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FY 1988 Annual Report

Energy Analysis Program

March 1989

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APPLIED SCIENCE DIVISION ANNUAL REPORT

ENERGY ANALYSIS PROGRAM

FY 1988

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ENERGY ANALYSIS PROGRAM*

INTRODUCTION

The Energy Analysis Program continues to be involved in wide range of topics relating to the energy system of the United States and numerous other countries. Our interest in energy use and conservation in buildings has remained high, with increasing attention being devoted to studies of commercial buildings. The appliance standards continues to be the leading energy policy analysis activity of the Program. A long-term commitment to characterizing and understanding measured data of energy use in buildings continues. Interest in electric utility issues, with particular emphasis on demand-side activities and programs, continues high. New interest in competition among electricity generation options for utilities complements the demand-side analyses.

The involvement in international energy studies has increased from previously high levels, with no waning in the commitment to the detailed analysis of factors affecting energy use by end-use. Building energy policy studies in the countries of the Association of South East Asian Nations continue to combine the Program skills in international studies, building energy analysis, and policy studies. An increased involvement in China has been of particular note during the past year.

The environmental initiatives of the previous year saw some important results, as analyses of effects of climate change on vegetation in California and habitat change and species extinction were completed. These efforts indicate success in the effort to significantly broaden the interests of the Program.

A new and potentially critical theme emerged and took hold in the energy and environmental communities during the past year: the potential for global warming. The Program has become involved in a variety of initiatives and analyses relating to this important topic. Data on energy demand growth in developing countries were analyzed in greater depth than previously in order to support the efforts of the Environmental Policy Agency (EPA) to understand measures to stabilize the atmosphere. Data on electricity use in developing countries were assembled to support longer-term efforts by the U.S. Department of Energy to assess the impact of electricity use in developing countries on global climate change. Studies of effects of increased temperature levels on selected vegetation types were initiated for the EPA. Numerous additional projects were designed to deal with key issues relating to global climate change, including a number of efforts with the Peoples Republic of China. Some or many of these are likely to be carried out over the next several years.

The year saw few major new problems in the energy economies of nations, with energy prices remaining relatively low and supplies in ample quantities. As a result, energy continued to play a small role in the national political scene. Nonetheless, the energy policy community continued to take note of the fact that low oil prices will not last forever, and possibly not even for another decade. There has been growing concern about an energy efficiency "plateau," resulting from low energy prices and reduced incentives to continue to improve the energy performance of economies. The advent of much more broad-based concerns about global warming has raised the recognition of the importance of long-term energy issues, even while the current situation appears manageable. It is in this broader context that new areas for energy analysis are likely to develop in the Program over the coming years.

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*This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building and Community Systems, Building Systems, Building Services, and Building Equipment Divisions, the Office of the Assistant Secretary for Environment, Safety, and Health, the Office of Policy, Planning and Analysis, of the U.S. Department of Energy; the U.S. Department of Housing and Urban Development under an Interagency Agreement (IAA-H-87-59); the Agency for International Development; the National Science Foundation under Interagency Agreement No. BSR-8717168; the NASA Earth Sciences Division (UPN-677-80-06-05); the Environmental Protection Agency under Interagency Agreement No. DW89933219-01-0; the Residential/Commercial Technology Analysis Division of the Gas Research Institute under GRI Contract No. 5085-800-1318; the Electric Power Research Institute; through the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

Utility Accounting in Public Housing

R. L. Ritschard and K. M. Greely

Public housing currently provides shelter and energy for over 3.4 million low-income tenants. Annual energy costs to the federal government for the public housing sector now exceed $1 billion. Preliminary studies indicate savings as high as 50% could be realized by improving the energy efficiency of the public housing building stock. These savings have not been realized, partly because local public housing agencies lack relevant energy-related information.

