Home Energy Rating and Labeling Demonstration Program," LBL-22758.

Evaluation of the Implementation of Home Energy Rating Systems*

E. Vine, B.K. Barnes, and R. Ritschard

The rating and labelling of new and existing energy-efficient homes by local, state, and federal government agencies, utility companies, and other organizations has been an activity marked by periods of intense interest and benign neglect. During the late 1970's, home energy rating systems (HERS) became important components of several energy conservation programs conducted by governmental and non-governmental organizations at national, regional, and local levels. By 1982, it seemed that the idea of a home energy rating system had become entrenched as an effective means of pursuing the goal of energy conservation. Since that time, however, a number of these systems have been abandoned, and only a few have endured. Nevertheless, a number of HERS exist, and interest in HERS has increased in selected areas of the country.

ACCOMPLISHMENTS DURING FY 1987

In January 1986, we conducted a national telephone survey of home energy rating systems to examine the different kinds of HERS and implementation systems being used and to discover the range of possible implementation problems and solutions experienced by the users of these systems. We first contacted all state energy offices in the U.S. to discover where existing HERS were operating. Major systems were followed up in each state, and we examined those operated by local governments and utility companies. We identified 28 states willing to provide examples of some form of HERS that was currently in operation.

HERS Distribution

The 28 states provided information about 34 HERS programs: 14 of these were located in the Southeast, 8 in the Midwest, 5 in the Northeast, 4 in the Pacific/Mountain region, and 3 in the Southwest. HERS seem to be concentrated mainly in those areas concerned with regulating cooling loads. Most (20) of the programs were developed at the national or regional level, 6 by states and 7 by large utility companies or energy production and distribution authorities, as compared to the local level, where 14 HERS were developed, usually, by smaller utilities. Home builders associations, in particular, have tended to play a critical role in the adoption of most successful programs, are often consulted within the development phase, and have helped implement some of the major HERS in operation.

HERS Findings

The first critical observation, based on our survey, is that it is virtually impossible to treat HERS in isolation from other energy conservation efforts. In particular, HERS' connection to auditing is often complex and inseparable. The promotion of HERS is intimately connected to the promotion of energy efficiency, and HERS are rarely offered in isolation. More frequently, a HERS is a part of an energy-efficiency package.

This diversity in HERS implementation is in part a consequence of the diversity in the target populations which range from homeowners and homebuyers (consumers) to real estate appraisers. Moreover, different expectations for, and uses of, HERS exist within these groups, and these differences affect the kinds of strategies evolved for successful implementation of HERS. Often, in the development of a particular program, the different goals and interests of participants need to be reconciled through negotiation; the alternative being the withdrawal of support by critical parties, or even the development of rival systems.

Many failed HERS started from the assumption that consumers were energy experts, and that the provision of a HERS was only viable if it met a market demand. When consumers were surveyed and found to be uninterested in energy efficiency, many energy authorities treated this information as evidence that a HERS was unwanted, unnecessary, and unviable. Accordingly, many failed HERS were typically passively operated, with little or no promotional budget, employed a tool that could not evaluate alternative paths to energy efficiency and that presented the rating in a way that had little chance of convincing the homeowner of the need to weatherize or retrofit. In contrast, we found that such a lack of interest on the behalf of the public was due to lack of knowledge and information, and that part of the function of a HERS should be to educate the public, increase their energy awareness, and create a demand for energy efficiency.

We found that the success in implementing a HERS is dependent on success in *marketing* the HERS. Successful marketing is achieved only after a

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings and Community Systems, Building Services Division, U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

comprehensive appreciation and treatment of the diversity in target populations. Programs that have had a restrained approach to the implementation of HERS—by insisting on treating implementation problems as basically technical, engineering problems (e.g., focusing on the accuracy of the tool), or by taking a laissez-faire approach to marketing (e.g., simply meeting a demand for energy efficiency, rather than helping to create more demand)—or programs that have adopted an aggressive, non-responsive approach, have had a poor track record.

HERS that are actively marketed, have a comprehensive appreciation of the market, are adaptive to the needs of particular users, and include user participation in the operation and revision of the program, are more successful in terms of penetration rates and in improving the energy efficiency of the older housing stock. Where successful, HERS have penetrated an estimated 40% of the new construction market and 20% of existing construction, and energy savings have ranged from 10% to 50%. These savings do not take into account the impact of HERS on non-participants, so that HERS are more successful than indicated by the direct savings alone.

Home energy rating systems have been used effectively in the new housing market, influencing builder behavior through the institution of voluntary programs. Typically, HERS have been very successful in this regard, especially when two market criteria are met: (1) the HERS was introduced in a recessionary period, when builders are most receptive to novel ways of promoting their buildings, in ways that involve actual savings to future homeowners; and (2) the HERS is aggressively promoted by the HERS agency, with widespread media campaigns and much support of the builder, including cooperative advertising, and marketing materials and assistance.

For existing stock, the only valid measure of the success of a HERS involves consideration of the effective implementation of retrofits and weatherization activity. There are some HERS currently addressing existing homes, but the opportunity for more work in this area continues to be large. We believe that the key to such an effective implementation involves an authoritative measuring device that can be used to evaluate a building's current energy efficiency, as well as evaluate alternate ways of improving that energy efficiency. This evaluation should be capable of translation into cost-effective terms, which generally has the most significance to the average homeowner.

A further important key to the success of a home energy rating system involves the inclusion of the homeowner in the use of the tool, so that the homeowner is informed what might be done to his house, what this physically involves, and what the consequences will be in terms of energy, cost, and, very importantly, comfort. And we further feel that it is important to the success of a HERS to provide assistance to the homeowner to make such changes. This assistance should not simply take the form of zero or low-cost loans, but also information about local sources of materials and contractors to do the work. Educational programs, including workshops on how homeowners can do some of this retrofitting themselves, may also be of great benefit.

PLANNED ACTIVITIES FOR FY 1988

This research has been concluded and no further activities are planned.

SUGGESTED READING

1. Vine, E., et al. (1987), "Implementation of Home Energy Rating Systems," LBL-22872.

Federally-Assisted Housing: Progress and Plans*

R. Ritschard, C. Goldman, K. Greely, E. Mills, and E. Vine

The U.S. Department of Housing and Urban Development (HUD) is America's largest landlord and pays the largest residential energy bill—over $2 billion per year for all federally-assisted housing programs. Forty percent of low-income renters reside in public housing. Preliminary analysis of this sector indicates that a significant potential exists for improving the energy efficiency of its stock. However, these potential savings have not been fully realized for a number of reasons, such as lack of technical information on the effectiveness of various conservation measures, retrofit costs and paybacks, available financing mechanisms, and the perception that there are few incentives to conservation.

In FY 1985, the U.S. Department of Energy (DOE), as part of a multifamily retrofit research program, initiated an effort to improve the energy efficiency of the federally-assisted housing stock with initial emphasis on public housing. LBL, in its lead role in this sector, compiled background information on public housing buildings, their physical characteristics, energy use patterns, conservation potential, and barriers to energy retrofit activity. From this technical background data, we formulated a research agenda and multiyear plan that begins to address the perceived barriers to attaining the conservation potential in public housing.

To overcome the barriers in this sector, we followed several approaches. These include analysis of utility bill data for several years calculating weather-corrected consumption levels, compilation and analysis of building and energy consumption data for past and current retrofit activities, evaluation of financing and HUD subsidy policy alternatives, development of simplified analysis tools and other models for audit and retrofit evaluation, occupant surveys, direct monitoring of retrofit performance, and information networking.

To date, our studies of public housing have:

- Created a computerized *data base* on the physical, demographic, and energy characteristics of nearly 1800 public housing buildings, which represent 91 projects and approximately 32,000 dwelling units; utility bills include 1 to 5 years of data.
- Performed an analysis of available *baseline energy use* at 91 projects to develop energy use indices for different building types and locations (see Annual Report article in this section by Greely, *et al.*).
- Conducted systematic evaluations of existing utility billing data on pre- and post-retrofit activities at 43 selected public housing sites to determine the range of *energy savings* and found the median savings to be 14%; median payback was 12 years (versus 3 years in private multifamily buildings).
- Developed a methodology for examining the relative *financial impacts* on HUD and public housing authorities (PHAs) of different conservation investment strategies and applied it at two local authorities (San Francisco and Trenton) to test alternatives to current HUD policies, such as the Performance Funding System which was found to discourage maintenance, third-party financing, and the use of PHA surplus funds for energy conservation.
- Monitored *domestic hot water consumption* in four public housing apartment buildings and constructed a model of household water consumption based on tenant interviews.

ACCOMPLISHMENTS DURING FY 1987

In FY 1987, we conducted three major activities in support of the overall goal of improving energy efficiency of public housing buildings. First, we identified and assessed simplified analytical tools used to evaluate energy and cost savings of options in multifamily buildings. Since building practitioners are increasingly relying on microcomputer-based techniques (rather than on main-frame computer programs) because of their ease of use, speed, and cost, we limited our evaluation to four public-domain microcomputer programs developed with DOE support: ASEAM-2, CIRA, COSTSAFR, and PEAR.

Our assessment concluded that none of the DOE-sponsored programs evaluated meets the specific needs of in-field auditors, weatherization program designers or managers, or policy-makers involved with retrofit decisions for multifamily buildings. However, each program, individually, possessed one or more important feature required in retrofit evaluations. In addition to the public domain programs, we identified 27 other simplified

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings and Community Systems, Building Services Division of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

methods developed by the private sector. We also concluded that a follow-on assessment of a subset of these private sector programs was needed to test their appropriateness for retrofit analysis in multifamily buildings.

A second major activity in FY 1987 was to develop a generic accounting program that tracks utility consumption and costs at the local housing authority level and assists in reducing utility costs. The overall goal of this task is to assist small, medium, and large housing authorities to increase their potential for additional energy conservation and operational efficiency. The utility accounting program, which is co-sponsored by HUD, can be directly used by both PHAs and regional HUD offices to explore opportunities for utility bill reduction and the need for additional maintenance.

This year, we completed a draft program that employs a menu-driven format for use with the Lotus 1-2-3 software package for IBM-compatible personal computers. The user each month enters raw consumption data on gas, oil, electricity, water, and "other" utilities, such as solar meter readings. As the year progresses, the program can provide estimates of year-end consumption and costs so that a housing authority can budget ahead. The program's output, which is both tabular and graphical, is suitable for use with special HUD reporting forms for utility accounting and annual performance funding requirements, as well as for utility reviews periodically submitted to HUD. A design of the program format, as a series of input and output screens, was sent to a panel of reviewers with representatives from DOE, HUD (both the national and regional offices), local housing authorities, and the technical community.

The third accomplishment was in the area of information networking and technology transfer. In FY 1987, we organized and participated in a workshop on "Overcoming Barriers in Public Housing" at the Affordable Comfort Conference (Pittsburgh). We also led a workshop at the annual convention of the National Association of Housing and Redevelopment Officials (New Orleans) on "Energy Conservation in Public Housing: What Have We Learned?". The participants at the New Orleans workshop represented various PHAs who had first-hand experiences on what has or hasn't worked over the past several years to reduce utility costs in the public housing sector. At each of these conferences, LBL's research results were exchanged with both the technical community and building practitioners from local housing authorities around the country. Articles on public housing issues were also written and published this year in the *Maintenance and Modernization Supervisor*, which is one of the major trade publications serving the federally-assisted housing sector.

PLANNED ACTIVITIES FOR FY 1988

Next fiscal year, we will perform several tasks in support of the federally-assisted housing study. They include: (1) complete the utility accounting program and test it at selected housing authorities; (2) update the retrofit analysis at 43 public housing projects in order to evaluate the persistence of savings over time; (3) prepare input, which is specific to public housing buildings, to the multifamily energy auditing methodology being developed by DOE; (4) evaluate utility data from HUD's Modernization Needs Study collected by Abt Associates; and (5) continue the technology transfer/information network activities.

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Determinants of Measured Energy Consumption in Public Housing*

K.M. Greely, E. Mills, C.A. Goldman, R.L. Ritschard, and M.A. Jackson

U.S. public housing currently shelters more than 3.5 million low-income tenants and accounts for 5.7% of the multifamily housing stock in this country. The program, which was initiated in 1937 with the passage of the U.S. Housing Act, is operated and managed by the U.S. Department of Housing and Urban Development (HUD). Annual energy costs now exceed $1 billion, which is 85% of the annual operating subsidies provided by HUD, or one-third of annual operating costs. Because energy expenditures are so high, they are a prime target for HUD's efforts to cut costs in response to tightening budgets. Our study describes a method for analyzing housing project energy consumption that HUD can use to establish energy-use guidelines and to evaluate public housing authorities' (PHAs) operating budgets.[1] Energy use indices such as those developed here can also help PHAs monitor their energy consumption and plan effective energy management strategies.

In this study, we analyze energy use in 91 selected public housing projects across the U.S. using both utility billing data and fuel oil consumption data. We believe this analysis represents the most comprehensive examination of energy consumption patterns in public housing based on *measured* data. After adjusting annual consumption for changes in weather, we examine correlations between energy use and building and occupant characteristics, using multiple regression analysis. Energy use and costs for different subgroups of our sample (for example, high-rise and low-rise buildings) are also characterized. In addition, we compare measured energy use in public housing with engineering estimates of public housing consumption, as well as with measured consumption in privately owned multifamily buildings.

The 91 selected projects are drawn from 19 local housing authorities and represent 1789 buildings and 31,928 apartments. All regions of the country are represented, although 70% of the projects are located in the Northeast. Most of the projects in our data base are located in climates that have between 4000 and 6000 heating degree-days. Only 13% are located in climates with relatively mild heating seasons compared to 44% of the public housing stock. Sixty% of the projects in this study are low-rise buildings (four stories or less), a slightly smaller percentage than within the total public housing stock. Almost 75% of the selected projects are centrally heated, a much higher percentage than in the total public housing stock (37%).[2] Gas is the most common space heating fuel in our projects, followed by oil, which is much more prevalent in our sample than in public housing in general (44% versus 13%). The selected sample has a significant number of senior projects (32%), which parallels trends in the overall stock.

ACCOMPLISHMENTS DURING FY 1987

This study utilizes a two-part model. In the first part, actual energy use is normalized to consumption in a year with "typical" weather, using the Princeton Scorekeeping Method, a widely used energy analysis model that finds weather-normalized annual consumption by regressing energy use versus degree-days calculated at the best-fit reference temperature. Then, in stage two, this normalized energy use is used to examine the influence of project characteristics on consumption levels, using multiple regression analysis.

We found that annual energy consumption of the space heat fuel (which includes domestic hot water and some cooking consumption) was 105 MBtu/apt. (129 kBtu/sq.ft.), while total fuel and electric consumption was 122 MBtu/apt. (158 kBtu/sq.ft.). Median energy (fuel and electricity) expenditures were close to $1000/apt. for this group of projects. Some interesting patterns emerged when the projects were separated by building type, heating system and fuel type, and type of occupant. Median energy consumption in the high-rise projects was 16 to 23% lower than for the low-rise projects, after we adjusted for floor area and the number of units, respectively. On average, the projects that heated with gas used 25% (per square foot) to 32% (per apartment) less energy than the oil-heated projects. The senior projects used 11% less energy than the family buildings, when adjusted for differences in floor area.

Projects in this study used 8% (per square foot) to 16% (per apartment) less fuel and electricity than previous engineering estimates of consumption for the public housing stock developed in the Ehrenkrantz report (a HUD-sponsored study assessing the physical condition of the public housing stock).[2] Non-heating electricity use was the same for both our projects and the stock estimates, while oil and gas consumption was 16% (per square foot) to 19%

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building and Community Systems, Buildings Services Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

(per apartment) lower for our sample than that estimated in the Ehrenkrantz report. Lower consumption among projects in our sample may reflect the energy-conserving character of the PHAs that contributed data. Energy use per square foot in this group of projects is still significantly higher (74%) than in the privately owned multifamily stock. (See Figure 1.)

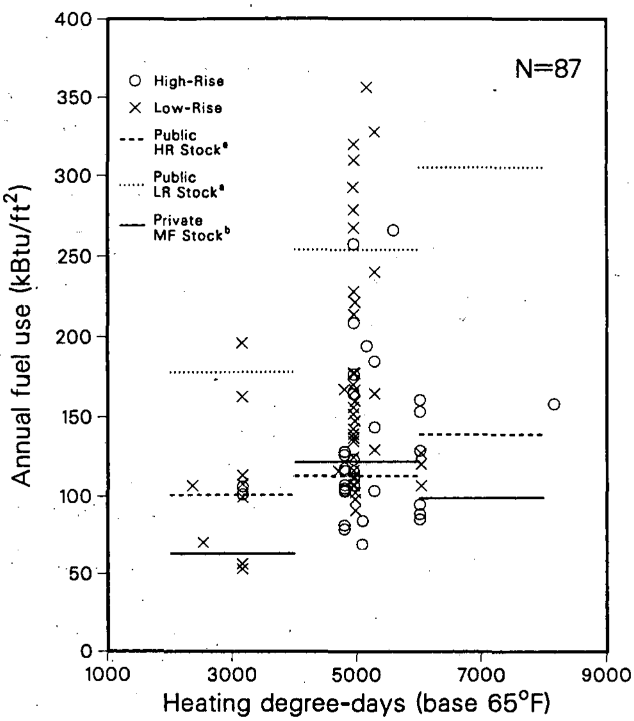

Figure 1. Comparison of consumption of space heat fuel with heating degree-days for different building types. Space heat fuel includes consumption for space heat, domestic hot water, and some cooking. Measured consumption at many projects is lower than engineering estimates of public housing stock use, but still significantly higher than private multifamily consumption. (XBL 8711-9090 A)

We developed two multiple regression models that were able to explain between 50% and 80% of the variation in fuel consumption in our sample of projects, using building and demographic characteristics and housing authority as independent variables. In these projects, occupant type was the most important factor that explained variation in energy consumption; projects occupied by seniors used less energy than family projects. The results of this analysis also suggest that the management practices of local housing authorities is an important determinant of energy use in these projects. We conclude that this two-stage methodology could be used to help HUD and PHAs increase their understanding of energy use patterns among projects and gain greater control of energy expenditures.

PLANNED ACTIVITIES FOR FY 1988

During the next year, we plan to apply this two-part model to a statistically representative sample of the public housing stock that is currently being compiled as part of a HUD-sponsored study. A regression model derived from this sample could give HUD a basis for developing PHA energy use guidelines that would take into account structural and demographic factors.