We have developed a utility accounting microcomputer program (based on Lotus 1-2-3® spreadsheets) that allows local housing agencies to track use electricity, gas, oil, other fuels, water, and sewer easily and accurately within individual housing projects. After a user enters monthly utility usage and costs into the program, it will adjust utility usage and costs to calendar months and convert consumption to common units (e.g., therms or cubic feet of gas and kWh of electricity to Btus of energy); weather-correct energy usage to that which would have occurred in a year having typical weather; compare each year's consumption and costs to previous years; and compare the consumption per unit-month to that in typical public housing apartments or privately-owned apartments having similar climate and building characteristics. The software helps produce executive summaries and other tables and graphs (see Figure) for tracking utility usage and costs across different years. The program also combines for analysis utility data for all projects within a public housing agency, calculates the allowable utility expense levels, and prepares two important annual reporting forms required by the U.S. Department of Housing and Urban Development (HUD). The output of the program can be used to verify proper rate payment, identify excessive energy use at given projects or buildings, and determine whether savings from previous energy retrofits have persisted over time. The software can also be used by local public housing agencies and by HUD to explore opportunities for reducing utility bills and to locate buildings and equipment requiring maintenance. We expect the program and documentation to be available by the end of 1988. These will be widely disseminated to local public housing agencies through the HUD User Network, which reaches more than 2600 U.S. housing agencies.

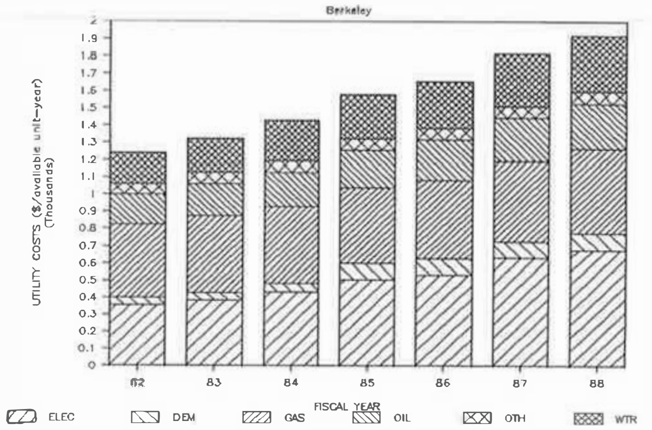

Figure. Sample energy computation produced by utility accounting program: annual utility costs per available unit. (XBL-891-159)

Energy Management Practices in Public Housing

E. Vine

To balance their budgets, U.S. public housing authorities (PHAs) must spend less energy. We have evaluated successful energy management practices conducted by U.S. public housing authorities. The study was undertaken to help other housing authorities learn how to manage their energy use. Housing authorities were selected primarily through interviews with U.S. Department of Housing and Urban Development (HUD) headquarters and regional offices; PHAs actively trying to manage their energy use were potential candidates for a mail survey.

An energy management survey was sent to 49 PHAs, yielding an 84% response rate. Topics addressed included energy actions, energy information, key energy actors, energy audits, program participation, financing and information sources, site description, energy management, maintenance, tenant involvement, type of metering, appliance purchasing criteria, energy use in 1980 and 1987, energy conservation measures installed, problems in managing energy, and problems in installing energy conservation measures.

We present below selected preliminary results from this study: all PHAs reported that they had saved energy since 1980; all PHAs had conducted energy audits; most PHAs (80%) had prepared an energy management accounting report; about 50% of the PHAs used in-house computers for tracking energy and cost data; about 40% of the PHAs had prepared a written energy plan for controlling energy costs, and 80% of these were currently using the plan; almost all PHAs had a preventative maintenance program; estimated average energy savings from retrofits was reported to be 21%; and the most effective energy conservation measures were insulation, window replacement, boiler replacement, and lighting conversions.

In FY 1989, we will continue analyzing these data, using multivariate statistical analysis to group these factors that determine successful energy management. We will also test several hypotheses concerning organizational change as it affects energy management.

Energy Requirements for Multifamily Buildings

R. L. Ritschard and Y. J. Huang

Over the past few years, multifamily buildings have been the most rapidly growing residential sector. As a result, multifamily housing has become an important sector of the energy economy.