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Computer-Generated Residential Building Loads Data Bases*

J. Huang, J. Bull, and R. Ritschard

Large computer models for detailed building energy simulation such as DOE-2 are very useful for calculating the energy saving potential of various building conservation measures through repetitive simulations under consistent operating and climatic conditions. The resultant data base can be applied to the development of energy conservation standards, design guidelines, or simplified analysis tools.

Over the past decade, the Building Energy Analysis Group has conducted extensive computer analysis of the impact of conservation measures on residential energy use in different U.S. locations. From 1982 to 1986, we compiled a large data base of residential energy use using the DOE-2.1A and DOE-2.1B programs. The technical documentation for this effort is in a LBL report[1], while the data has been incorporated into the PEAR (Program for Energy Analysis of Residences) microcomputer computer program.[2]

In 1987, we were asked by Pacific Northwest Laboratories (PNL) to create a new version of this data base for a microcomputer-based residential energy standard PNL was developing in conjunction with ASHRAE, with support from DOE. We substantially reduced the effort required for this task by utilizing regression techniques developed from our earlier work. This allowed us to produce a data base that was compact, analytical, and flexible. Although the data base is presented in various ways, the primary output are sets of regression equations that comprise a simplified technique to estimate energy use in typical houses of varying sizes, shapes, and conservation levels.

ACCOMPLISHMENTS DURING FY 1987

The new data base was generated during FY 87 using a enhanced version of the DOE-2.1C program. The simulations cover three prototype buildings (one-story, townhouse, and apartment) in 45 U.S. locations. For each prototype and location, three foundation conditions (slab-on-grade, basement, and vented crawl space) and a range of insulation, wall mass, infiltration, and window options were considered. The changes in annual heating and cooling loads due to these building variations were analyzed through regression techniques, and reduced to generalized functions relating to the thermal and physical characteristics of the building components, e.g., areas and U-values for ceilings, walls, and floors, plus solar aperture and orientation for windows, or effective-leakage-areas for infiltration (Figure 1).

The methodology for the new data base is based on our earlier work[3], but incorporates recent advances in modeling abilities and analysis techniques. In addition to the improved algorithms resident in DOE-2.1C, enhancements were made to the code to model two-dimensional heat flow through walls and underground surfaces, and more realistic window operations for shading and natural ventilation. A quadratic regression with five variables, four for window solar apertures in each orientation and one for total solar gain, was found to produce reliable estimates of energy savings for different window conditions (Figure 2).

To account for two-dimensional heat flow in walls, we developed a finite-element program, WALFERF, to calculate response factors for two-dimensional heat conduction. In addition to specifying the thermal properties, thicknesses, and sequence of materials making up each block, WALFERF also requires the number of blocks and their widths.

Since the standard DOE-2 program does not adequately model the building-to-ground interface, we worked with the Underground Space Center (USC) at the University of Minnesota to incorporate into the DOE-2 program heat fluxes calculated by a two-dimensional finite difference program developed at

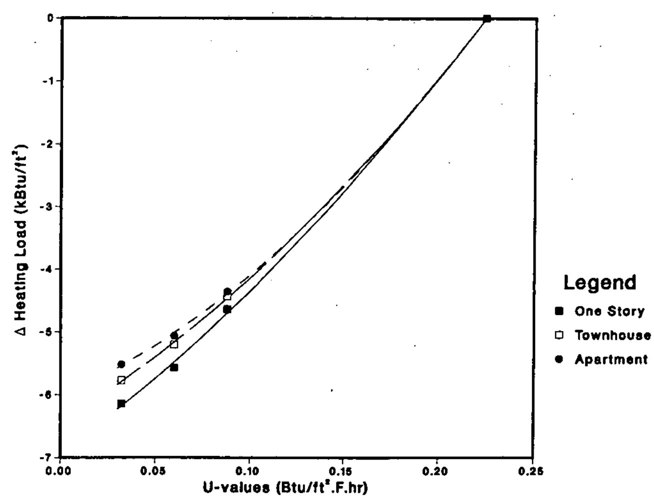

Figure 1. Correlations of Δ wall heating loads to U-values for Phoenix. (XBL 8711-4982)

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings Energy Research and Development, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098, through Battelle Pacific Northwest Laboratory.

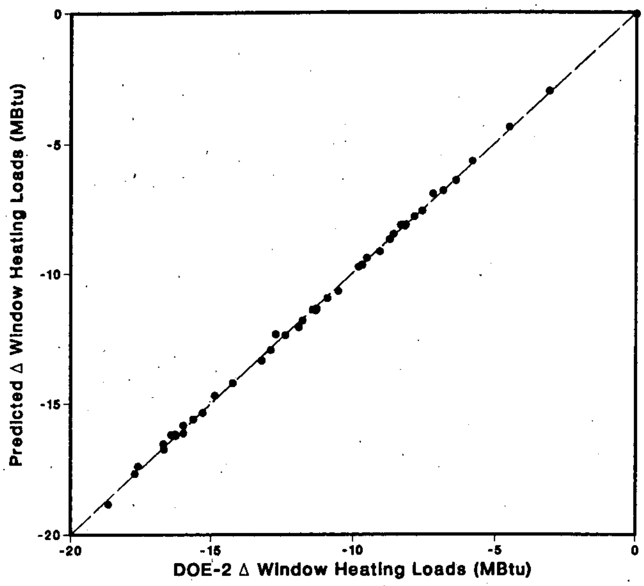

Figure 2. Quadratic correlation of Δ heating loads to solar aperture times solar usability in Albuquerque. (XBL 8711-4985)

Albuquerque NM WYEC One Story Prototype Siding

Heating Load

Ceiling	Delta Component (MBtu)	(KBtu) (/sf)	Wall	Delta Component (MBtu)	(KBtu) (/sf)
R-0	.00	22.58	R-0	.00	19.81
R-7	-21.01	8.94	R-7	-11.65	9.44
R-11	-24.37	6.76	R-11	-13.31	7.96
R-19	-27.38	4.81	R-13	-15.32	6.18
R-22	-28.52	4.07	R-19	-16.31	5.29
R-30	-30.05	3.07	R-27	-17.95	3.84
R-38	-30.97	2.47	R-34	-18.95	2.95
R-49	-31.77	1.96			
R-60	-32.28	1.62			
Slope(DD)	4468.29		Slope(DD)	3773.11	
Curve(DDS)	-111.142		Curve(DDS)	-16.709	

Slab		(/ft)	Heated Basement		(/ft)
R-0	-16.12	39.78	R-0	-8.95	82.97
R-5 2ft	-19.37	20.20	R-5 4ft	-14.13	51.76
R-5 4ft	-19.96	16.64	R-5 8ft	-15.20	45.32
R-10 2ft	-20.01	16.34	R-10 4ft	-15.42	43.99
R-10 4ft	-20.81	11.52	R-10 8ft	-17.02	34.35
Intercept	.000		Intercept	9.144	
Slope(DD)	4155.71		Slope(DD)	2834.65	
Curve(DDS)	-.186		Curve(DDS)	-22.466	

Figure 3. Sample data base; tabular output. (XBL 8712-5165)

the USC to simulate below-grade heat flow. This procedure captures the seasonal thermal behavior of the underground surface with its enormous thermal mass and heat capacity (see accompanying Annual Report article on foundation insulation modeling).

The data base is presented both as tables giving the Δ load for incremental changes in conservation level, or more analytically as regression coefficients expressing the Δ loads of each building component as a function of its physical and thermal characteristics. Figure 3 is a sample of the data base tables in the technical report[4]. The columns give the Δ loads for various insulation levels from the uninsulated base case, while the "slope" and "curve" give the quadratic and linear regression coefficients for the component load as a function of total ceiling or wall conductance.

PLANNED ACTIVITIES FOR FY 1988

The analytical format of the new data base makes it a flexible tool for calculating energy use in typical residential buildings. In FY 1988 we hope to incorporate the new data in the PEAR microcomputer program, and develop further the analytical approach used for both the DOE-2 simulations and the results analysis. We are also planning to analyze in more detail interactions between different building components, notably those affecting building cooling loads such as ventilation rates and thermal, and those relating to window solar gain.

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Conservation Potential of Foundation Insulation Measures*

J. Huang and J. Bull

In the last decade, there have been significant improvements in the thermal integrity of new houses through increased use of ceiling and wall insulation, multiple-pane windows, and reduced infiltration. Current building practices, however, often ignore foundation insulation because of uncertainty about their potential benefits. Although measured data have indicated that the conservation benefits may be large, there is need for a systematic study of the thermal performance of different foundation options.

In FY 1987, the Building Energy Analysis Group worked on a DOE-funded project headed by the Underground Space Center (USC) at the University of Minnesota to develop a handbook on energy-efficient building foundation design.[1] The purpose of the handbook is to provide design guidance to architects and designers on residential foundations with emphasis on energy and structural issues. LBL's role in the project was to develop with the USC a procedure for simulating the energy uses of a typical residential building with nearly 90 different foundation conditions for 13 U.S. locations.

ACCOMPLISHMENTS DURING FY 1987

The energy performance of a building foundation is difficult to simulate due to the thermal coupling between the building and the surrounding subsoil. Whereas light-frame walls respond thermally to temperature changes within a few hours, and even a massive wall within a day or two, the thermal responses of foundations extend over months or even years.

The procedure developed jointly by LBL and USC was to combine the capabilities of a finite-difference program at USC to simulate below-grade heat flows with that of the DOE-2.1C program at LBL to simulate whole house performance. The USC model is a fully-implicit integrated finite difference heat conduction program that provides a detailed two-dimensional heat flow simulation for the foundation and subsoil. The use of DOE-2.1C provides a hourly simulation of the rest of the house with realistic operating conditions, as well as compatibility with previous data base work done at LBL (see accompanying Annual Report article on residential loads data base). For foundations with floating zone temperatures such as unheated basements and crawl spaces, we developed an iterative procedure alternating between the two programs to capture adequately seasonal variations in the below-grade heat flux due to the heat storage of the soil.

We used the USC model to simulate on a daily time-step the heat flows in a representative one-foot vertical section of the foundation and surrounding soil (Fig. 1) under three conditions: 1. the same constant indoor temperatures as used in DOE-2 Loads, 2. a different constant indoor temperature, and 3. a series of sinusoidal varying indoor temperatures of different amplitudes. We then integrated these heat fluxes over the "footprint" of the prototype foundation to derive the average hourly fluxes each day through the underground surfaces of the prototype buildings (Fig. 2).

The fluxes calculated with the first condition are substituted for the standard heat flow calculation for underground surfaces in DOE-2 Loads. The fluxes calculated with the second condition are used to derive steady-state conductances for the foundation, while those calculated under the third condition are used to derive the periodic changes in heat flows due to seasonal variations in the indoor temperature:

$$Q_{\text{Loads T}} + \Delta Q_{\text{constant } \Delta T} + \Delta Q_{\text{sinusoidal } \Delta T}$$

For unconditioned spaces such unheated basements and crawl spaces, there are large seasonal fluctuations in the zone temperature, and hence large

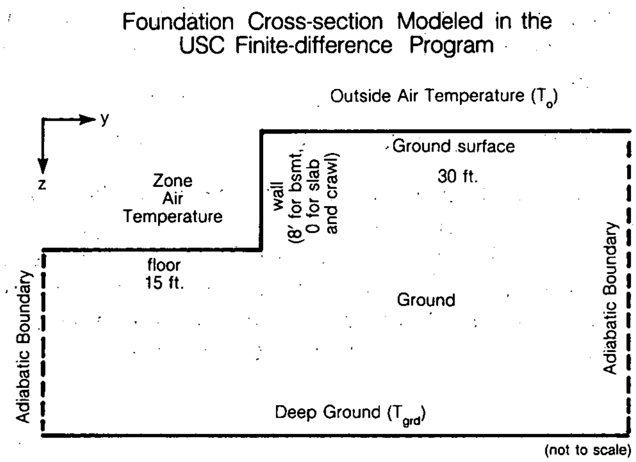

Figure 1. Foundation cross-section modeled in the USC program. (XBL 8711-9360)

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings Energy Research and Development, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098, through Oak Ridge National Laboratory and the University of Minnesota.

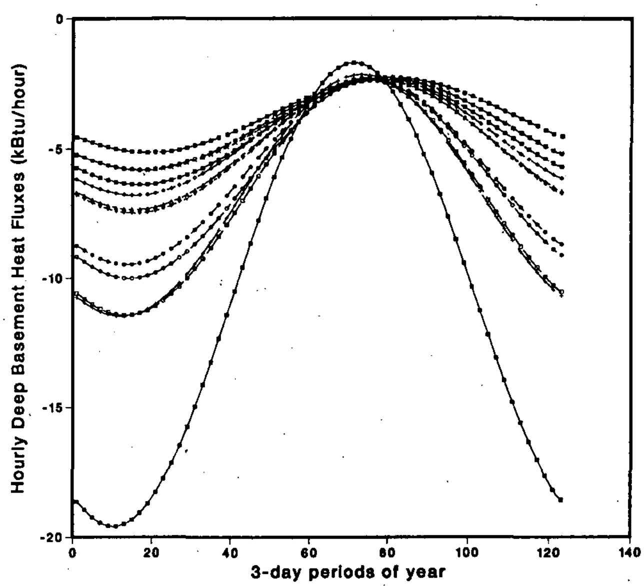

Figure 2. 70°F temperature fluxes for various deep basement foundations in Minneapolis, MN. (XBL 8711-4984)

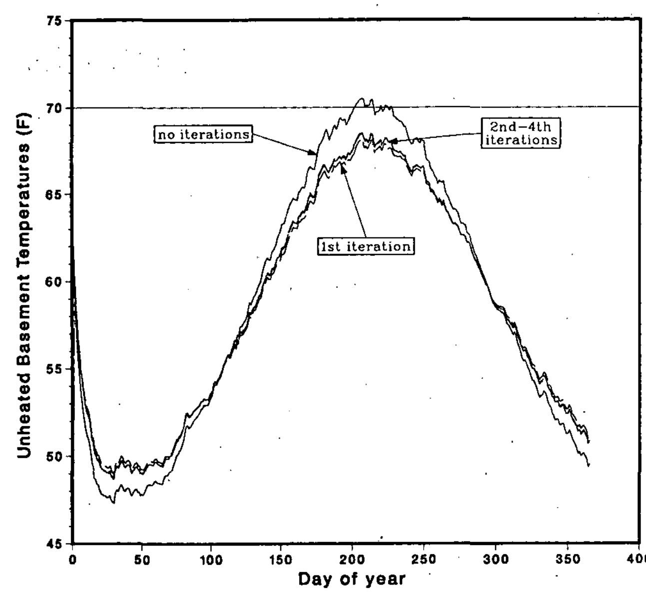

Figure 3. Floating temperatures in an uninsulated basement in Minneapolis, MN, after 5 iterations. (XBL 8711-4983A)

dynamic flux modifications for changes in indoor temperatures ($\Delta Q_{\text{sinusoidal }\Delta T}$). Since the zone temperatures are outputs from the DOE-2 simulations, we developed an iterative procedure using the zone temperatures from the preceding DOE-2 run to determine the $\Delta Q_{\text{sinusoidal }\Delta T}$ for each subsequent simulation. We found that by alternating between the USC model and DOE-2.1C, we achieved convergences in the computed zone temperatures and building energy uses by the fourth iteration (Fig. 3).

By the end of FY 1987, we have completed half of the 1300 required simulations. The results will appear as tables in the foundation design handbook showing the changes in annual heating and cooling energies from base case foundations with no insulation. In addition, the handbook includes an economic analysis that compares these energy savings to construction costs and develops design guidelines.

PLANNED ACTIVITIES FOR FY 1988

The data base is scheduled for completion before the end of 1987, and the handbook by early 1988. In addition to completing the data base for 89 foundation types in 13 cities, we will also perform sensitivity analyses on the impacts of different soil conductivities and snow cover on the energy savings of foundation conservation measures. To document the methodologies used in our energy simulations and economics analysis we are planning to present three technical papers at the ASHRAE Summer 1988 conference in Toronto.[2,3] By that time, we also hope to have completed comparisons of our results to available measured data and results from other simulation efforts.

Although at present we are only using the results from DOE-2 for total annual heating and cooling energy use, the data also includes a wealth of information on monthly and peak loads, and zone temperatures. Both USC and LBL are interested in improving our modeling capabilities and developing useful applications of the data.

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BUILDINGS ENERGY DATA

Overview

The Buildings Energy Data Group (BED) compiles and analyzes measured energy performance data on buildings and equipment. The Group's goal is to identify building design strategies and end-use technologies that save energy or modify electrical loads, and are cost-effective. We provide these measured results to institutions and persons responsible for improving energy efficiency in the buildings sector. In addition, we use the data to estimate regionwide potential savings from energy-efficient technologies.

The core of BED's activities rests in the Buildings Energy-Use Compilation and Analysis (BECA) series. Each data compilation addresses a sector of the buildings end use:

- New, low-energy homes (BECA-A)
- Retrofits of existing residential buildings (BECA-B)
- New, energy-efficient commercial buildings (BECA-CN)
- Retrofits of existing commercial buildings (BECA-CR)
- Residential water heating systems (BECA-D)
- Validations of computer loads models (BECA-V).

Each compilation is an independent data base, but all rely on the same computerized data base management system (DATATRIEVE). Each data base can be queried so as to produce buildings with similar features, location, function, etc. The article by Goldman and Greely on multifamily retrofits (a subset of BECA-B) is an example of the compilations developed by the Group. In another subcompilation, Piette and Wyatt assessed the measured energy performance of cool storage systems in commercial buildings.

An important research goal of the BED Group is to develop, refine, and promote the wider use of standard "yardsticks" of building energy performance. For automobiles, a dynamometer test yields a single parameter of fuel efficiency (miles per gallon). Unfortunately, one cannot measure a building's energy use under similarly controlled conditions. Instead, we must collect detailed information about the building, including its energy consumption, physical characteristics, and operating schedule. This information permits us to convert "raw" measurements into standard energy performance indicators. In the past, indicators focused on energy savings and cost-effectiveness; we are now developing parameters that describe peak power savings or, more generally, reshaping of electrical demand profiles.

The BED Group is also active in two areas that complement the core data compilation effort: primary data collection and conservation potentials studies. In special circumstances, BED measures energy use in specific buildings or equipment. This usually occurs after we have identified significant gaps in available data or collection techniques. The article by Akbari *et al.* describes measurements of the higher temperatures caused by the urban heat island. In another study, we tapped in-place energy monitoring systems to demonstrate that valuable commercial building performance data could be obtained quickly and cheaply. We also participate in monitoring projects or analysis of primary data. The article by Meier and Nordman describes the incremental value of metered data in an analysis of energy savings from new building standards.

Measured data on energy use and savings are key inputs to least-cost utility planning. The BECA compilations provide a valuable data base from which to estimate the potential for energy efficiency and electric load-shaping. The BED group has undertaken numerous investigations of the potential energy savings in the buildings sector. The potentials studies typically examine a series of end-use measures, calculate the costs of conserved energy, and develop "supply curves of conserved energy" (or peak savings) to express the aggregate potential for end-use efficiency. The article by Krause describes how we developed supply curves of conserved electricity (and load shape impacts) for Michigan. Related activities include the development of improved, microcomputer-based software to simplify the assessment of energy efficiency potentials. This software will be linked to a data base on end-use technology characteristics—much of which originates from our BECA research—containing data on measured energy use, savings, costs, and related technical issues.

An Updated Compilation of Measured Energy Savings in Retrofitted Multifamily Buildings*

C.A. Goldman and K.M. Greely

The multifamily sector, consisting of residential buildings with two or more units, comprises almost 27 percent of the U.S. housing stock (in terms of household units). Annual site energy use in these buildings is approximately 2.3 quads (1 quad = 10^{15} Btu) and directly or indirectly costs U.S. households almost $20 billion.

We have compiled and analyzed measured data on 200 U.S. retrofit projects in existing multifamily buildings that are now part of the Buildings Energy Use Compilation and Analysis (BECA) residential data base. We examined the costs of conservation measures and practices and the savings they generate. In this article, we also discuss the cost-effectiveness of different retrofit strategies in fuel and electrically heated buildings.

We obtained information on retrofit projects from several sources, including city energy offices [70], public housing authorities [38], research institutions and national laboratories [17], non-profit and for-profit energy service companies [36], and utilities [39].† During the past year, 40 electrically heated buildings from the Pacific Northwest have been added to our compilation. The data collected typically included metered energy consumption, installed retrofit measures and their costs, the price of the space heating fuel the winter after retrofit, and a brief description of the physical characteristics of the building. In most cases, we (or our data source) used the Princeton Scorekeeping Method (PRISM) · to analyze energy consumption data before and after retrofit. PRISM estimates a weather-normalized annual energy consumption (NAC) from parameters obtained from a regression of either utility bill or meter readings of the space heat fuel and daily average outdoor temperature. The NAC represents consumption that would occur in a year with typical weather conditions.

ACCOMPLISHMENTS DURING FY 1987

Median annual energy savings for our group of buildings were 9 MBtu per dwelling unit, or 16% of pre-retrofit energy use. Fuel-heated buildings saved more absolute energy, but percentage savings are similar in both groups (17% vs. 14%). We have found that energy savings are between 10 to 30% of pre-retrofit energy use in 60% of the buildings in our compilation. The median payback time for electrically heated buildings is over 20 years, while those of privately owned and public fuel-heated buildings are 4 and 10 years, respectively. In most cases, it is not cost-effective to spend more than $1500/unit.

The kind of retrofits implemented in a building depend mainly on the type of energy used for space heating. In fuel-heated buildings, various HVAC system retrofits (heating controls, equipment replacement, and altered operation and maintenance practices) and domestic hot water system alterations are the most popular conservation strategies. Shell measures (insulation, weatherization, and window modification or replacement) are more commonly implemented in electrically heated buildings. Retrofit costs are less than $250/unit in 35% of the buildings; median costs for heating system retrofits were much lower than costs for shell retrofits ($150 vs. $1350/unit).

The most cost-effective strategies in the fuel-heated buildings were heating controls, especially outdoor reset and cutout controls, and balancing of single-pipe steam systems. Heating system replacements and conversions (e.g., high-efficiency boilers, separate domestic hot water generators, and distribution system conversions) have somewhat longer payback times (5 to 20 years), but resulted in substantial savings (15–30%), as illustrated in Figure 1. The shell and window measures common in electrically heated buildings had payback times of about 20 years, with savings of 14 and 11%, respectively (Figure 2). Almost all of the electrically heated buildings in our compilation were retrofitted as part of utility programs with high investment levels; program economics could be improved by targeting high users (many electrically heated buildings have very low pre-retrofit consumption levels) and focusing on less expensive lighting and domestic hot water retrofits.

PLANNED ACTIVITIES FOR FY 1988

We are investigating the stability of savings in buildings during the years following a retrofit. Preliminary evidence suggests that substantial changes in consumption, both positive and negative, can occur between the first and second year after retrofit. Dur-

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings Energy Research and Development, Building Systems Division of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

†Numbers in brackets represent number of data points obtained from each source.

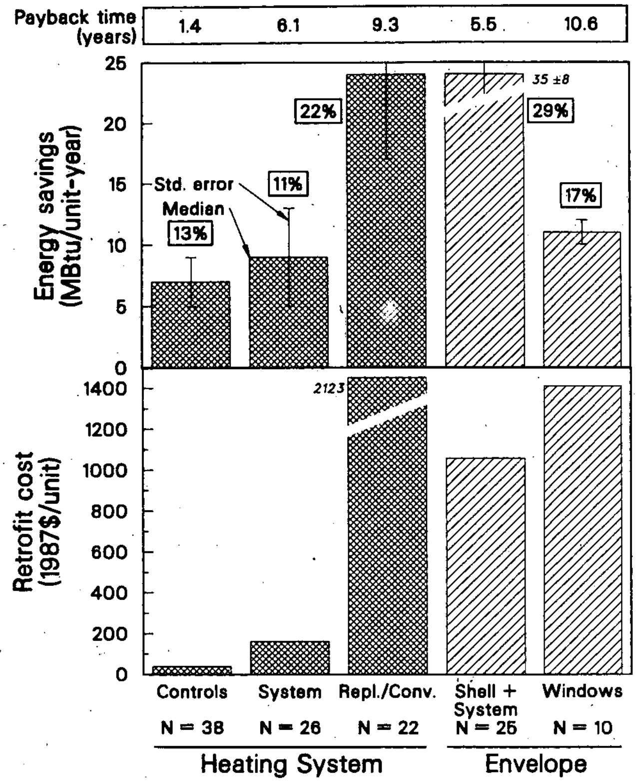

Figure 1. Energy savings and costs of retrofits in fuel-heated multifamily buildings. "System" refers to groups of measures that affect the heating or hot water systems. "Repl./Conv." are replacements or conversions of the boiler/furnace or distribution system. "Shell + System" includes combinations of retrofits which reduce heat loss through the building shell, and measures affecting the heating or hot water systems. (XCG 8710-14122).

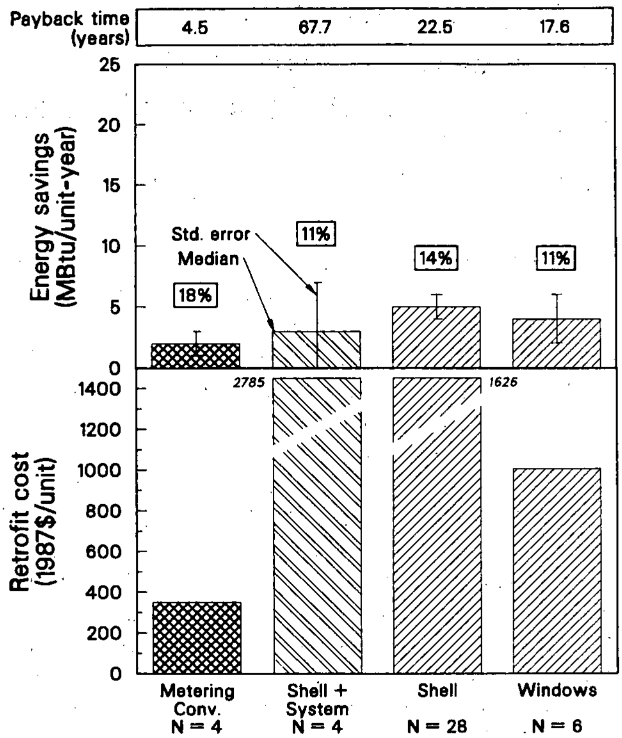

Figure 2. Energy savings and costs of retrofits in electrically heated multifamily buildings. "Metering Conv." are conversions of a master-metered billing system to one with individual apartment submeters. "Shell" refers to combinations of retrofits which reduce heat. (XCG 8710-11421)

ing the coming year, we will obtain additional post-retrofit consumption data for as many of the retrofits in our data base as possible, to increase our understanding of the building and retrofit characteristics which influence the persistence of savings.

Another activity during FY 1988 will focus on estimating the energy savings potential of the U.S. multifamily stock by extrapolating from the measured data in the BECA residential data base. Using data from the Energy Information Administration's Residential Energy Consumption Survey, we will compare characteristics of the U.S. stock with those of buildings in our compilation, to see what kinds of retrofits would be applicable to the stock, and how much savings could be expected if these retrofits were implemented.

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Incremental Value of Measured Data from the Residential Standards Demonstration Program*

A. Meier and B. Nordman

In an attempt to reduce future electricity needs, the Bonneville Power Administration (BPA) proposed to implement stringent efficiency electricity standards for new, electrically heated houses. BPA first sought to determine the potential energy savings for houses built to the Model Conservation Standards (MCS) through a major monitoring program. The Residential Standards Demonstration Program (RSDP) sponsored the construction of over 300 houses built to the MCS and selected over 300 recently-built houses to serve as controls. BPA asked LBL to estimate the actual energy savings from the MCS. A simple comparison of energy use was not possible because the houses differed greatly in their design and operation. Moreover, BPA sought to determine the energy savings under "normal" conditions to permit comparisons with its simulations of prototype houses. We applied techniques developed to support our compilation of new, low-energy homes (BECA-A) to analyze the savings. In particular, the program, SUBMET, normalizes metered space heating energy for differences in floor area, internal gains, inside temperatures, and climate.

We relied on weekly energy and temperature data from the triple-meters (which monitored space heating, water heating, and appliances) and temperature loggers. We also drew upon surveys and audits to provide floor areas and occupancy data.

MCS houses typically used 45% less space heat than Control houses (see Fig. 1). The regionwide savings were about 3.5 kWh^2-yr, but vary with climate zone. The estimated savings change when the assumptions are modified for internal gains and inside temperature. Most reasonable sets of assumptions yield annual savings over 3 kWh/ft^2-yr. The most sensitive assumptions are the choice of standard internal gains and the fraction of appliance energy that is converted to useful heat.

*This work was supported by the Bonneville Power Administration through the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

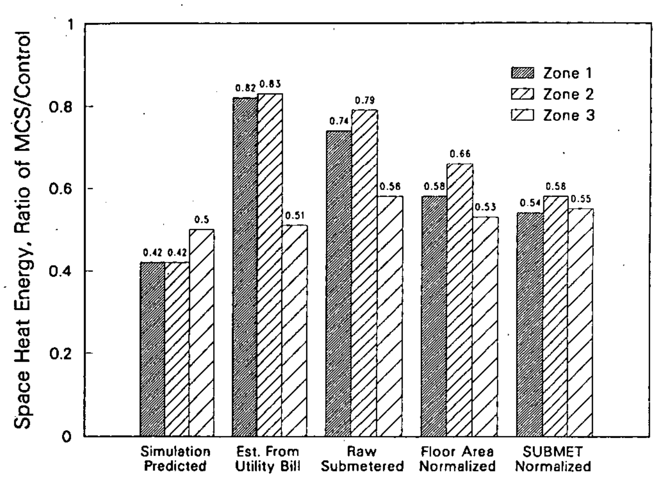

Figure 1. Five indicators of MCS/Control space heat energy. Each column represents the ratio of average space heating energy for MCS homes to their counterpart Control homes. A ratio of 1 would indicate that two groups used the same amount of space heat, while a ratio of 0.42 would indicate that the MCS houses used only 42% as much as the Controls. Differences in the groups disappeared as adjustments for more factors were incorporated. (XBL 8712-5274)

ACCOMPLISHMENTS DURING FY 1987

A program to monitor the energy use of buildings is expensive and time-consuming. Nevertheless, such information is essential to energy forecasters and planners because the costs of surplus capacity—or a shortfall—are even more expensive. We have focused on the incremental value of monitored data in assessing energy performance of buildings. Our goal was to determine the improvement in accuracy resulting from additional data collection.

Simulations always play an essential role in a comprehensive monitoring program. The simulations may consist of simple heat loss calculations or computer models to predict energy use and savings. BPA estimated the energy savings from the MCS for prototype houses compared to current construction practice. The simulations also determined the most cost-effective package of conservation measures. These predictions (shown in Fig. 1) predicted that the MCS houses would use less than half of the heating energy used by houses built to current practice.

The success of a program is often judged on the basis of monthly utility bills. By this measure, the MCS homes used about 17–49% less total energy. The savings in climate zones 1 and 2 are not surprising because the utility bill includes non-space heating end uses, such as water heating and lighting, but the fraction of total savings for houses in climate zone 3 is very close to that predicted for space heating alone. This behavior cannot be explained with a utility bill analysis.

A comparison of space heating energy alone causes the savings in the three climate zones to converge. This comparison requires a second meter on the house and typically costs a few hundred dollars. In this case, the additional information changes results slightly.

A simple improvement can be obtained by adjusting each house's space heating use to reflect its floor area. When this is done, the MCS houses in all of the climate zones save 34–42%. The disparities among the climate zones are much smaller, and all zones are achieving savings closer to those predicted by the simulations. Much of the apparent difference in energy use was due to MCS houses being larger than the Control houses. The combination of space heating and floor area data greatly improved the accuracy of the results and explained the discrepancies found with utility bills alone.

Finally, we used SUBMET to normalize the measured space heating use so as to approximate the operating conditions used in the simulations. SUBMET adjusts for climatic differences (within each climate zone), floor area, inside temperature, and internal gains. After these adjustments, it appears that MCS houses used 42–45% less space heat than the Controls. The enormous differences among the climate zones virtually disappeared after accounting for differences in internal gains and indoor temperatures.

The MCS still did not achieve the energy savings predicted by the simulations. Both technical and behavioral factors may explain the (relatively small) difference. Control houses were better insulated and had lower measured infiltration rates than assumed in the simulations. In addition, the occupants operated the houses differently than assumed in the simulations. There is also considerable variation within the sample, so that the ratios predicted by the simulations are within the range of high statistical confidence. Alternatively, SUBMET may provide a biased estimate because it normalizes inside temperature based on only one indoor temperature. If the occupants practiced zone heating, a bias might be introduced.

We will test the zone heating hypothesis by tapping a richer data set on a smaller group of RSDP homes where multiple temperature sensors were installed.

PLANNED ACTIVITIES FOR FY 1988

We will develop statistical indicators to compare temperature deviations to permit a quantitative assessment of their differences. In addition, we will examine houses with unusually high and low space heating needs, and try to explain them in terms of the building characteristics and occupant behavior. Finally, we will compare the energy performance of the houses in the RSDP to those houses already in our BECA-A data base.

Analysis of Utility Program Experience: Preliminary Results from the MEOS Study*

F. Krause

The Building Energy Data Group has been expanding its work on technology cost and performance assessments to include experience with utility incentives programs to promote customer efficiency investments and participation in load management.

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A preliminary analysis of several appliance, lighting efficiency, and load management programs in the residential sector was performed as part of LBL's contribution to the Michigan Electricity Options Study (MEOS).

It is widely recognized that the implicit economic decision-making in the purchase of energy-consuming devices by energy consumers does not follow lines of least-cost rationality. One objective of the MEOS demand-side analyses was to define the amount of energy and peak demand savings that could be realistically obtained from the technologies considered, if utilities were to *aggressively* pursue specific incentive programs to shift the purchasing behavior of their customers. This requires incorporation of achievable annual participation rates and cumulative penetration fractions into the analysis. Also, the administration and incentives cost of such programs must be ascertained. Such an analysis is presently difficult because only a limited number of programs have been carefully monitored over an extended period of time, and even fewer programs have been aggressively pursued.

ACCOMPLISHMENTS DURING FY 1987

Our method was to assume that aggressive programs would provide incentives in such a way as to eliminate all extra first costs for participants (full incentives). High incentives alone do not guarantee high participation rates, but they do make participation less sensitive to non-financial program features. Programs also have to observe a number of lessons that emerged from a review of the literature and from interviews with program managers. Among these are:

- Large-scale programs should be preceded by well-designed and thoroughly evaluated pilot and demonstration projects.
- Monitoring, feedback, and quality control functions should be built into the implementation process.
- Programs should make use of market segmentation techniques and other methods to flexibly target different consumer groups and local conditions.
- Community groups and trade allies can be one of the most effective agents in the implementation process.
- Promotion of demand-side measures should emphasize how such measures contribute to the broad values sought by customers, such as increased comfort, safety, reliability, environmental health, and productivity.
- Information and incentives strategies should build upon market forces wherever possible, and reward savings rather than expenditures.
- Efficiency standards can be one of the most effective complements to incentives-based programs.

The program-based scenario in the LBL study assumes that full incentives are offered until most or all existing stocks have been turned over. The scenario also foresees for each end-use a *two- to five-year pilot project phase* in which program designs are optimized before full-scale implementation begins. The onset of major savings is correspondingly delayed.

The impact of increasing incentives on penetration fractions is schematically illustrated in Fig. 1, which shows the cost of conserved energy or peak power based on the sum of technology costs and costs for program administration (processing of rebates, advertising, etc.), for a stylized two-measure supply curve.

Two issues in calculating the cost of program-based demands-side resources are the free rider and spill-over effects of the program. In most cases, variable incentives based on careful analysis of existing purchasing patterns can minimize the free-rider problem. Spill-over effects are harder to quantify than free riders, but they will also counteract the free-rider problem. In a well-designed rebate program the spill-over effect can be made to dominate and provide program-induced savings from non-participants at zero program cost.