LBL has contracted with the Gas Research Institute (GRI) to use the DOE-2.1C computer program to develop a comprehensive data base of hourly heating and cooling loads for prototypical multifamily buildings. This data base, covering 16 building types in 15 U.S. cities, reflects regional variations in climate, building construction and insulation practices, and represents the general population of multifamily buildings. Our major research goal is to provide GRI and its contractors with a reference set of building loads for use in planning and analyzing R&D programs in gas technology. The results also provide a general reference set of multifamily energy requirements for use by energy analysts. The full data base, which includes hourly heating and cooling loads (sensible and latent), domestic hot water loads, and electric consumption for each apartment unit and for the total building, will be available as part of this project.[1]

The Figure shows several important features representative of multifamily buildings. First, smaller buildings with 2-4 units usually have higher energy requirements per square foot than do multistoried buildings of five or more units. Second, energy use in older buildings is generally greater than that of newer ones. Third, in a southern climate like Atlanta, energy use for cooling may be equal to or greater than that for space heating. Finally, heating loads were more affected by improvements in thermal integrity (representative of newer buildings) than were cooling loads.

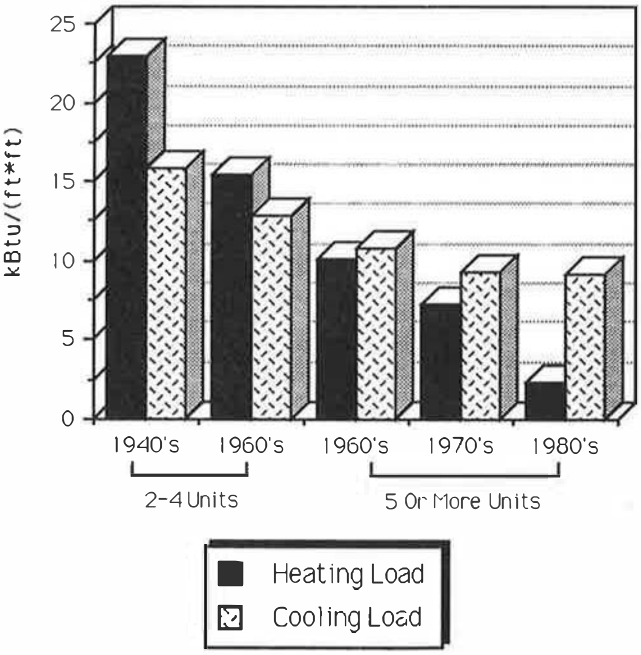

Figure. Estimated heating and cooling loads (per square foot) in typical multifamily buildings, Atlanta, GA. (XBL-8810-3732)

Due to the size of this data base, an interactive microcomputer program is being developed that will allow users to derive monthly loads, hourly profiles, or loads binned in different formats (e.g., by temperature and humidity ratio or by temperature and hour of day). In the next year, we will begin to use some of these data to assess different multifamily technologies. (See next article for a preliminary comparison of central vs. individual heating, ventilation, and air-conditioning (HVAC) and domestic hot water (DHW) systems in multifamily buildings.)

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A Comparison of Central vs. Individual HVAC and DHW Systems in Multifamily Buildings

S.J. Byrne

Separate energy billing for apartments motivates energy-conscious occupants to control their energy use; such billing is facilitated by individual all-electric heating, ventilating, and air-conditioning (HVAC) systems and domestic hot water (DHW) systems. On the other hand, large, central systems are more efficient, require less maintenance, last longer, and allow more flexibility in choice of energy type. This project provides information on tradeoffs between individual and central HVAC and DHW systems in terms of energy performance and life-cycle costs in two climates, for different types of new multifamily buildings, and under varying operating conditions.

Using the DOE-2.1C computer program to model energy consumption in two typical apartment buildings—one in Chicago, the other in Atlanta—we analyzed two HVAC/DHW configurations per building; a central system consisting of a central chiller and gas-fired boiler which supply four-pipe fan coils (FPFC) and a gas-fired DHW system; and an individual system consisting of packaged terminal air-conditioners (PTAC) and electric water heaters in each apartment. To approximate energy-conserving operation, the individual PTAC system was modeled with and without a setback thermostat. We used each city's average prices for energy and equipment.

For both cities in our analysis, projected annual energy costs were lowest for the central HVAC/DHW system. This was especially true for Chicago because of its higher heating demand and higher price differential between electricity and natural gas. A life-cycle cost comparison of system types showed that in Chicago, multifamily buildings with more than seven apartments (in Atlanta, more than thirteen) should be designed with central HVAC and DHW systems.

Shown below is an example plot of life-cycle cost vs. number of apartments. The intersecting lines at "A" illustrate the point at which the system type should be changed to achieve the lower life cycle cost of the two alternatives. The line segment shown between points "A" and "B" represents a building with a central chiller sized at the minimum capacity that is commercially available. The life-cycle cost between "A" and "B" is not as low as it would be if it were possible to extend the FPFC line to the left of "B" (by using a smaller chiller), represented by the dashed line. However, the oversized chiller alternative still results in a lower life cycle cost within the range "A" to "B"—than the PTAC system.

We plan to continue this work by analyzing the effectiveness of other system configurations, operating strategies, and newly developed metering devices. We will also evaluate other building designs and other cities.

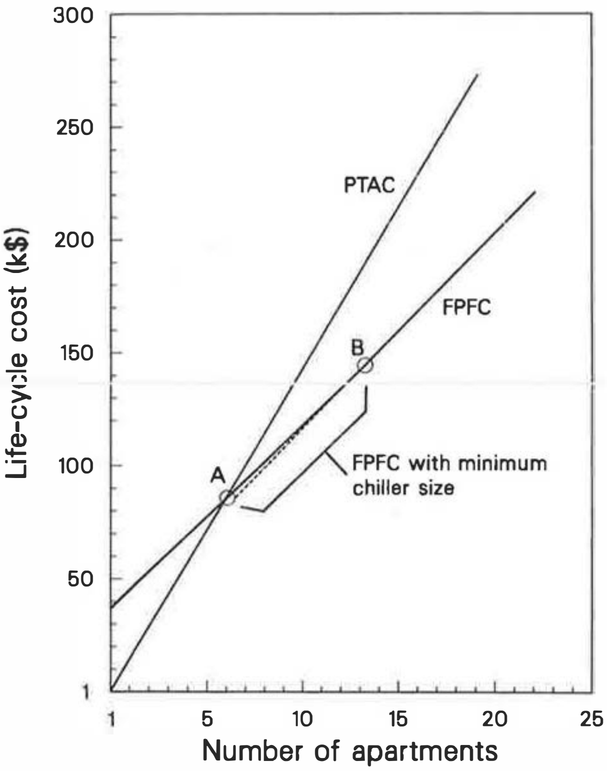

Figure. Life-cycle cost, in Chicago, of central FPFC and individual PTAC with night setback. (XCG-8810-6793)

Analysis of Energy Performance of Unbalanced Single-Pipe Steam Heating Systems in Multifamily Buildings

Y. J. Huang and R. L. Ritschard

For the past two years, LBL has contracted with the Gas Research Institute to analyze the space conditioning loads of prototype multifamily buildings in different U.S. locations (see previous two articles). Roughly 9 million or 40% of all multifamily units are heated by centralized steam or hot water systems, of which nearly half were built before 1940. The great majority of these older units are located in Northeast and Midwest cities, and heated by single-pipe steam systems.

Because this antiquated heating system is prevalent among multifamily buildings, we developed and implemented a simplified simulation model for a single-pipe steam heating system as a modification of the DOE-2.1C program. This model was then used to analyze the energy consumption of older multifamily apartment buildings.

In this simplified model, three new variables were defined: *fill-fraction*, *mass-heat*, and *anticipator-fraction*. A single thermostat located somewhere in the building controls the steam boiler. The amount of heat delivered to each apartment zone varies according to interactions between boiler capacity, radiator size, and the new variables.

Fill-fraction (see Figure) defines the delay between the time the boiler turns on and when the apartment begins receiving heat. This delay is due to the time needed by the boiler to generate enough steam to displace the cold air in the piping and to heat absorption by the piping mass. *Anticipator-fraction* defines the reduction in maximum heat available to a zone as allowed by the anticipator. By shutting off the boiler, an anticipator reduces the heat output from the radiators even though the thermostat may still be asking for heat. *Mass-heat* defines the residual heat stored or released to the zone hourly by the radiator and piping mass depending on changes in the boiler operating time. The graft shows effects of differing fill-fractions on heat supplied to different apartments.