Another important variable in the utility cost of demand-side resources is the level of incentive that is needed to achieve desired levels of customer participation. Utility experience shows that substantial participation can be achieved at significantly less

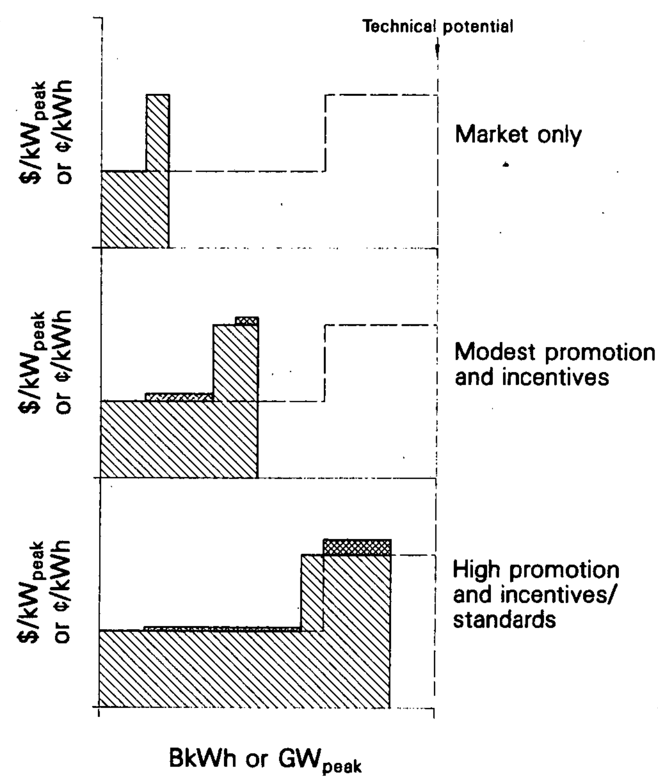

Figure 1. Technical potential and program-based scenarios: Costs of savings to society. (XCG 868-7347)

than full incentives. Utilities have also found that as programs mature, the level of incentives can be lowered and in some cases entirely substituted by effective information and promotion. This is partly the result of the programs' spill-over effects on the retail markets, such as better informed salespeople and greater stocking of high efficiency merchandise. Another reason is that in the larger utility incentives programs, the prices of demand-side technologies tend to drop as the program moves them out of their small, specialty or high-income market niche, where dealer mark-ups are high.

Since in our program scenario full incentives are provided over extended periods of time (eight to 15 years), the program costs developed in the LBL MEOS study define an upper bound for the likely cost of buying efficiency from customers.

PLANNED ACTIVITIES FOR FY 1988

We expect to prepare program experience reports on utility programs to promote efficient new construction practices and efficient commercial and residential lighting technologies.

SUGGESTED READING

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Technology Assessment: Cool Storage In Commercial Buildings*

M.A. Piette and E. Wyatt

In the last five years, utilities and state agencies throughout the country have sponsored programs to encourage better energy efficiency and load management in buildings. One promising load management technology is thermal storage for cooling commercial buildings. Commercial space cooling currently accounts for about 20 to 40 percent of most utilities' summer peak demand, and the Electric Power Research Institute estimates that commercial cool storage systems could avoid 17 GW of U.S. summer peak demand by the year 2000. The basic approach is to reduce on-peak demand (kW) by shifting the compressor's operation to off-peak hours, when electricity charges are lower. Cooling energy is stored in the evening using a medium such as water or ice, to be used the next day during occupied hours, which coincide with higher peak-period utility rates.

Commercial cool storage is not a new technology, but its widespread application in today's commercial buildings has required new developments. Most important are improvements in equipment and changes in operating strategies for various load conditions to optimize cost effectiveness under today's electricity rate schedules. About 200 new cool storage systems were installed in 1986, about double that of 1985; a similar doubling in 1987 is anticipated. The majority of systems are found in new office buildings, because they have low cooling requirements in the morning followed by high afternoon peak demands. Installations are most common in areas where utilities charge high demand rates or there is a high differential between day and night electricity rates. More than 20 utilities currently also offer direct rebates for cool storage, based on the estimated shifted peak demand (kW).

ACCOMPLISHMENTS DURING FY 1987

During 1987, we studied the current status and future potential of commercial cool storage.[1,2] There is clearly no single "best" system because the parameters, i.e., building type, load profile, status of existing equipment (if a retrofit or addition), first costs (considering any utility incentives or tax incentives), and electricity rate structures, strongly influence the design. Research and development is underway on more efficient refrigeration systems, ice building and storage techniques, and advanced phase change materials. Until recently cool storage has been used mainly in larger buildings with central chilled water systems. Now, a few manufacturers are offering packaged unitary rooftop air conditioning units with

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building and Community Systems, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

ice storage. It is estimated that package units represent nearly three-fourths of the installed capacity for 1985.

Determining the cost-effectiveness of a cool storage system requires a comparison with a base case cooling system. Most cool storage systems are more expensive than conventional HVAC systems. The base case for an existing building is usually the "pre-retrofit" conditions. But comparison of "pre-" and "post-retrofit" building performance must consider any other changes in the building in addition to the installation of a cool storage system, which may be difficult. The base case for a new building is based on a "conventional" system. Performance analysis for a new buildings is, therefore, very sensitive to the specified characteristics of the "conventional" system. The most precise performance comparisons are based on actual metering of cooling loads. Measured cooling loads can then be used to calculate how a conventional system would perform under the same conditions that the cool storage system operated. Use of measured data accounts for the differences in weather and occupancy that occur between actual and simulated (or design) conditions.

Many cool storage buildings dramatically improve over the first few years. Figure 1 demonstrates the value of submetered cooling data in assessing the success of the cool storage system. While the average of the monthly on-peak demands for the cooling system fell from 1982 to 1985, the whole-building on-peak demands remained fairly constant.

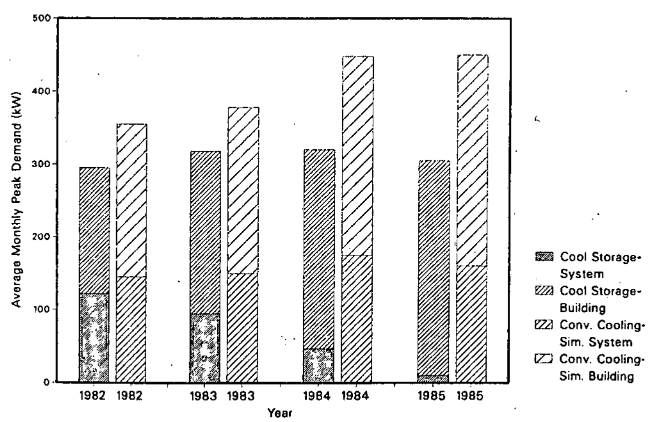

Figure 1. Average of monthly demands for an office building in the midwest USA for the whole building and for the cooling system alone during on-peak periods in four successive cooling seasons. As the operators mastered the cool storage system, they significantly reduced the average monthly demand. "Sim" and "Conv" refer to simulated and conventional, respectively. The simulated energy use grew in part due to the installation of a computer center. (XBL 8712-5275)

Early cool storage installations experienced a number of startup problems. For example, many early systems were sized improperly. Table 1 summarizes the operating experiences for ten buildings. Sizing errors, control failures plagued many of the buildings. Inexperience of building operators was cited as a problem for six of the buildings. In almost every case system performance improved over the first few years as experience with the equipment and building operation was gained.

Standardized techniques for performance analysis have not been developed because the choice of relevant physical performance parameters depends on the rate schedule. Furthermore, both designers and building operators require training. Better estimates of cool storage potential require more detailed

Table 1. Summary of Early Operating Experiences for Ten Buildings.

	Occurrences
SYSTEM DESIGN	
storage sizing	4
compressor sizing	2
condenser sizing	1
refrigerant receiver	2
water flow inadequate	1
storage poorly insulated	1
SYSTEM O & M	
control strategy unsatisfactory	1
improper expansion valve settings	2
time clock malfunctions	6
compressor failure	3
compressor control failure	3
refrigerant leaks	4
storage leaks	2
inexperienced maintenance personnel	6
inexperienced outside contractors	5
poor sensor calibration & maintenance	3
insufficient cooling on hottest days	1
excessive storage during mild weather	4
CHILLED WATER SYSTEMS	
poor tank stratification	2
ICE SYSTEMS	
ice thickness control failure	4
improper operation of ice agitator	1

peak demand and building characteristic data than are currently available. Such data will be of value to architects, engineers, and energy planners.

PLANNED ACTIVITIES FOR FY 1988

During FY 1988 we will continue to collect submetered data on the actual performance of installed systems from utility monitoring programs now underway. Our analysis will consist of comparing the cool storage system performance with estimated performance for conventional systems, as well as comparing the performance among the numerous buildings.

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Strategies for Reducing Urban Summer Heat Islands*

H. Akbari, J. Huang, and A. Rosenfeld

Urban climatologists and energy researchers have demonstrated that developed urban areas create summer "heat islands" with a typical daily average intensity of 3–5°C. In high-latitude cities with cooler weather, heat islands can be an asset in reducing heating loads, but in mid- and low-latitude cities, heat islands can contribute to the urban dweller's summer discomfort and significantly increase air conditioning loads. For example, the Los Angeles basin uses 5 gigawatts of air conditioning, an amount which represents $10 billion in power plants and another $5–10 billion for HVAC equipment. Ironically, much of this need for cooling energy is due to the man-made heat island brought on by urbanization.

The urban heat island results from the interaction of many factors, such as increases in the surface roughness and anthropogenic heat release from buildings and vehicles, coupled with decreases in the urban albedo and decreases in the evaporation rate which follow as trees and vegetation are replaced by impervious building materials. While some planners have regarded urban heat islands as inevitable products of urbanization, others have speculated that they could be alleviated by adding vegetative cover, spraying water on building tops, increasing the number of fountains and pools, choosing light colors for building exteriors, avoiding the use of dark-colored asphalt and bitumen in streets, altering urban dimensions, or minimizing the anthropogenic heat release rate.[1]

The objective of the heat island research at Lawrence Berkeley Laboratory is to *quantify* the energy saving potentials of such urban conservation strategies by developing and applying analytical models to simulate urban microclimates and the cooling energy requirements for buildings located within them. The results can be used to identify the most cost-effective methods for mitigating the urban heat island and to develop guidelines and suggestions for city planners, landscape architects, and architects. We have developed preliminary numerical models to simulate the effects on urban microclimates from changes in the amount of urban vegetation and the magnitude of urban albedo. Assuming that the changes are implemented city-wide, these models predict significant energy savings.

We have also begun addressing the constraints and possible conflicts that may arise in the implementation of such city-wide energy conservation measures. For example, if the number of trees and other forms of urban vegetation is significantly increased, the vegetation may block views, shade buildings excessively, and cause physical damage to urban structures through their branch and root systems. Similarly, increasing the urban albedo by using light colored paints and building materials may cause glare and increase construction costs. In gen-

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings Energy Research and Development, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

eral, the cost of poorly planned schemes to reduce the urban heat island could greatly reduce the benefits derived.

ACCOMPLISHMENTS DURING FY 1987

We have simulated the effect of increased vegetation on summer cooling loads of a prototypical house in four representative cities: Sacramento, Phoenix, Lake Charles, and Los Angeles.[2] The results are summarized in Table 1. Table 1 shows that the combined effects of shading and evapotranspiration on energy consumption is greatest in Sacramento, and lowest in Los Angeles. This is due to the difference in cooling hours between the two locations. The effect on peak power and cooling hours is greatest in Los Angeles, and smallest in Phoenix. This is again due to the fact that in Los Angeles, there are only 65 cooling hours per year, whereas in Phoenix, there are 3647 hours. The table shows that peak power savings on the order of 18%–30% is feasible.

In a separate study,[3] we have simulated both the direct and indirect effects of albedo changes on building cooling energy use in Sacramento during the peak summer period from July 9 to July 12. Results are presented in Table 2. Table 2 shows that a typical house with an albedo of 90% in a surrounding with an overall albedo of 40% consumes 62% less energy, has a 35% lower peak power demand, and experiences 44% fewer cooling hours.

Implementing the strategies we have discussed involves changing the urban environment in ways which will affect both public and private property. For instance, planting trees would result in conflicts such as who should pay for trees and what would be the effect of trees on the water supply. Similarly for albedo modification, the conflicts include the overall urban glare, choice of color, and who should be paying for urban modifications. In order to avoid conflicts, it is important that researchers and planners begin to integrate these strategies with all aspects of urban living. In many instances, public support and involvement will be essential. In reference to such

Table 1. Savings in annual cooling energy use and peak cooling power with increased urban tree canopy for the prototype house. All savings are with respect to the basecase described in the first column.

	Base-case	Savings from 10% increase (=1 tree/house)		Savings from 25% increase (=3 trees/house)	
Location		Shade Only (%Δ)	Shade+ evapotrans. (%Δ)	shade only (%Δ)	shade+ evapotrans. (%Δ)
Sacramento					
Annual kWh	1420	9	24	16	53
Peak kW	7.10	9	18	11	34
Cooling hrs	904	4	18	7	57
Phoenix					
Annual kWh	6911	3	13	6	33
Peak kW	8.87	5	9	6	18
Cooling hrs	3647	0.5	4	2	17
Lake Charles					
Annual kWh	3908	2	12	4	35
Peak kW	7.17	5	12	6	22
Cooling hrs	2489	1	7	2	24
Los Angeles					
Annual kWh	359	~ 0	~ 0	~ 0	~ 0
Peak kW	4.46	10	20	12	44
Cooling hrs	65	18	66	28	85

Table 2. Direct and indirect savings in cooling power and energy resulting from albedo modifications for the prototype house from July 9 through July 12. For cases where energy use increased, the numbers are given in parentheses. The albedo of the surroundings and of the house are represented as α_s and α_h, respectively.

Conditions					
House (α_h)	0.30	0.12	0.90	0.12	0.90
Surrounding (α_s)	0.25	0.25	0.25	0.10	0.40
	Basecase	Direct Savings		Direct + Indirect Savings	
		(Δ%)	(Δ%)	(Δ%)	(Δ%)
Energy kWh	74	(7)	19	(66)	62
Peak kW	7.07	(5)	14	(14)	35
Cooling hours	43	(2)	7	(37)	44

instances, we have studied[4] the importance of problem perception and have made clear that planners and resource managers cannot fully anticipate public attitudes and desires without enlisting the direct involvement of community members.

PLANNED ACTIVITIES FOR FY 1988

We have planned three major activities for FY 1988. 1) We will comprehensively study the wind-shielding and shading effects of trees in several representative heating and cooling climates in order to simulate the overall saving potential of trees. 2) We will organize a workshop among the heat island specialists, urban designers, and governmental offices in order to facilitate exchange of information among researchers. 3) We will continue our efforts to enhance our simulation capabilities such that we will be able to simultaneously simulate many aspects of the suggested mitigation measures.

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Analysis of Whole-Building Short-Interval Electric Load Data*

H. Akbari, K. Heinemeier, P. LeConiac, and D. Flora

As part of a statewide program, California utilities have collected 15-minute interval load research data for commercial buildings with time-of-use rate schedules and a connected load exceeding 500 kW. Some utilities have also conducted energy audits of commercial buildings as part of a survey of California's building stock. These databases provide valuable sources of *measured* information for analysis of energy use in California commercial buildings.†

The building characteristics, occupancy, and actual operation combine to create a unique demand "signature" in the building's load shapes. Some quantitative insights can be extracted from the 15-minute load data through a series of detailed analyses of temperature response, annual load-shape, frequency of equipment use, and comparisons of building load profile on the building's peak day with its profile on the utility's peak day.[1,2] While these analyses are by no means exhaustive, they form a basis for understanding the individual end uses of energy in commercial buildings without specifically monitoring them.

ACCOMPLISHMENTS DURING FY 1987

We analyzed load data and audits from eleven utility load research buildings. These buildings include four schools, three department stores, one refrigerated warehouse, three office buildings, and two hospitals, all located in Southern California. The data for these buildings contained 15-minute whole building, electric energy use data (kWh) for one year.

Many of our findings are used in a subsequent study to develop an algorithm for disaggregating whole-building load into its major end uses. The algorithm relies mostly on measured whole-building load for operating schedules of buildings and their HVAC systems. Our analysis has concluded that:

- Load research data are an invaluable source of information for analyzing and understanding patterns of customer electricity use, segregated by major end uses. Used to advantage, these data would provide a reliable basis for understanding and developing estimates of major end-use load profiles, by customer class.
- Buildings of the same category generally have the same characteristic load profiles, and, in many cases, the yearly load characteristics among the buildings of the same type are so similar that we can predict the building type merely by examining the load data.
- None of the buildings' annual peaks occurred on the system peak day in 1984. However, for all the buildings except schools, the load profiles on the system and building peak days are very similar.
- Analysis of the frequency distribution of hourly loads has yielded the expected values and variation of the hourly electricity consumption. An example of the frequency distribution of energy consumption during a shoulder hour is shown in Figure 1. Two distinct groupings are observed: one indicating normal operation of the building at that hour and one indicating early startup of the HVAC systems.

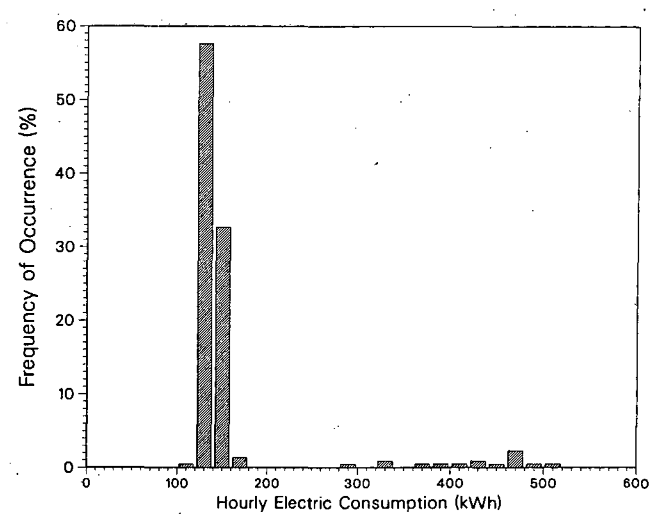

Figure 1. Frequency distribution of hourly load for an office building. Information about the building operation can be obtained by studying the distribution of the load across the year for each hour. Two modes of operations are indicated for the 7 a.m. shoulder hour. (XBL 8711-4707)

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings Energy Research and Development, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

†Although the data used in this study have come from buildings in California, the methodology and results can be applied to many commercial buildings having comparable load data.

- Hour-to-hour load variations provide information on seasonal changes in the operating schedules of a building.
- There is significant correlation between whole-building load and outside temperature for those hours that a building is air conditioned. This analysis has provided further information on the actual operating schedules of air-conditioning systems.

PLANNED ACTIVITIES FOR FY 1988

For FY 1988, we are planning to develop an integrated method to estimate commercial load shape and energy use intensity. The planned activity will build upon our analysis of the measured whole building load. One technique, which has already been tested on several buildings,[3] will exploit in-place energy management and control (EMCs) systems to obtain the whole-building data. We will also refine and apply our end-use disaggregation algorithm to estimate load shape and energy use intensities.

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ENERGY CONSERVATION POLICY

Overview

The Energy Conservation Policy Group continues to work in three general areas: research on energy conservation policies for commercial buildings in Southeast Asia, analysis of impacts of appliance efficiency standards in the United States, and assessment of impacts of demand-side programs on electric utilities, their ratepayers, and society.