Simulations were done using this model to analyze energy consumption and indoor temperatures of prototypical pre-1940 buildings heated by single-pipe steam systems under various operational strategies. Sensitivity studies showed that mass-heat would cause typical steam systems without anticipators to overheat from 3° to 6°F and would use 15% to 30% more energy than standard forced-air systems. The effects of three different fill-fractions (none, fast, and slow), anticipator-fractions (0, 10, or 20 minutes), and two thermostat locations were also analyzed. Because of differences in their fill-fractions, top- and ground-floor apartments generally have unbalanced

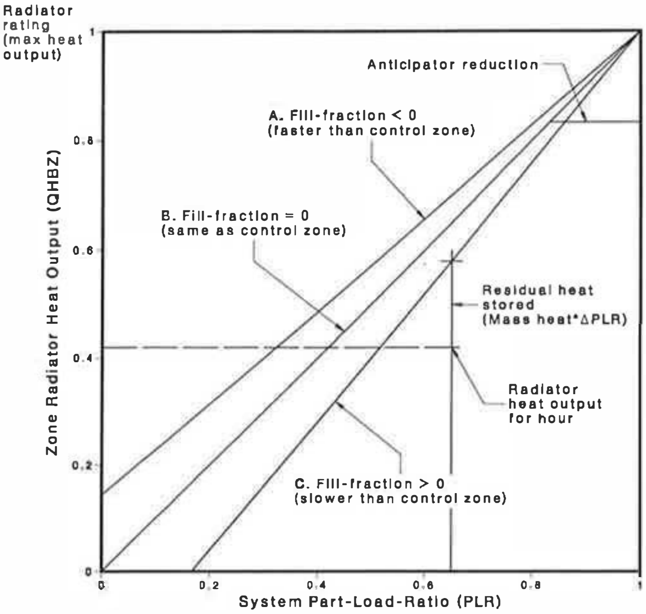

Figure. If a zone's fill-fraction is the same as that for the control zone, the zone receives the same amount of heat (line B in the Figure). If its fill-fraction is greater, the zone will receive heat sooner than the control zone, but the differential disappears as the system part-load-ratio or boiler on-time reaches full load conditions (line A). Conversely, if its fill-fraction is less, the zone receives heat later than the control zone, but the differential again disappears at full-load conditions (line C). The dashed line indicates net heat output into a zone with a slower fill time than the control zone during an hour when ΔPLR is positive and PLR is less than the anticipator-fraction limit. (XBL-8811-3854)

heating and substantially different temperatures. If the thermostat is on the ground floor, the building load is greatly reduced, whereas the top units are underheated.

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Estimating Nationwide Conservation Potential From Measured Data

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

Most estimates of regional or nationwide conservation potential have been based on simulated savings derived from engineering models. In contrast, we have developed an approach for estimating conservation potential from measured energy use and have applied this new methodology to two sectors of the U.S. housing stock.[1] Such refined estimates of conservation potential are necessary to accurately assess the extent to which energy conservation has occurred and the amount of savings remaining to be tapped.

Because measured savings have been shown to occur, their use adds certainty to estimates of conservation potential. However, the savings are specific to particular types of retrofits in certain subsectors of the stock. The challenge is to correctly adjust measured savings to compensate for differences between measured projects and the regionwide stock.

The Building Energy Use Compilation and Analysis (BECA) project documents the measured energy performance of new buildings and equipment and the measured energy savings from retrofits. To demonstrate our methodology, we chose two well-documented BECA compilations representing retrofitted multifamily buildings and new, electrically heated, single-family homes.

We first examined the conservation potential of new, electrically heated, single-family homes. We derived savings from construction of efficient new homes by comparing consumption of energy-efficient, electrically heated homes with that of similar "current practice" houses. These savings were combined with estimated construction rates for the next decade to yield a potential energy savings of 0.22 quads per year by 1997 (1 quad = 10^{15} Btu), about 45% of the projected space heating consumption by the new homes. Adjustments were then made to account for differences between new homes in the BECA compilation and the projected stock of new construction, i.e., heating system type, floor area, climate, and energy consumption (see Figure). These adjustments increase the potential energy savings to 0.32 quads per year.

To estimate the conservation potential of existing multifamily buildings in the U.S., we first classified the BECA

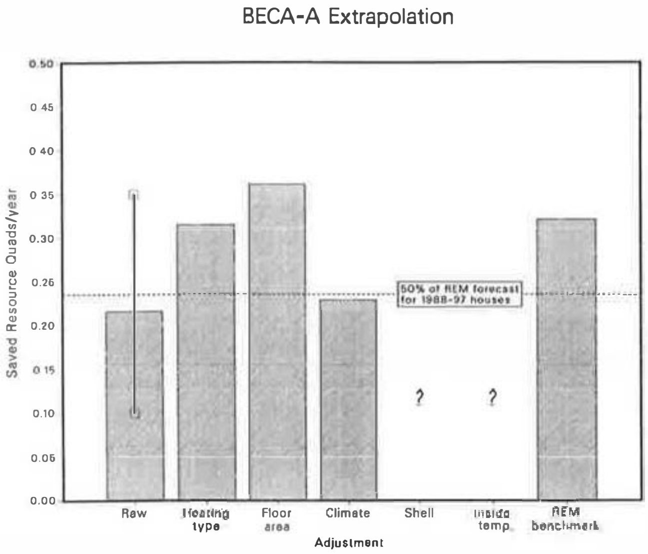

Figure. BECA extrapolation of stockwide savings for new, electrically heated houses. Each bar represents the change in the savings estimate caused by each additional adjustment. "REM" refers to the baseline energy use estimates for new, all-electric homes, from LBL's Residential Energy Model. Adjustments for shell characteristics and inside temperature can be performed as better data become available. (XBL-8811-3855)

multifamily buildings into those with "typical" and "intensive" retrofit packages, segmented by key building and heating system types. Savings for each segment were then extrapolated to the entire multifamily stock, using statistically representative information on consumption and building characteristics of the stock. After adjusting for differences in climate and pre-retrofit usage between BECA buildings and the U.S. multifamily stock, we found that if typical retrofits were installed in all U.S. multifamily buildings, it would save about 0.2 quads per year, while intensive retrofits could save about 0.5 quads per year. These results suggest that current energy consumption in the multifamily sector could be reduced by 9-22%.

We conclude that our method more accurately estimates the conservation potential of a sector than do traditional engineering methods because it is based on measured savings from existing buildings. We plan to improve our methodology through additional adjustments and apply our approach to other sectors of the U.S. building stock.

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Least-Cost Utility Planning

F. Krause, J. P. Harris, M. D. Levine, and A. H. Rosenfeld

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

In response to a Congressional mandate, the U.S. Department of Energy supports a broad R&D program on least-cost utility planning. LBL's role is to help develop and apply new data and analytical tools to assist utilities and state regulatory commissions in pursuing a balanced, least-cost energy strategy. Most of this effort addresses demand-side opportunities for end-use efficiency and load-shaping, e.g.,

- assess demand-side technologies (performance, cost, reliability, etc.)
- review and evaluate demand-side program experience, including effects of these programs on market penetration of new technologies
- develop and refine analytic tools and models for demand-side analysis and integrated resource planning
- apply new data and analysis techniques to utility-specific studies (see Figure)
- other technology-transfer efforts to encourage use of state-of-the-art planning methods.

Future work will continue evaluation of demand-side programs and technology assessments, collaborative studies with states and utilities, and a special focus on innovative strategies such as utility "resource auctions" for demand-side and supply-side resources.