The accompanying articles describe the main findings of the research and analysis in these three areas. Here we describe each of these efforts more generally, highlighting issues that are likely to be important in coming years.

The project on energy conservation in commercial buildings in Southeast Asia raises issues for both the United States and the developing world. Early research has shown the potential for significant energy and dollar savings in Southeast Asian buildings. Of the 12 billion spent annually on electricity for space conditioning, ventilation, and lighting in buildings in the five target countries (Indonesia, Malaysia, Philippines, Singapore, and Thailand), near-term savings of 10% ($200 million per year) can be achieved at relatively low investment and intermediate-term savings of 20 to 30% are possible, but with higher investment. A number of key technical issues need to be studied in much greater depth to know how best to achieve these savings. Knowledge is particularly weak on the performance of actual buildings in the region, methods for designing for natural ventilation, and procedures for achieving comfort (air conditioning and natural ventilation) at high efficiency. At the same time, a great deal is now known about increased energy efficiency in hot, humid climates through efficient lighting, improved window systems, better building envelopes, and daylighting of buildings.

The crucial question is how can government policy and private investment be translated into efficiency improvements in real-world buildings? The benefits—lower costs to the consumer, reduced oil use (the main fuel for electricity), and reduced drain on limited public capital for expanding electric power—are clear but the means to achieve these benefits is not so evident.

The project is now moving into a phase in which much more will be learned about these issues. A model conservation code for the region has been prepared. An in-depth analysis of the impact of a similar code in one country has been initiated. Now work is beginning on formulating broader policy approaches and increasing private sector involvement in energy conservation investments. The next several years will undoubtedly lead to much greater understanding of some factors that can stimulate and others that will retard effective policy implementation in a vibrant group of developing nations.

The appliance standards effort, while focused on the United States rather than the developing world, raises similar issues. The project has learned a great deal about the availability and costs of options to increase energy efficiency of residential appliances. It has also gained considerable knowledge about efficiency choices by consumers through its effort to forecast efficiency in the absence of standards. More recently, a model of the impacts of higher efficiency products on appliance manufacturers has been developed and applied. All of this work taken together appears to demonstrate that the market, if left to its own devices, will underinvest in energy efficiency by a significant amount. Findings from the analysis of manufacturer impacts show that an individual manufacturer is likely to lose money if it greatly increases the efficiency of its product offerings (everything else remaining unchanged and the efficiency increase cost-effective). However, if all manufacturers increase efficiency at the same time (as under standards), profits are much more likely to remain unchanged or to increase rather than to decline. In short, the analysis of appliance standards suggests that active policies are required if the benefits of higher efficiency appliances are to be achieved.

The utility analysis confronts similar themes—relating to the adoption of socially beneficial energy efficiency measures—but in the context of a regulated electric utility, its regulators, and its customers. Here again the basic issue is: what is needed to spur cost-effective investment in energy efficiency and other demand-side measures? It is probably too early in the research effort to draw conclusions. However, because the project is now working closely with electric utilities (directly and through utility organizations) and with their regulators (directly and through the National Association of Regulatory Utility Commissioners), insight into this issue is likely to emerge in the coming years.

In short, a major theme of the Energy Conservation Policy Group involves the complex interaction among many different groups in the process of studying, formulating, refining, and (in many cases) ultimately adopting and implementing policies to improve the efficiency of energy use in a cost-effective way.

Energy Conservation Policy for Commercial Buildings in Southeast Asia*

M.D. Levine, H. Akbari, J. Busch, S. Byrne, J.J. Deringer, K.H. Olson, I. Turiel, and M. Warren

The overall purpose of this project is to stimulate the development and implementation of policies to increase the efficiency of energy use in commercial buildings in five countries in the Association of South East Asian Nations (ASEAN): (1) Indonesia, (2) Malaysia, (3) Philippines, (4) Singapore, and (5) Thailand. This is carried out through training, research projects, analysis and assessment, and information dissemination.

Previous research demonstrated that significant energy savings in commercial buildings are possible. Figure 1 shows the types of measures that can reduce energy costs and the magnitude of savings that can be achieved. This figure makes clear that the largest reductions in energy use are for windows and lighting measures and that the overall reductions are substantial (more than 20% for daylighting alone). These large savings are particularly impressive when one recognizes that Singapore, for which the analysis was performed, already has among the most energy efficient buildings of any place in the tropics, having instituted an energy conservation standard in 1979 and having now achieved full compliance with the standard. For the ASEAN region as a whole, 20% savings (achievable in a ten-year time frame with a payback of two to four years) represents an *annual* electricity savings of about $400 million. (More than one-third of the electricity used in the region is in commercial buildings.)

*This work was supported by the U.S. Agency for International Development through the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

ACCOMPLISHMENTS DURING FY 1987

There were three different training activities during FY 1987: (1) courses in energy auditing of commercial buildings, with each course having 20–30 participants, conducted in Indonesia (twice), Thailand, and Malaysia, (2) a week-long workshop in Singapore for ten ASEAN delegates, covering research and policy activities of the project, and (3) a training course for four ASEAN delegates at LBL dealing with research on natural ventilation. In addition, the project supported ASEAN participation in a major conference in Singapore of the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) and attendance at other meetings and workshops throughout the region.

Research conducted at LBL included completion of wind tunnel work on natural ventilation in buildings, emphasizing effects of the external environment and interior partitions; completion of a users' guide for modeling natural ventilation in buildings; and parametric studies using DOE-2 on measures to increase efficiency of air conditioning use. The most important aspect of the research effort was the design

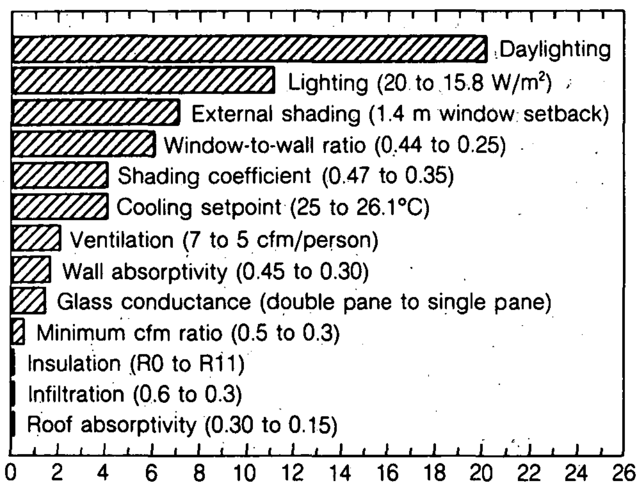

Figure 1. Reduction in total energy use (%). (XBL 841-68A)

and setting up of research projects within each of the ASEAN countries. A total of 26 research projects were initiated. These involved studies of such topics as energy auditing and monitoring of commercial buildings, preparation of natural ventilation design guides, assessment of the performance of energy management systems in buildings, computer simulation studies of the energy performance of buildings, and the analysis of policies to increase the energy efficiency of buildings in ASEAN.

In the area of assessment and policy, three documents of considerable importance to the overall project were completed.[1-3] The first is a model code for energy conservation in new commercial buildings. This is an innovative, detailed document that will provide the basis for standards and guidelines, as well as other policies, for the ASEAN region. The second document is an analysis of the energy and economic impacts of standards in one country. This will provide a basis for ASEAN researchers to evaluate their own policy approaches. The third document is a survey instrument to be employed throughout ASEAN to obtain data about extra energy use in buildings and decision-making on energy efficiency.

In short, the project has accomplished many of the key activities needed to set the stage for policy formulation on energy conservation in commercial buildings in ASEAN.

PLANNED ACTIVITIES FOR FY 1988

The project is expected to emphasize the following areas in FY 1988: (1) technical support from LBL for the research projects located in the ASEAN region, (2) continued training and workshops in selected areas of research and analysis, (3) engagement in a dialogue with public and private sector participants in ASEAN on policy development (using results of the project), (4) broadening policy research to include energy pricing reform and other economic policy vehicles to achieve project objectives, and (5) expanding the role of private sector participants and technology transfer in the project.

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Analysis of Federal Appliance Efficiency Standards*

H. Ruderman, P. Chan, P. Cunliffe, A. Heydari, J. Koomey, M.D.Levine, J.E. McMahon, T. Springer, S. Stoft, I. Turiel, and D. Wood

LBL is responsible for an integrated analysis of the impacts of federal appliance efficiency standards. The research involves a detailed assessment of the impacts on consumers, manufacturers, electric utilities, and on the nation as a whole. Our analysis is carried out in four major tasks: (1) an Engineering Analysis to quantify the efficiency improvements of various design options and their costs; (2) a Consumer Analysis to project the energy use, shipments, purchase price, and operating costs of more efficient products; (3) a Manufacturer Analysis to determine impacts on the appliance manufacturing industry; and (4) an Impact Analysis to examine the impacts of standards on various groups. The latter includes changes in consumer life-cycle costs, competition within the manufacturing industry, fuel savings and reduced need for new generating capacity by electric utilities, an assessment of environmental impacts, energy savings by fuel type, and the net present benefit of standards to the nation. Figure 1 shows how the parts of the analysis are interrelated, and how they fulfill the legislative requirements for evaluating the impacts of standards.

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings Energy Research and Development, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

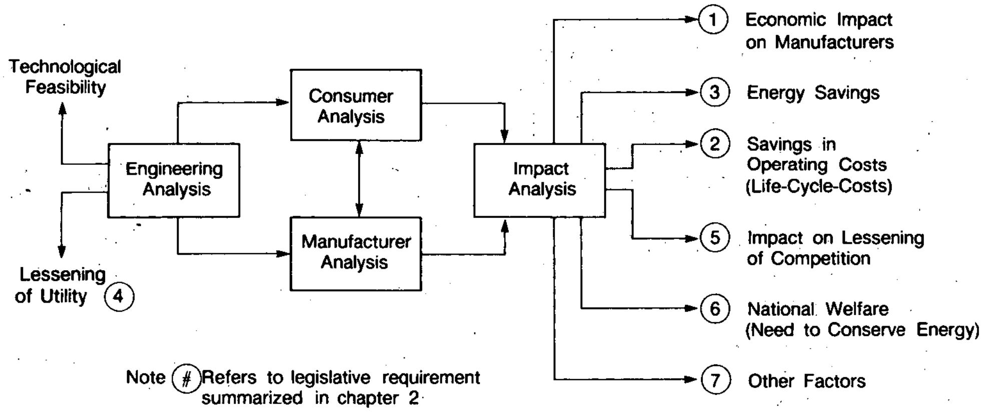

Figure 1. Satisfaction of legislative requirements through the analysis process. (XBL 856-8918)

ACCOMPLISHMENTS DURING FY 1987

In March 1987, Congress passed and the President signed the National Appliance Energy Conservation Act (NAECA)[1] establishing efficiency standards for household appliances. The legislation provided for periodic update of the standards by the Department of Energy. The first update will be for refrigerators and freezers, which DOE plans to complete by the end of 1988. DOE is also required to set standards for small gas furnaces (<45,000 Btu/h input) and to consider setting standards on television sets. Work during FY 1987 focused on analyzing the impacts of the NAECA and on supporting DOE's rulemaking on refrigerators, freezers, small gas furnaces and television sets.

Analysis of the NAECA Standards

NAECA prescribes energy performance standards for major energy-using household appliances and space conditioning equipment. Several improvements were made to existing data and models for our analysis of these standards. We incorporated a new method using discount rates and lag factors in the forecasting model to predict appliance efficiencies in the absence of standards. The manufacturer impact model was used to estimate the effects of standards on heat pump and central air conditioner manufacturers. Conclusions from this analysis were applied to other parts of the industry. We also developed methods for evaluating impacts on electric utilities and the environment.

Our analysis shows that in general the impacts of the legislation on consumers, appliance manufacturers, electric utilities and the nation as a whole are beneficial. The standards are estimated to reduce residential energy consumption by 16 Quadrillion Btu (Quads) during the period 1990 to 2015. Figure 2 shows that the annual savings grow to 0.95 Quads by 2015. More than 90 percent of the reduction is in electricity use. The largest energy savings are achieved for refrigerators, followed by water heaters and central air conditioners. These savings are shown in Figure 3, along with the net present benefits of the standards. Because most of the electricity saved at the margin is generated from gas and oil, about 60 percent of the energy saved is likely to be in the form of gas and oil and the remainder in the form of coal, nuclear, and hydroelectricity. The standards are estimated to eliminate the need for 16,000 MW of new generating capacity by 2015, mostly in peaking units.

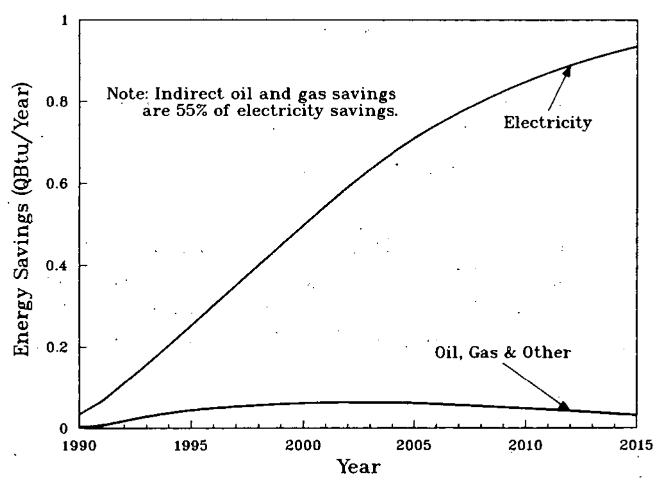

Figure 2. Annual energy savings of NAECA standards. (XCG 8711-11474)

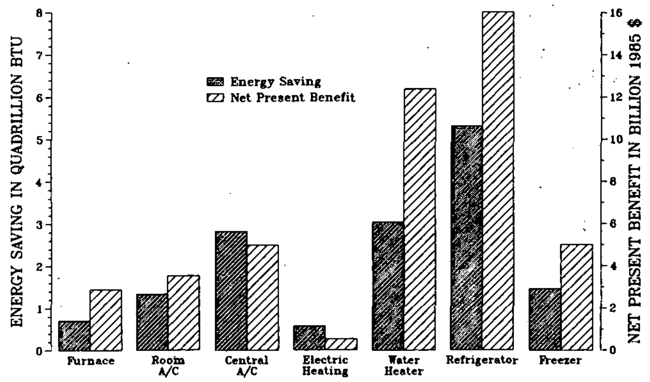

Figure 3. Energy saving and net present benefit of NAECA standards by product. (XCG 8711-11475)

The impact of the standards on consumers appear to be favorable for nearly all classes of products based on a decrease in life-cycle cost ranging up to several hundred dollars per new appliance. The net social benefit of the standards (evaluated at a social discount rate of five percent) is about $35 billion using average energy prices and $48 billion using one set of estimates of marginal electricity costs. The impacts on the appliance manufacturing industries as a whole are found to be negligible. However, the small high-cost segments of some industries (never more than 10 percent of an industry) may suffer a loss in profit of up to one third. The environmental impacts of the legislation appear to be favorable, particularly in reductions of emissions from electricity generation. However, the standards could increase chlorofluorocarbon production by about one percent, possibly leading to adverse health effects due to increased exposure to ultraviolet radiation. We have documented our analysis in a draft LBL report,[2] which will be submitted for publication.

Refrigerators, Freezers, Small Gas Furnaces, and Television Sets

The Engineering Analysis collected and compiled data on the efficiency and cost of designs options for the products being considered for standards. Much of the data collection was performed by subcontractors and consultants who are familiar with the industry. LBL staff visited several appliance manufacturing plants to obtain data and discuss energy-efficient designs. We adapted the ADL Refrigerator/Freezer Model to analyze the energy performance of refrigerators and freezers incorporating these designs. Input data for the model were obtained from appliance manufacturers and suppliers of components. Data collection for other products has been completed by the subcontractors, and their final report will be ready in the first quarter of FY 1988.

A major part of the effort during the year was in modifying and updating the LBL Residential Energy Model (REM) used to forecast appliance efficiency, shipments, prices, and energy use. A new method for forecasting completions by house type and state was incorporated in the model. The model now can calculate the number of households that are potential purchasers of small gas furnaces. New cost-efficiency data from the Engineering Analysis were added, and the algorithm for forecasting efficiency changes with and without standards was improved. We derived market share elasticities for small gas furnaces. More details of the changes made to the LBL-REM may be found in the accompanying article by McMahon and Chan.

The Manufacturer Analysis concentrated on rewriting the Typical Year Model (LBL-TYM) for use in the current analysis. From industry financial and economic data, the model estimates the market power of a typical firm, and from this estimate and the assumption that firms maximize profits, it computes a markup. The markup then determines the extent to which the firm can pass through its costs to consumers. The spreadsheet model is convenient for displaying and changing financial parameters, and it presents a balance sheet for the firm in an easily understood format. It also provides a Monte Carlo facility which makes a large number of runs with inputs chosen randomly to reflect their uncertainty. During these runs the output is automatically saved and analyzed; this reveals the uncertainty in the model predictions. We met with a panel of experts on the refrigerator and freezer industry and the gas furnaces industry to present the model and obtain data on the financial parameters.

The Impact Analysis methodology will change little from that used for the NAECA standards. Some issues in calculating marginal electricity costs and using them in calculating net social benefits have been resolved with DOE. We are fully documenting our analysis in a Technical Support Document (TSD) that will be published by DOE in conjunction with their Notice of Proposed Rulemaking (NOPR) regarding the first update to standards.

PLANNED ACTIVITIES FOR FY 1988

The analysis of standards on refrigerators, freezers, small gas furnaces and television sets will be completed in the first quarter of FY 1988. A draft of the Technical Support Document will be submitted to DOE at the same time. DOE will publish the

TSD and the NOPR in the spring of 1988. Additional analysis of these products may be required during FY 1988 depending on the comments received on the two documents. DOE is expected to issue the final rule in January 1989.

We will also analyze the impacts of possible amendments to the standards on clothes washers, clothes dryers, and dishwashers during FY 1988. Engineering data on design options have already been collected. We anticipate little change in the analytic methodology. Toward the end of FY 1988, we will begin examining new data sources and possible model improvements for the future analyses mandated by NAECA.

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The LBL Residential Energy Model*

J.E. McMahon and P. Chan

Detailed forecasting models have been used since the mid-1970's to assess potential impacts on consumers of proposed federal energy conservation policies. The first such model intended as a policy analysis tool for the residential sector was the Oak Ridge National Laboratory (ORNL) Engineering-Economic Model of Residential Energy Use.[1] A version of the ORNL Model was moved to LBL and adapted for an analysis of Consumer Product Efficiency Standards in 1979 (see Fig. 1). Public comments during the rulemaking process and new analyses at LBL have suggested many changes in the methodology for simulating residential energy consumption. Some of those changes have been implemented and described in U.S. Department of Energy publications,[2,3] conference proceedings, LBL reports, and previous LBL annual reports describing the analysis of mandatory appliance efficiency standards.

The accumulation of major changes to the method, including a new analysis of fuel and technology choice for space heating and cooling in new buildings, makes the LBL version of the ORNL model unique. The increasing availability of data and the need to analyze issues raised by interested parties in the rulemaking process have driven the transition from the ORNL to the LBL Model. The major methodological differences include: representation of recent equipment efficiency trends, forecasting of future appliance efficiencies based on an analysis of market behavior during the last decade; calculation of appliance replacements based on historical purchases and retirements; the data base for equipment costs and efficiencies; and treatment of competitive space conditioning systems (including heat pumps and small-capacity gas furnaces). In addition, the LBL Model has been integrated with

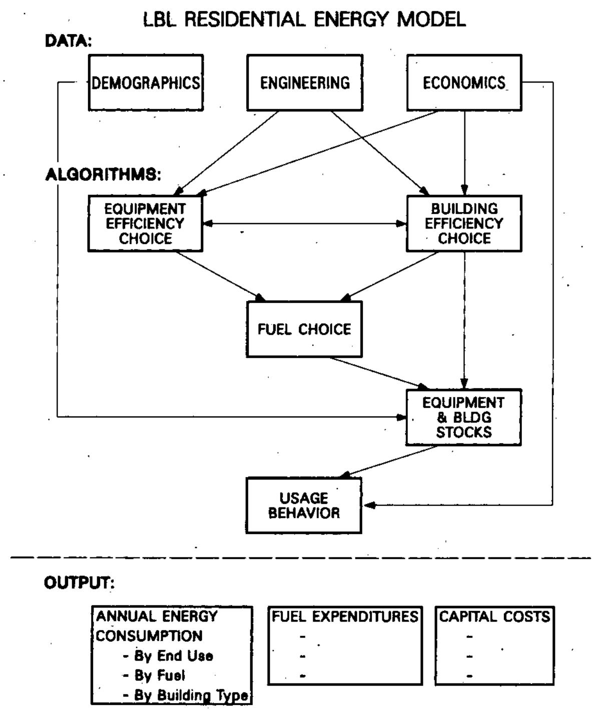

Figure 1. Logic diagram showing major components of LBL Residential Energy Model. (XCG 8412-13510)

*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings Energy Research and Development, Building Equipment Division of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

other tools for the study of individual electric utilities. A recent description of the current model, including changes to the original ORNL Model, is available.[4]

ACCOMPLISHMENTS DURING FY 1987

The space conditioning market share elasticities have been replaced.[5] The new method draws on the household-specific data from Annual Housing Surveys (1975–79), the same data used by REEPS (the EPRI-sponsored residential end-use demand model). Furthermore, the new method gives elasticities that vary with the size of the perturbation in the independent variables; links room and central heating choice; and links central air conditioning choice to space heating choice. In addition, those housing units having small heatloads can be treated as a separate market segment when analyzing market choice of heating and cooling fuel and technology.

The *accuracy of previous forecasts* of equipment efficiency and shipments has been assessed.[6] For many products, the changes in method and data have improved the accuracy. Those areas with the largest remaining forecasting errors have been identified.

A version of the LBL Residential Energy Model has been developed for use on personal computers. This greatly increases the transportability of the model and makes it more accessible to a number of users.

Regional disaggregation of the model has been completed. The input data for ten Federal Regions has been gathered. All demographic inputs have been benchmarked to the 1980 Census.

Equipment prices have been reestimated to include different markups by market segment. This provides a better characterization of the real-world pricing structure, including the importance of the builder market.

The impacts of the National Appliance Energy Conservation Act have been analyzed, and are reported in an accompanying article.

PLANNED ACTIVITIES FOR FY 1988

New analyses will be performed of national consumer, energy, and market impacts of possible federal appliance efficiency standard levels. Appliances under consideration include: refrigerators, refrigerator-freezers, and freezers; small gas furnaces; televisions; clotheswashers; dishwashers; and clothes-dryers.

Updated engineering and pricing information regarding alternative equipment designs will be incorporated into the data base as available.

The interaction between internal loads (e.g., waste heat from refrigerators) and space conditioning energy use will be incorporated in the LBL Residential Energy Model.

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Analyses of Energy Intensities and Load Shapes*

H. Ruderman, I. Turiel, J.H. Eto, and K.E. Heinemeier

The California Energy Commission (CEC) every two years prepares forecasts of electricity demand and peak loads in the state. Over the past ten years the CEC staff have developed a series of models and methods used to prepare these forecasts.[1] The CEC now wants to improve the data used in their forecasting models for the *1989 Electricity Report*. They have contracted with LBL through the U.C. University-Wide Energy Research Group to provide data on (1) commercial sector end use intensities and (2) residential end-use load shapes for use in their models. The two subprojects started during the summer of 1987 and will continue for one year.

End-use energy utilization intensities (EUIs) are needed for electricity demand forecasting and for conservation policy analysis. Various methods have been used to estimate commercial sector EUIs for the California utilities. Because end-use metering is very expensive, most EUI studies rely on some combination of survey data and statistical and engineering analyses. The resultant wide variation in EUI estimates for some end uses and building types tends to reduce confidence in the results. The first phase of this project will provide a detailed comparison of the definitions and analytical methods used to generate commercial EUIs, recommendations for resolving differences, and a list of topics requiring additional data collection or research. Where data are available, EUI estimates will be compared to actual metered data, and needs for further end-use monitoring identified. The second phase will consist of a pilot project with Southern California Edison (SCE), for which EUIs will be calculated using on-site survey data, 15-minute interval whole-building load research data, and the DOE-2 Building Simulation Model. Initially, the survey data will be analyzed to develop descriptions of representative building prototypes. DOE-2 will be used to estimate space conditioning energy used based on these descriptions. All estimates of EUIs will be reconciled to the measured load shape and billing data.

The California Energy Commission has developed and used peak load models to forecast electric load growth in the residential and commercial sectors. The models calculate hourly loads on peak days based on end-use specific daily load shapes, for both weather-sensitive and non-weather-sensitive end uses. The purpose of this part of the project is to analyze available metered data on end-use load shapes to refine the current estimates used in the CEC peak demand models. Initial emphasis will be placed on residential loads because of data availability; future work will concentrate on non-residential end uses. The 17 end-use load shapes currently in the CEC Residential Peak Load Model[1] will be compared to monitored data collected by California utilities and out-of-state sources. Where necessary, the existing load shapes will be modified or replaced by those derived from the more recent data. The project will also assist the Commission staff in laying the groundwork for transforming the peak demand models into models that forecast hourly loads throughout the year, based on LBL's experience in constructing and validating its Residential Hourly and Peak Load Model.[2]

ACCOMPLISHMENTS DURING FY 1987

Commercial Sector End-Use Energy Intensities

During the early part of this project, we gathered data and reports describing previous EUI studies carried out for California utilities. We received all of the reports and started analyzing the survey data tapes that were used in these analyses. We also obtained and began validating a more detailed on-site survey of data for 375 SCE commercial buildings.

Several meetings have been convened with SCE and CEC to coordinate this project with one that will develop end-use load shapes for the commercial sector. A detailed workplan is being developed to combine these two projects so that they use common data and arrive at one set of EUIs and load shapes.

Residential End-Use Load Shapes

During the first few months of the project, we focused on identifying sources of residential load shape data. Contacts were made with investigators doing load shape research in the major California utilities, out-of-state utilities, EPRI, and other research organizations. We began collecting and reviewing published reports containing residential end-use data. We obtained a copy of the CEC Residential Peak Load Model and reviewed the algorithms and input data requirements.

*This work was supported by the California Energy Commission through the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

We convened a workshop on residential load shapes in September which was attended by 35 people representing the CEC, all five major California electric utilities, and selected consulting firms. Talks were given on how load shape data are used in the CEC and LBL models for forecasting and impact analysis. Several utilities described their residential monitoring programs. There were two talks on using statistical procedures to disaggregate whole house loads into end uses. Based on the workshop and our other contacts, we are preparing a report to CEC summarizing available end-use data.

PLANNED ACTIVITIES FOR FY 1988

Commercial Sector End-Use Energy Intensities

During the coming year, we plan to achieve two major objectives:

(1) Review all California EUI studies and attempt to reconcile differences in estimated EUIs by the use of common definitions of business types, floor area, etc.

(2) Develop estimated EUIs for the SCE commercial sector using on-site survey data and load research data from SCE.

When the first objective is accomplished, we will recommend a common set of definitions to be used in future EUI studies. The data developed in reaching the second objective will be utilized by both CEC and SCE in future electricity demand forecasts.

Residential End-Use Load Shapes

Activities for the remainder of the project will center on the collection and analysis of data on the weather-sensitive and non-sensitive residential end-use load data. We are planning to obtain the data from utilities in the form of hourly loads by end use for each house in the sample. We will ask for data that is cleaned and verified. Auxiliary information, such as hourly weather data and household characteristics, will also be collected. The analysis will aggregate the data over households and utilities where appropriate and over time periods to get daily load shapes for typical days. For the weather-sensitive end uses, we will construct the time-temperature matrices required by the CEC Peak Load Model. The data from different sources will be compared and combined to arrive at the final load profiles.

The results of our analysis will be presented to the CEC in the form of machine-readable files. We will also submit three interim reports on data sources, non-weather-sensitive load shapes, and weather-sensitive load shapes, as well as a final report documenting the entire project. The final report will also include recommendations for improving the CEC model.

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Least-Cost Planning for the Pacific Gas and Electric Company*

E. Kahn, C. Pignone, and G. A. Comnes

The goal of this project is to develop methods for evaluating demand-side programs explicitly within the context of the traditional electric utility resource planning process, an approach that is generally known nowadays as least-cost planning (LCP). The project is designed as a study of the Pacific Gas and Electric Company (PG&E) and is partially funded by the company. The analysis is based on the use of an Electric Power Research Institute integrated utility planning model, the Load Management Strategy Testing Model (LMSTM), for production costing and forecasting, the DOE-2.1 building energy simulation model, for demand-side effect estimation, the LBL Residential Energy Model (LBL-REM) for electrical load forecasts, and locally written software for program evaluation and cost benefit analysis.

Following the completion of the calibration of LMSTM to the detailed production costing models used at PG&E, a LCP exercise based on large-scale implementation of two demand-side programs was carried out through several time horizons. The first test case is a somewhat hypothetical one that estimates the consequences of widespread adoption of the emerging thermal energy storage (TES) technology in commercial buildings. The second program (RAC) draws on past LBL work and involves the implementation of an efficiency standard for new residential room air conditioners, central air conditioners, and heat pumps installed in the PG&E territory.

ACCOMPLISHMENTS DURING FY 1987

The two test cases were completed and they show diverse results and illuminate different methodological issues. The analysis of TES begins with an elementary estimation of market penetration, which in the absence of better information is the only approach possible. All results, therefore, rest on assumptions of customer acceptance, as is usually the case in demand-side analysis. The RAC case couples the sophisticated capabilities of LBL-REM to the policy screening capability of LMSTM. Using LBL-REM gives greater plausibility to estimates of energy and load effects but only at the expense of tricky consistency problems.

Interesting results were obtained for the two cases studied. TES is a winner for customers and society and the results suggest incentives are not needed to accelerate adoption of this emerging technology. The heavy demand charge in the current PG&E large customer rate schedule itself provides a sufficiently strong load shifting incentive.

The RAC case is driven by the high customer costs of efficient appliances and comes out a net loser from the societal and customer perspectives. But it is a winner to PG&E because the costs are borne by customers through appliance purchases whereas the costs of efficient appliances are borne by customers. At a time of capacity expansion, higher oil and gas prices, and, therefore, higher prices for purchase power, this program could be justified, but these conditions are not likely to exist for PG&E until the later years of this century, so timing of the program becomes a critical factor.

The LCP principle is simple, but implementing it is remarkably complex. The experience of this study suggests that comprehensive planning with today's tools and methods is a task beyond the reach of most utility planning departments. Using mainframe models requires the dedication of a significant staff and achieving LCP literacy is a lengthy process. Carrying out analyses requires constant compromises and approximations, that, in some cases, can drive results. Certainly, the chances of LCP being reduced to a routine process are slender and the search for the ultimate LCP model appears futile. Further, the concept of LCP rests on assumptions about the industry as a whole that are not likely to hold over time. Notably, the steady infiltration of competition into the industry is eroding the assumption of a vertically integrated monopolistic utility.

PLANNED ACTIVITIES FOR FY 1988

This project, as outlined, was essentially complete at the end of FY 1987. The remaining work involves documenting the work done and reporting to PG&E. The models and methods are now in place to carry out a full LCP exercise for any utility service territory for which adequate data and company cooperation is forthcoming.

*This work was supported by the Pacific Gas and Electric Company and the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings Energy Research and Development, Building Systems Division of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

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INTERNATIONAL ENERGY STUDIES

Overview

The International Energy Studies (IES) Group has been involved in research on energy demand since 1979. The work of the IES Group focuses on two areas: (1) energy demand in the industrialized countries; and (2) energy demand in the developing countries. The research on industrialized countries primarily addresses energy use in buildings, though work on the power generation sector is also underway. The research on the developing countries looks at demand in all sectors and also examines issues of energy supply.

The guiding philosophy of the Group is that understanding the evolution of energy demand requires careful examination of the structural forces that shape demand for energy, as well as the economic parameters. We seek to relate changes in energy demand to changes in the physical setting for energy use, looking in particular at changes in the efficiency of each energy end-use. We use comparisons of different countries to establish a context for understanding the observed patterns and for assessing trends in energy consumption.

The IES Group, which consists of scientists of different disciplinary backgrounds, is international in composition and multi-lingual. Visiting researchers from many different countries have been and are active participants in IES projects. The Group's work is a major activity in the Energy Analysis Program at LBL.

ENERGY DEMAND IN DEVELOPING COUNTRIES

Since its beginnings in this area with a study of energy use and conservation in Kenya's modern economy, the IES Group has expanded its research into energy demand in developing countries in four continents. In work funded by the U.S. Department of Energy and by several major energy companies, we have examined trends in energy use and structural change in 20 major energy-consuming developing countries in Asia, Africa, Latin America, and the Middle East, which together account for about 80% of developing countries' energy consumption.

The goal of our work is to understand how energy demand has changed in response to (often) rapid economic growth and two oil shocks. We examine how changes in economic structure, energy-use efficiency, and fuel mix will change demands in the future. A particular focus is the extent to which the growing demand for oil in the oil-exporting developing countries would reduce the amount of oil exported. The reduced exports combined with the declining production of oil in the U.S. would increase reliance on oil from the Middle East.

In addition to research on energy demand, the Group has also been involved in a number of evaluations of energy supply options for particular developing countries. A new area of work is assisting the U.S. Agency for International Development in developing effective programs to encourage expanded deployment of economically viable renewable energy options, and to better manage the use of electricity in developing countries.

ENERGY DEMAND IN THE INDUSTRIALIZED COUNTRIES

The Group's research on energy demand in the industrialized countries provides consistent information on energy demand in many of the world's largest energy-consuming countries as well as a context to better understand changes in U.S. energy consumption. Beginning with a comparison between the U.S. and Sweden, the research has evolved to include 9 European countries as well as Japan, the U.S., and Canada.

We developed the first and only data base of residential energy use in industrialized countries, now used as a reference by the International Energy Agency, energy authorities in many countries, and major oil companies. We have published several overviews of industrialized countries' residential energy use, and separate studies of individual countries focusing on the reversibility of oil use and structural change in electricity demand.

Additionally, we have expanded the work to include the service and power generation sectors. Current work on the residential sector includes analysis of the evolution of gas demand in Europe, development of scenarios of future energy demand, and investigation into the impacts of lifestyle changes on future household energy use.

The Causes of Rising Transportation Oil Demand in the LDCs*

S. Meyers

LBL has been engaged in the analysis of energy use in the Less Developed Countries (LDCs) for several years. The LDCs have been the most important source of increase in world oil use since 1973, and the largest source of growth in LDC oil use has been the transportation sector. To better understand the dynamics of growth in this sector, it is necessary to look in detail at the structure of transportation in these major LDCs.

ACCOMPLISHMENTS DURING FY 1987

LBL gathered data on oil use, motor vehicles, and air travel for a number of LDCs.[1] For 15 major LDCs, combined oil use in transportation increased from 57 to 133 million tonnes oil equivalent (TOE) between 1970 and 1985. Transportation accounted for half of their total increase in oil use, and its share of total oil use rose from 46% to 49%. The growth in transportation occurred despite increase in the price of transportation fuels and substantial substitution (nearly 6 million TOE) of ethanol for gasoline in Brazil. For all LDCs (except China), the increase in gasoline use between 1976 and 1986 accounted for nearly all of the growth in total Non-Communist World gasoline consumption since 1976, and the LDC share grew from 12% to 17%.

Between 1970 and 1985, absolute growth in gasoline use was greatest in Mexico, Saudi Arabia, Venezuela, and Nigeria, all major oil producers with low domestic gasoline prices. Very high growth rates were recorded in Saudi Arabia (18% per year average), Nigeria (17%), and Taiwan (14%). For diesel fuel, the largest absolute growth was in Brazil, Mexico, and India. The fastest growth rates were in Taiwan (16%) and Nigeria (15%), but growth averaged 7% per year or higher for most of the 14 countries. For jet fuel, absolute growth was greatest in Saudi Arabia, Brazil, and Mexico, while the fastest growth rates were in Saudi Arabia, Nigeria, and South Korea.

Growth in Motor Vehicle Ownership

The main cause of the growth in oil demand has been increase in the number of motor vehicles in operation. The largest sources of growth in passenger cars have been Brazil, Mexico, Argentina, and Saudi Arabia. Brazil, Mexico, and Argentina have by far the most cars among LDCs. Ownership and growth in trucks is more evenly distributed among countries.

Across countries, car ownership increases steeply as gross domestic product (GDP) per capita rises. The increase is less strong for commercial vehicles. Car ownership relative to GDP per capita is high in Latin American countries with major auto manufacturing.