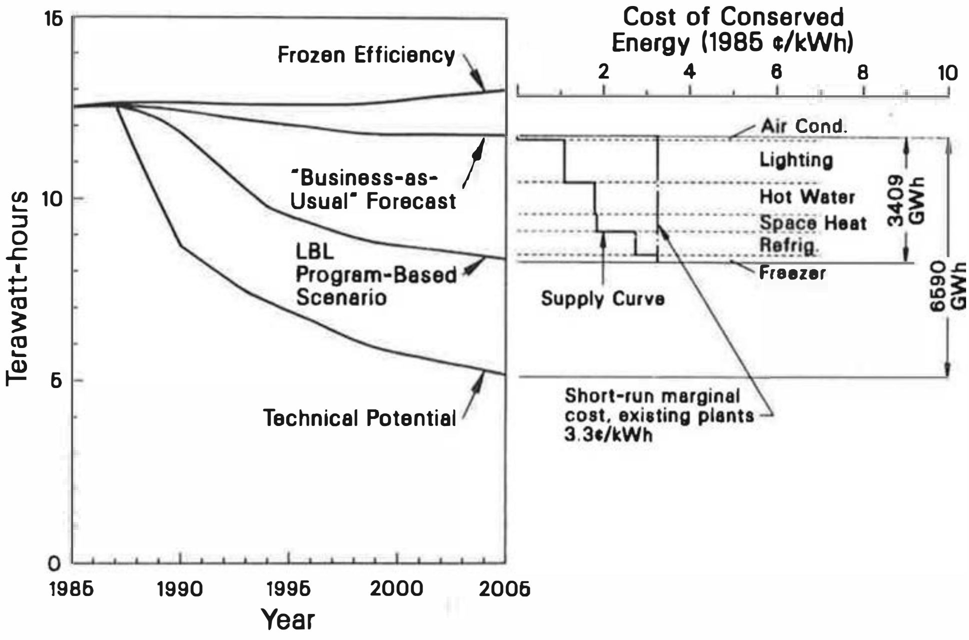

Figure. Graph of Michigan residential electricity use using a conservative "supply curve" to establish technical potential and program scenario. (XCG 881-6508)

Rated vs. Measured Energy Use of Refrigerators

A. K. Meier and K. E. Heinemeier

The energy use of refrigerators is important to both consumers and utilities because they are the largest end use of electricity in most American homes and, together, consume the equivalent electrical output of 25 large power plants. The U.S. Department of Energy (DOE) developed an energy rating procedure for refrigerators. The rated energy consumption was determined through a laboratory test which is the basis for the Energy Guide labels. These labels assist the consumer in selecting the refrigerator with the lowest life-cycle costs, while planning agencies use the energy ratings to forecast electricity demand.

The laboratory test of refrigerator energy use does not attempt to duplicate the actual conditions of a typical refrigerator because they are difficult to determine. Instead, the laboratory test involves measuring the energy use of a refrigerator in a 32°C room, with the door closed, and with no food loads inserted or removed. In spite of these unrealistic assumptions, the energy consumption from the laboratory test has never been carefully compared to field use. In this project, we compared the rated energy use of refrigerators to measured field use.[1]

We collected measured refrigerator use from numerous utility studies and other monitoring programs. The correlation between rated and measured energy use for the 192 units was, on average, excellent (see Figure). However, there was considerable variation among individual refrigerators. This variation was probably due to different operating conditions (especially ambient temperature) and the presence of icemakers, plus random variation in the mechanical performance of individual units.

Monthly energy data were also available for most of the refrigerators. We compared the energy use in the peak and valley months. There was considerable fluctuation in monthly energy use; the maximum and minimum months often differed by more than 30%. These data suggest refrigerators are a greater contributor to the summer electrical peak than previously thought. The results are surprising because most forecasts assume that refrigerators have a nearly constant electrical demand. While the label was quite good at predicting annual energy use, it underpredicted the refrigerator's contribution to the summer peak.

However, for newer (and more efficient) models, the test is less accurate; the rating overpredicted energy use by more than 20% in our sample. This suggests that this type of verification may become even more important in the future.