Since 1970, motor vehicle ownership has risen considerably faster than GDP in many LDCs, paralleling the experience of the low-income developed countries in the 1960. In Taiwan, for example, growth in passenger cars in the 1975–85 period was 3.3 times faster than growth in GDP, and growth in commercial vehicles was 2.2 times faster. In Japan between 1960 and 1970, similar values were 3.2 and 2.4. Taiwan's per capita GDP in 1975 was \$1700–\$1800, while Japan's in 1960 was about \$1700. In both cases, rising middle class income and the expansion of the motor vehicle production industry acted in a mutually supportive manner to bring rapid growth in motor vehicles.

Vehicle sales, and especially passenger car sales, are very sensitive to changes in GDP. In the major oil-exporting countries, sales rose rapidly after the oil price increases, but have fallen off sharply in 1986. The oil effect was less strong in Mexico and Venezuela, which already had relatively mature motor vehicle markets, than in Saudi Arabia, Nigeria, and Iran, where motor vehicle ownership was low prior to 1973. Vehicle sales also rose strongly in the rapidly industrializing countries. In Brazil, Taiwan, and South Korea, maturing of the motor vehicle production industry contributed to growth in demand caused by rising income. Sales in Brazil took off at a much lower level of GDP per capita than in Taiwan and Korea, where government policies have discouraged passenger car ownership (especially in Korea). In both cases, however (more so in Taiwan), sales of new motor vehicles have risen sharply in the 1980s. In the mostly-agricultural countries with large populations, motor vehicle ownership has risen modestly, but is still constrained by low income and government policies. In most of

*This work was supported by the Office of Policy, Planning and Analysis, the Assistant Secretary for International Affairs and Energy Emergencies, Office of International Energy Analysis, the Assistant Secretary for Fossil Energy, Office of Planning and Environment, and the Assistant Secretary for Conservation and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098; and by grants from British Petroleum Company, Chevron, Conoco Inc., Exxon, Shell Oil Co., Shell International Petroleum Co., Statoil and AGIP.

these countries, the market for commercial vehicles (particularly light trucks) has developed faster than for passenger cars.

Although rising income is the most important factor, growth in vehicle sales have been affected by other factors. Prices are relatively high in many countries due to taxation or lack of competition. Government policy affects vehicle supply and price by limiting domestic production or by placing restrictions or disincentives (high import duties and/or taxes) on imported and domestic cars. Domestic assemblers are often protected from external competition by import restrictions, but prices are high due to high taxation of imported components, taxes on completed vehicles, and in some cases, low production efficiency. In many countries, the domestic market is not large enough to support an efficient assembly industry, and too many assemblers competing for pieces of a small pie has led to inefficient use of capacity. Once the market grows past a certain point, as occurred in Latin America in the 1960s and in Taiwan in the late 1970s, economies of scale contribute to lower prices, which in turn helps the market grow.

The poor state of the road system in most LDCs and urban traffic congestion may have had some inhibiting effect on car purchase, but these factors probably affect usage much more than ownership. The same applies to fuel prices, though in countries where gasoline prices have historically been very high or very low they have probably had some effect on the passenger car market.

Growth in LDC Air Transportation

Between 1970 and 1985 the number of total air passenger-trips to and from and within LDCs increased 250%. Domestic travel within LDCs registered the highest growth, averaging 9.2% per year, while international travel between LDCs and international travel between LDCs and non-LDCs grew at 7.7% and 8.2% per year respectively.

Total passenger-km on LDC airlines in 1984 was about 10 times higher than in 1965. Three-fourths of the absolute growth took place after 1974. The fastest and most growth in air travel has occurred in Asia. There was steady growth in Latin America until the 1980s, when travel flattened out. There was no flattening out in Asia for either international or domestic travel. In Latin America, increase in international travel flattened out in the 1980s, but domestic travel was less affected. The highest absolute growth in passengers between 1976 and 1984 was in Saudi Arabia and Mexico, followed by India and Brazil. Nigeria, Saudi Arabia, Egypt, South Korea, Algeria, and Thailand all had growth in excess of 10% a year.

Across countries, air travel increases with GDP per capita, but some countries with similar GDP per capita have very different levels of per capita air travel. This illustrates the importance of country-specific factors in shaping demand for air travel. The correlation is stronger for domestic travel than for international. The ratio of growth between air travel and GDP varied considerably in the 1970-84 period, but was over two in most countries.

Factors other than income growth affecting LDC demand for air travel include the price and availability of flights and trip ground costs. For domestic air travel, physical and economic geography (diffusion of the industrial economy among cities) are important, as is the availability and attractiveness of alternative transport modes. For international air travel, influences include geographic location, the extent of international economic links, exchange rates and currency restrictions, cultural ties with nearby countries, and the number of citizens living abroad.

PLANNED ACTIVITIES FOR FY 1988

We will continue to investigate changes in transportation in major LDCs as part of the research activities of the International Energy Studies Group.

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Alternative Transportation Fuels: The International Experience*

J.A. Sathaye and B. Atkinson

Worldwide interest in alternative transportation fuels has risen considerably since the two oil price shocks in 1973 and 1979. The U.S. Department of Energy is studying potential alternative fuel programs for the U.S. transportation market. As part of this effort, LBL conducted an analysis of the international experience with alternative transport fuels and the implications for future U.S. activities.

ACCOMPLISHMENTS DURING FY 1987

LBL conducted an extensive review of existing worldwide alternative transport fuel programs during 1987. We concentrated on those programs which had achieved commercial development, or at least a significant pilot project stage. Detailed studies were done for Canada, New Zealand and Brazil.

Canada is of particular interest to the U.S. because of the similarity in the two countries between the transportation situation and the interdependence of their automobile industries. Canada began its programs in 1980, concentrating on natural gas as a source of liquified petroleum gas (LPG) and compressed natural gas (CNG). Programs focused first on LPG, achieving almost 2% of gasoline market penetration, and then on CNG, which achieved a smaller penetration. Government support played a key role in consumer acceptance of vehicle conversion and in industry construction of fueling stations.

New Zealand's programs demonstrate the benefits and costs of an ambitious energy independence program. New Zealand began its programs in 1979, aiming for greater energy self-sufficiency using its natural gas resources. A large investment was made in a synthetic gasoline plant, opened in 1985. This fuel now substitutes for 35% of the gasoline market. CNG substitutes for 10% of this market and LPG for another 3%. As in Canada, government incentives proved crucial to the startup and continuation of the programs. In the case of synthetic gasoline, investments were made based on an expected world oil price much higher than the prevailing price in 1987.

Brazil's alternative fuels programs offer the example of the most extensive effort made to displace oil in the transport sector. This country also based its commitment to a massive ethanol program on projected rising world oil prices. However, Brazil had the combined goal of reducing oil imports and reviving their sugar industry by using sugar cane as the primary alcohol feedstock. Unlike New Zealand, Brazil had a large domestic automobile industry, allowing a switch to alcohol vehicle production. Dedicated ethanol vehicles now comprise 90% of new car sales. The economic viability of Brazil's alcohol program has been debated since its inception, but the technical success and market penetration offer another example of the importance of government's role as well as the cooperation of key players.

In Europe, interest in methanol blends has risen considerably in the last decade. Part of the attention to alternative fuels derives from plans to phase out leaded gasoline by 1989. West Germany is the most advanced; a 3% methanol blend comprises nearly 80% of its gasoline market. There is some push for ethanol production from the countries with large agricultural surpluses. CNG is being used in Scandanavian countries with natural gas resources.

A number of developing countries possess large natural gas deposits and are implementing CNG programs. Pakistan, Thailand, Bangladesh, Argentina and Colombia are in the first phase of CNG use, and several others have pilot programs.

LPG has been used as a gasoline substitute in Europe since World War II, now meeting 11% of road transport demand in the Netherlands and almost 3% in Italy. LPG has penetrated certain markets in Japan, Korea, Thailand, Mexico and other countries, but its use in transport is not expected to increase because of its limited supply in the refinery petroleum product mix and competition from other uses.

Ethanol is used in transport in the Philippines and several African countries (Zimbabwe, Malawi, Kenya) for much the same reason as in Brazil: to bolster their sugar industries hit by low world prices. Both China and South Africa make methanol from coal.

The extent of further commercialization of alternative fuels is unclear due to the uncertainty of future oil prices. In countries such as New Zealand, government policies have shifted to encouraging the

*This work was supported by the Office of Policy, Planning and Analysis, the Assistant Secretary for International Affairs and Energy Emergencies, Office of International Energy Analysis, the Assistant Secretary for Fossil Energy, Office of Planning and Environment and the Assistant Secretary for Conservation and Renewable Energy, Office of Photovoltaics Technology of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098; and in part by grants from British Petroleum Company, Chevron, Conoco Inc., Exxon, Shell Oil Co., Shell International Petroleum Co., Statoil and AGIP.

private sector to take over the programs. In others, such as Argentina, lending agency support is critical. Brazil is considering ending subsidies for its alcohol program, and scaling down its new CNG/diesel substitution program to segmented urban markets.

Environmental and social impacts of alternative fuel programs were not a focus of our study. However, urban air quality has been an important motivation for several alternative fuel programs.

Lessons for the U.S. include the importance of government commitment and promotion, use of incentives such as guaranteed alternative fuel prices, grants and loans for conversion and fuel station construction, and fuel producer and distributor incentives. Information to boost public confidence in unfamiliar technologies is also essential. Involvement of state governments, automobile manufacturers, and energy companies in cooperation with the federal government is important in the initial stages as well as for the long-term economic success of alternative fuels. U.S. decisions on alternative fuel programs will influence those of other countries, particularly Canada, but also Europe and Japan, as well as the developing countries. Automobile manufacturers and conversion technology companies will be affected by the direction of U.S. programs.

PLANNED ACTIVITIES FOR FY 1988

A final report will be prepared, incorporating comments from reviewers from various countries. We will look more carefully at developments and prospects in Europe. Issues in alternative fuels programs include diesel substitution and the changing petroleum product mix resulting from reduced gasoline demand.

Renewable Energy Technologies in the Developing Countries: A Reassessment*

J. Sathaye and S. Meyers

Renewable energy projects in the developing countries have been supported by international lending and development agencies, by foreign assistance agencies in the industrialized countries, and by the developing countries themselves. The U.S. Agency for International Development (AID) has been involved in, or is currently supporting, over 200 programs which contain significant renewable energy components. Although there have been successful projects, the results have generally been much less promising than anticipated. The AID Office of Energy has been conducting a critical reassessment of AID's experience with renewable energy technologies. The reassessment is intended to clarify lessons learned and to help in setting future directions. LBL has assisted in this effort.

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ACCOMPLISHMENTS DURING FY 1987

In collaboration with other researchers, LBL reviewed many evaluations of renewable energy technology applications in the developing countries. While many projects have not proven successful over time, a number of technologies have been demonstrated to be reliable. Among these are small-scale applications of photovoltaic systems for communications and health clinics, small hydro for mechanical and electrical power, wind water pumping, some industrial-scale biomass fuel technologies, and improved charcoal stoves. Biogas, gasification, solar drying, and dendrothermal electricity have been difficult to apply successfully.

A lack of emphasis on involvement of the private sector for implementation and on commercialization was found to be a problem in many cases. Technologies that were not commercially proven were often problematic. A high degree of user involvement in project design and implementation was found to be an important ingredient for success. Participation in all phases of the project helps to ensure motivation and a transfer of technology. Many projects failed because they were not matched appropriately to local needs and social customs.

The availability and nature of local renewable energy resources, local human resources, and institutional capabilities are important to factor into design. Lack of attention to requirements for maintenance, spare parts, and local skills development caused problems in many cases. Another difficulty for dissemination of renewables is widespread subsidization of electricity and diesel fuel.

In addition to assisting evaluation of renewable energy experience, LBL helped to organize a workshop that brought together individuals from the U.S. renewable energy industry and from AID-assisted countries, as well as AID staff and consultants.

PLANNED ACTIVITIES FOR FY 1988

LBL is assisting in the completion of a report on new directions for AID's renewable energy activities. This includes providing updated information on technology status and costs and evaluation of financing and environmental issues.

Electricity Utilities in the OECD: Energy Secure?*

D. Hawk and L. Schipper

During the 1970's, electric supply industries worldwide were confronted with a rapid succession of changes including oil supply disruptions and new government requirements to mitigate against environmental impact of energy use. The economic, technological, and political conditions under which electric utilities operated were in transition. Coming out of the 1970's, many utilities recognized the need to establish mechanisms (if not already in place) to anticipate change and respond to it in a controlled, constructive way, thereby maintaining the stability and/or security of electric supply.

ACCOMPLISHMENTS DURING FY 1987

In this work we investigate the ability of the electricity supply systems in five European countries — France, Germany, Italy, Sweden and the United Kingdom — to respond to changes in the accessibility of energy inputs or the operability of generation facilities.[1] Accessibility and operability could be determined by economic, political or technical conditions. We briefly describe what each system looked like in 1972–1973 and their immediate (short term) responses to the oil shock of 1973. We then explain how the systems have evolved since and in response to the shock, by default or through deliberate utility planning. In the short term how resilient would these systems be to a shock today? (Short term refers to the level of remedies that can be considered. In this case, additions to capacity cannot be considered).

What kind of responses are we looking for? Potential resilience could be indicated by three characteristics of the supply system. First, is the generation capacity in use based on a diverse mix of fuels, and if so, what are the load factors? Could the load factor of certain plants be increased in order to compensate for the loss in production due to the closing of other plants that use a fuel which makes them no longer reasonable to operate? The second characteristic is the share of the generation capacity which has dual or multiple fuel capabilities. Thus, if an event or situation precludes the continued reliance on one fuel, these plants can switch to generating with the second fuel. The third characteristic is the extent to which the country can import electric power from surrounding countries. Power imports are seen as supply options comparable to deciding which plants to generate from. However, this option is dependent on whether the supplying country can transfer enough power at the right time. In this analysis, we have not only considered the range of possible responses, which are largely derived from the technical characteristics of the system, but also any political or regulatory constraints that exist.

Although the first oil crisis put brakes on energy growth in most Organization for Economic Cooperation and Development (OECD) countries, electricity demand continued to grow, spurred in part by the relative decrease in electricity costs *vis a vis* those for oil. After the Iran crisis in 1979, electricity prices increased significantly in most countries. Some substitution of electricity for oil continued, but overall electricity growth rates were slower than before 1979, particularly in Europe. In OECD Europe, electricity as a share of total end use energy increased from 11.3% in 1973 to 16% in 1985. In conjunction with increased demand, the utilities' share of total pri-

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mary energy requirements in OECD Europe rose from 27.4% to 35.9% in the same period.

The reduction in oil use among Europe's electric utilities has in particular played an important role in the overall drop in OECD oil demand since 1973. In 1985, the five countries under study used 36.9 million tonnes oil equivalent (MTOE) in their 77 GW of oil-fired capacity. If these countries used their 1985 oil-fired capacity at 1973 load factors, 73.8 MTOE oil would have been used — twice the amount actually used! The 1986 drop in the price of oil made that fuel once again attractive to some utilities, raising additional concern that oil use in this sector might increase in the near future, particularly if lower oil prices lead to lower electricity prices and a further stimulation of demand. Thus, the backout of oil from the utility sector may not be permanent; indeed, oil use in the UK skyrocketed during a coal miners' strike in 1984. The utilities face the question "more oil, or less?"

The hazards of a heavy reliance on oil are all too familiar. As we contemplate the fuels which have been considered alternatives to oil, we find that they are now also suspect due to security and environmental problems. Natural gas, seen by many as the cleanest fuel, still has not penetrated significantly into the utilities sector in Europe, in part because of continuing concerns over security of supply. A large share of Europe's gas is imported from the USSR and Algeria.

The combustion of coal causes many severe environmental problems, including acid rain and the "greenhouse effect." In addition to the environmental and supply disruption that would be associated with "another Chernobyl", nuclear power poses significant environmental risks at the stages of fuel reprocessing and waste disposal. Many people are also concerned with the security of reprocessing facilities in the face of terrorist threats. Suddenly the utilities find themselves somewhat less sure of the alternatives to oil, and see their institutional footing challenged from many directions.

PLANNED ACTIVITIES FOR FY 1988

In FY 1988, the final section of this report will be completed. This section will synthesize, summarize, and compare the changes that have occurred in these five countries and discuss future expectations for electricity supply as expressed by utility management and government personnel.

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Energy Conservation Policies for Buildings in OECD Countries: Did They Succeed?*

D. Wilson, S. Tyler, A. Ketoff, and L. Schipper

Energy conservation policy seeks to improve the efficiency of energy use by speeding up market forces or correcting market failures. In this project, we identify energy conservation programs which have given positive results, and why, in countries outside of the U.S. To analyze the potential transfer of foreign experience to the U.S., it is essential that specific government policies and programs are considered within their national contexts.

The project covers government conservation programs for the residential sector in Canada, Denmark, France, Japan, Sweden, United Kingdom, and West Germany.

ACCOMPLISHMENTS DURING FY 1987

Residential energy use dropped considerably in all Organization for Economic Cooperation and Development (OECD) countries after oil prices increased in 1973 and 1979. In some countries (Denmark, France), the drop has been abrupt, and was initially a consequence of behavioral response to price signals and information campaigns. In others (Canada, Sweden), progressive drops in consumption reflect the impact of conservation investments in the sector. An exploration of the factors determining the variation in household energy use allows an analysis of the impact of energy conservation policies in each of the countries studied.

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We distinguish between a conservation policy, its programs, and individual packages of measures. The policy establishes the overall goals and justification; the program connects various government and private institutions to the energy user (or producer of energy systems), while the package is a group of individual measures that are physically implemented.

In Denmark, where the climate is severe (more than 3100 heating-degree-days (base 18°C) per year), the thermal condition of the building stock was poor in the 1970's. This fact, and the fact that comfort levels in Denmark were high, left room for substantial reductions in energy consumption in the residential sector. Survey data indicate that the Danish people responded to the energy crisis by rapidly modifying their energy consuming behavior. Later on, retrofits of the existing building stock played a role as incentive programs were refined and were eventually offered as a package under the "Act on the Reduction of Energy Consumption in Buildings" of 1981. This package included professional audits and after-the-fact inspections to ensure the quality of retrofit work performed, subsidies for an approved list of energy-conserving measures, and a home energy certificate system. A national mandatory building construction standard for new buildings was implemented. This standard is the most stringent in the European Community, and is second only to the Swedish building standard in the world. Prices and taxes are also key to residential energy policy in Denmark. In general, household energy prices are high in comparison to those of other countries. Residential energy taxes were increased once in December of 1985 and twice in 1986 in order to counter the effects of falling oil prices, thus keeping energy costs artificially high.

In France, the residential sector has played a key role in the government's energy conservation programs because of the large share of oil consumption attributed to this sector. Energy conservation program activity in this sector began in 1974 and emphasized information exhorting behavioral change and efficiency improvements with the early creation of financial incentives for investments via a system of tax deductions. Regulations for minimum levels of thermal insulation, appliance efficiency standards and strong emphasis on indoor temperature levels were also features of early French government intervention in this sector. Later in the seventies, grants tied to anticipated energy savings were introduced for the residential sector, but were terminated within a couple of years because of their high administrative costs, the difficulty of accurately determining energy savings in advance, and the small proportion of investment costs actually represented by the grant. Since the emergence of the AFME—the French Agency for Energy Management—in 1981, the program emphasis in the residential sector has been on providing decision aides to prompt effective private investment in energy efficiency, largely through subsidizing residential audits. An increasing effort has been made to assure home owners of the security of energy retrofit investments by emphasizing both the financial incentives (tax credits and low interest loans) as well as the technical competence of the work (through auditor training and savings guarantees). This emphasis supplemented the substantial capital investment by the Ministry of Urbanism and Housing, which was heavily involved in providing financial incentives for housing retrofits, particularly in the large public housing and co-operative housing sectors. In addition, through its regional offices, the AFME has become involved with several comprehensive lócal Pilot Community projects which have attempted to mobilize local agencies, contractors, financial resources, landlords, and housing occupants in community-based conservation programs.

In Japan, residential energy policy and the framework for conservation programs was articulated as a package in the "Law Concerning the Rationalization of Energy Use" of 1979. This Law was intended to address comprehensively the variety of areas in which energy savings could be made in the sector. Responsibility for carrying out the intent and requirements of the Law was placed upon The Ministry of International Trade and Industry (MITI). This had the dual effect of centralizing the development and implementation of energy conservation programs and of applying an industrial perspective to this key process. The latter limited the ability of the programs that grew out of the Law to capture a large part of the potential energy savings in the residential sector. Where industrial solutions could be applied, as in the case of appliance efficiencies, the Japanese programs excelled. Where energy waste fell out of industrial territory, as in the case of housing construction practices, MITI's impotence resulted in potential savings being left untouched: no mandatory standards for the construction of new buildings were developed and incentives for retrofitting existing housing stock were not offered.

West German residential energy policy is built on the premise that governmental intervention is appropriate only in those cases where market failures exist. The "Energy Conservation Act" of 1976 provides the framework and legal basis for policies and programs which were seen as necessary in order for full and unhampered responses to market forces to take place. In 1978, the "Modernization and Energy Conservation Act" and the "Income Tax Act" provided a system under which grants and tax incentives could be used for encouraging the retrofit of existing homes in order to bring them up to the standard for new buildings. In addition to these standards and retrofit incentives, regulations for regular inspections and adjustments of heating equipment, individual heat metering in multi-family buildings, consumption-based billing practices, and appliance labeling were established. A "gentleman's agreement" for efficiency improvements was made with key actors in the home appliance industry. Despite the requirement for consumption-based billing, decreasing block rates are still in use for electricity, and part of the consumer's bill is based on the number of rooms in the dwelling (which is clearly divorced from actual energy usage). Because information programs in general disperse information upon request, at trade fairs, in magazines, and at local service centers, all of which require an initial action or "demand" on the part of the consumer, their effectiveness in providing information beyond that for which a market exists is questionable.

For each of these countries, we completed a broad evaluation of programs and policies which resulted in energy-saving activities that otherwise would not have been carried out. Very few detailed evaluations of conservation programs have been performed in the countries analyzed. Many of those which do exist have been completed by the same agencies responsible for the implementation of the programs. This might lead one to question the objectivity of the evaluations.

PLANNED ACTIVITIES FOR FY 1988

In FY 1988 we will complete the comparison of national energy conservation programs, and evaluate individual programs or packets of programs, focusing on how well those programs reached their intended participants, i.e., the consumers.

Energy Interdependence: Global Issues and Options*

L. Schipper, A. Ketoff, and J. Sathaye

An informal meeting was organized by members of the Lawrence Berkeley Laboratory's International Energy Studies Group in Berkeley, on May 30, 1987, to discuss a number of issues related to key aspects of the world energy system. Twenty-eight representatives of academia, government, and the private sector from the Americas, Europe, and Asia participated in the meeting.[1]

During the last two decades, the relative importance of the various countries and institutions on the world oil scene has changed; oil consumption in North America, Europe, and Japan is virtually unchanged from that of 1973, while in rest of the world it has continued to increase, reaching 43% of the world total in 1985, as compared with only 29% in 1970. Oil and energy *production* has also seen a restructuring. Finally, increased energy efficiency provided the greatest contribution towards reduced world oil demand; the impact of greater efficiency will continue to be felt even if oil prices remain low. In short, the energy system is significantly different from what it was in the early 1970s, yet many decisions are based on information and mental maps of the older system.

It is now clear that oil supply and its price, as well as efficiency of use, may be only one part of the story, one whose relative importance is diminishing. There are other concerns that in the long term may be more serious. Most notable is the worsening global environmental impacts of energy use. The time scale for global environmental change through man's intervention, spurred by energy use, is rapid in contrast with natural global climatic and environmental changes. The *ecological* and *political* time scales for responding to problems, once identified, are not well known. Unfortunately, the resilience of both human societies and the ecosystem to various energy-related "shocks" of varying rapidity, magnitude, and extent is insufficiently understood.

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ACCOMPLISHMENTS DURING FY 1987

Concerns over the Energy System of the Late 1980's and Beyond

Among those topics that received the most attention on May 30 were the following:

- Global environmental disruption often has consequences not reversible on a short time-scale. The growing awareness of its link to energy production and use indicates that we may be approaching limits and critical decisions. Are present and future decision-makers prepared?
- A similar awareness of the links among energy, food, urbanization, and industrialization makes decision-making on the basis of energy alone both difficult and sometimes dangerous. How can present energy models and analysis paradigms be adopted into the wider human and economic context in which energy is but one variable?
- Accelerated restructuring of the demand for energy caused by changing economic growth patterns, rapidly evolving energy-use technologies, and even demographic forces has proven too complex to be handled by the data systems and models of yesterday. What can be done to improve our understanding of the system today?
- Increased energy efficiency contributed significantly to reduced energy and oil demand, relative to activity after 1973. Has the scope for improved efficiency narrowed, or will technology drive further improvements?
- Energy matters are now dispersed over a much wider circle of institutions, countries, and cultures than in 1973. What is the appropriate language today for understanding the problems and communicating the concerns in this diverse environment?
- The transformation of the world oil market into a commodities market with round-the-clock operation places a new actor between oil in the ground and the final consumer, namely the oil trader. How does this new layer of institutions affect the stability and long-term development of the world oil and energy market? What are the new *roles* of the actors, and the new *rules* under which they act?
- Availability and price stability of oil has been a major concern internationally. Does the current price of oil and increased availability mask impending shortages?
- The role of local biomass fuels (such as wood, charcoal, or dung, often termed "non-commercial energy") has been largely overlooked by national and international authorities, although this is the predominant energy form in many countries or regions. How would local, regional, and world energy decisions be affected if biomass and its associated problems are included in the picture?

These issues all point to the most important difference in the energy system of today *vis-a-vis* that of 15 years ago: the linkages between energy and other inputs and outputs in the economy, including human capital and information, have changed, and will continue to evolve with rapidly transforming dynamics of the world economy. The changing linkages could lead to future energy-related crises which would require adoption of new options important to both private and public institutions.

The consensus of the group that met in Berkeley was that a new approach is needed that will *quickly* sense global and regional changes in economies, geopolitical factors, and shifting demands for energy and its forms and sources. A new learning process could greatly improve our understanding of the linkages among energy, economic security, environment, and food. This process should be a new, international effort, far beyond that of a single study. Participation in such an effort would be open to experts from any country, and effort would be made to avoid groupings around familiar regional lines, i.e., North *vs.* South, industrialized *vs.* developing, etc. This effort could provide a forum to voice unencumbered views on controversial issues of international concern. As many of these links are too complex and are changing too rapidly for any single institution to follow, and are becoming more international and interdependent, only a decentralized effort could provide the forum for such an activity.

This forum will have as its primary responsibility the identification of issues and options, and the subsequent improvement of our learning and analytical tools to deal with them, in meeting the new kinds of energy-related problems we expect in the 1990's and beyond. Policy and economic analysis and synthesis from this effort will have an international perspective, which is essential to identify emerging global energy issues. An international perspective will provide a much more accurate determination of emerging perceptions and values regarding important energy issues. Policy development explorations will reflect interaction between experts from research institutions and policy officials from government and professionals from industry.

PLANNED ACTIVITIES FOR FY 1988

In FY 1988, the LBL group, with input from others joining the effort through computer networks, will carry out a new activity, provisionally called the Energy Roundtable Experiment. The Energy Roundtable will initially consist of several dozen energy decision-makers and experts from around the world. The Roundtable experiment will address itself to several of the issues outlined above through a series of position papers and electronic conferences. One or more individuals or groups will be asked to take the lead in developing each paper, but members of the Roundtable would be encouraged to contribute to each paper through the electronic medium, under the leadership of a motivator. The two topics chosen are energy and transportation in the future, and electricity in developing countries. Shell International Petroleum Company will make available an existing electronic conference channel through which this experiment will be carried out. If the experiment is successful, a larger effort will be launched later in FY 1988.

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RESOURCE MARKET MECHANISMS

Overview

The Resource Market Mechanisms group analyzes and conducts research on the methods used for the transfer of natural resources, particularly the transfer by means of formal competitive auctions from government to the private sector, as well as on broader energy policy issues.

The following article contains a description of an analysis of the design of auctions for the purchase by utilities of power from cogenerators and small power producers. In the past, we have studied auction design issues for coal leasing, timber sales, oil leasing, and the use of auctions by the State of California. There has also been modelling in support of natural gas deregulation policy analysis, and a study of U.S. energy vulnerability in the 1990's. We are currently interested in the use of auctions for deregulating all new electric power generation and in modeling the supply situation for alternate fuel vehicles.

Designing Auctions for the Purchase of Electric Power by Utilities under PURPA*

M.H. Rothkopf and E.P. Kahn

The Public Utilities Regulatory Act (PURPA) requires there to be procedures for electric utilities to buy electric power from qualifying cogenerators and small power producers (QFs) at rates up to "avoided cost". This has led to price-posting procedures at prices calculated as the utility's marginal cost. Unexpectedly large sales at these prices and slow adjustment to falling energy cost are partially responsible for payments to QFs in excess of the utility's true avoided cost. Using competitive bidding instead of posted prices has been proposed as a way to avoid this outcome.

ACCOMPLISHMENTS DURING FY 1987

We have written a report that reviews bidding theory and explores four issues that arise in designing auction systems for the purchase of power from QFs under PURPA.[1] (In addition, in one appendix it considers broader auctions involving non-QF bidders.) One of these four issues is the choice of auction format between progressive oral auctions, Dutch oral auctions, standard discriminatory or "first-price" sealed bidding (if you win, you get paid the amount of your bid), and nondiscriminatory or "second-price" sealed bidding (all winning bidders are paid the amount of the best losing bid). Another issue is the extent to which non-price factors influence the auction and the manner in which they do. A third issue is the way in which bid acceptance procedures deal with the discrete quantities of power offered by different bidders. For example, if a utility that needs 500 MW that it can supply at 10¢ per kWh receives three all-or-nothing bids, one offering 300 MW at 7¢, one offering 250 MW at 8¢ and one offering 200 MW at 9¢, which bids should it accept? The fourth issue is the frequency of auctions. After discussing these issues, the report explores practical details through a case study of a PURPA auction using publicly available data representative of conditions facing Southern California Edison Company.

With respect to auction format, the report recommends sealed procedures over oral ones. It identifies flaws in the arguments in favor of the economic efficiency of nondiscriminatory sealed bidding and recommends familiar discriminatory sealed bidding over the much less common nondiscriminatory format.

In discussing non-price features, the report notes the tradeoff between simplicity and economic precision. It identifies some factors, such as capacity value and transmission access costs, that are rela-

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tively amenable to differentiation into components with separate payment streams and performance factors. Others, such as financial risk (see Fig. 1) and dispatchability are not. It also notes with approval the approach taken in Massachusetts to deal with financial risk, and it notes the difficulty of dealing with dispatchability when it is important.

The discrete nature of bids can cause difficulties. There are many different ways to decide which of a given set of bids to accept. The report recommends that bid acceptance rules be spelled out precisely before an auction. The minimum cost selection of bids for meeting a given power requirement may involve accepting a bid with a higher unit cost than a bid that is rejected. It is undesirable for the utility to accept rigidly the discrete nature of the bids and select the set of bids that provides the desired amount of power at the minimum cost. The report recommends four measures that a utility can use to reduce the impact of the discrete nature of the bids. These are (1) encouraging multiple bids by a bidder offering incremental quantities, (2) allowing a marginal bidder to downsize the quantity offered if it is too big (given the other lower bids) to be acceptable, (3) allowing a reasonable tolerance in the definition of the required quantity, and (4) valuing excess power beyond the desired quantity at its value to the utility in deciding if a marginal bid is acceptable. With these four measures, the report recommends a bid acceptance procedure that considers bids sequentially in order of increasing cost per kWh. Such a procedure will have good economic and bidder incentive properties and will be more stable and "fairer" than a procedure that rigidly minimizes utility cost given the bids.

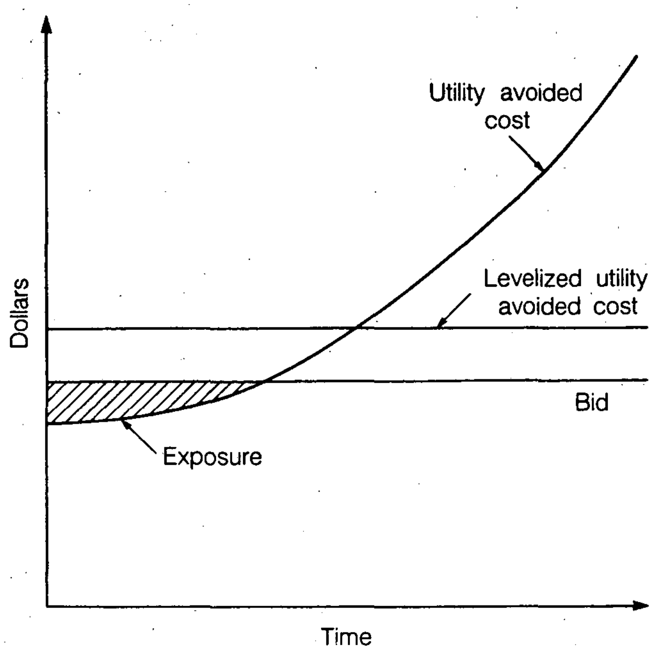

Figure 2. In an auction in which bidders bid both a price and a quantity, a bidder with a lower average cost curve (AC_l0) and marginal cost curve (MC_l) can nonetheless be a high cost bidder if he estimates a higher price ($> P_l$) and selects the quantity to offer so that anticipated price equals marginal cost. (XBL 8711-4779)

The report recommends that PURPA power purchase auctions be held at least every few years if utility need for capacity allows and that they not be held at much shorter intervals. Too frequent auctions can put large projects at a disadvantage and facilitate collusion. Too infrequent auctions can put at a disadvantage time sensitive potentially attractive projects.

The Southern California Edison case study is based on cost conditions anticipated by the utility for the mid-1990's. It uses the UPLAN model to estimate avoided cost based on methods prescribed by the California Public Utilities Commission. We provide a simple characterization of the "demand curve" for power. Bidders are represented by cost functions approximating the opportunities available to natural gas-fired cogenerators in Southern California.

From the study, we have been able to observe that large-scale projects will cause difficulties in designing bid acceptance procedures, that estimation error can introduce some inefficiency in first price auctions, and that utility costs will exceed social cost minima by 10–20%. Most of these deviations, however, are transfers of economic rent to producers and not economic inefficiency. In particular, economic inefficiencies associated with the use of discriminatory auctions were typically under 0.5%. Furthermore, utilities are likely to pay less for power under auction procedures than using posted prices.

Included with the report are a number of appendices. Some of these present original theoretical derivations. One calculates the effect of revealed second-price auctions in models with subsequent negotiations in which part of the revealed economic rent is captured. Another calculates the optimal selection of quantity to bid when a bid is both a price and a quantity. One appendix presents a workable mathematical procedure for selecting the lowest cost set of bids to a utility. Another presents a precise specification of a sequential bid acceptance procedure and an example of its application. One large appendix contains an extensive discussion of additional issues that would arise if an attempt were made to deregulate all new power generation capacity by removing the technology restrictions (i.e.

small power or cogeneration) on bidders in PURPA power supply auctions. The final appendix illustrates how the interaction of bidders' capacity and bid price decisions can reduce the economic efficiency of discriminatory auctions. (See Fig. 2.)

PLANNED ACTIVITIES FOR FY 1988

We plan to extend this work to consider in detail the additional issues that would arise if auctions were used for all new long-term power generation—not just QF power. We also plan to study auctions held for QF power to observe their effectiveness in practice.

REFERENCE AND SUGGESTED READING

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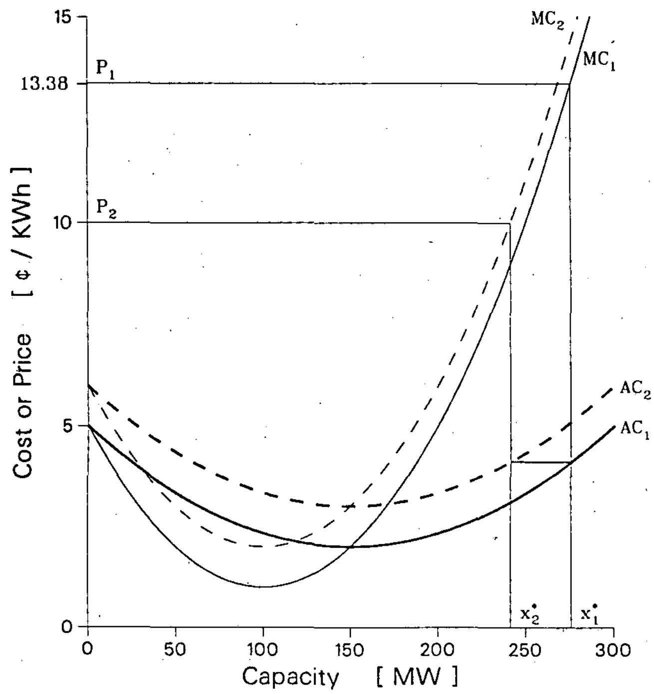

Figure 1. Utility exposure to financial risk from levelized payments in the face of increasing avoided costs. (XBL 878-9071)