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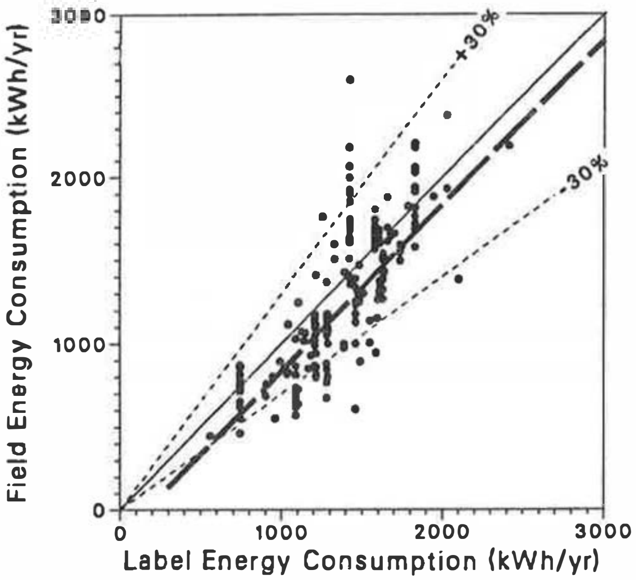

Figure. A scatterplot of DOE laboratory test ("label") consumption versus the measured annual field consumption. A line of perfect agreement is drawn for reference; units to the right of the line represent those with the label consumption greater than the field consumption. On average, the field consumption was very close to the rating, although individual models show some scatter around the line of agreement. The "columns" of points represent groups of identical refrigerators. (XBL-8810-3619)

Experience with Energy Efficiency Programs for New Buildings

E. Vine and J. Harris

This report evaluates the experience with implementing programs promoting energy efficiency in new residential and commercial construction. This report is one of a series of program experience reports that seek to synthesize current information from both published and unpublished sources to help utilities, state regulatory commissions, and others to identify, design, and manage demand-side programs.

We focused our investigation on nonregulatory programs that are designed to complement—or in some cases substitute for—mandatory energy efficiency requirements in local and state building codes. We evaluated the following types of nonmandatory programs: technology demonstrations and demonstration programs, financial incentive programs (including rebates, conservation rates, reduced hookup fees, reduced rates on loans and loan qualifications, guaranteed savings, and tax credits), consumer information and marketing programs (including energy rating systems and energy awards), technical information programs (including professional guidelines, design tools, design assistance, and standards-related training, compliance, and quality control), and site and community planning.

In addition to presenting findings for each program category, we summarize general program conclusions, applicable to most of the energy conservation programs reviewed in this report: (1) many different types of nonmandatory programs appeared to be successful in overcoming barriers to promoting energy efficiency in new buildings; (2) no program strategy was clearly dominant; (3) few program evaluation studies exist, resulting in a paucity of quantitative data on program effectiveness, especially beyond the pilot or demonstration stages; (4) only a few programs were designed as part of a long-term strategy to promote energy-efficient construction; (5) successful programs were often characterized by intervention early in the design and planning process in order to minimize delays in the project design, approval, financing, and construction process; (6) education, training, and design assistance activities were especially important; (7) most programs focused on the early design stages of a program without addressing issues normally arising later in the program (e.g., details of construction, quality control, building commissioning, and operations and maintenance); (8) utility rate designs were typically not used as conscious reinforcement for promoting energy-efficient construction; (9) many programs were considered successful for both energy and nonenergy reasons (e.g., improved thermal comfort, creation of new markets, and improved customer relations); (10) nonmandatory programs can reinforce and pave the way for codes; and (11) most of these programs can be easily implemented in other areas around the country and in other countries.

For the design and implementation of energy conservation programs for new buildings, the evidence suggests that a comprehensive and long-term perspective is needed to design and choose programs. Long-term goals and objectives of programs need to be made explicit in order to provide program guidance. A well-integrated package of programs should contain the following program strategies: design assistance, financial incentives, quality control, training and education of design professionals and the building community, simple and easy-to-use design tools, rating and labeling of buildings, effective marketing and promotion, energy awards for buildings and for design and building professionals, building commissioning, operations and maintenance activities, process and impact evaluation, monitoring, and feedback activities.

Implementation of energy efficiency programs is not an easy task, and there have been many failures at various stages in the implementation process. The challenge is to design and implement a program that meets the needs of the target audiences as well as promote energy-efficient construction.

Analysis of Commercial Electric End-Use Data

H. Akbari, I. Turiel, J. Eto, and L. Rainer

Direct metering is the most expensive method for gathering reliable load shape data on electrical end uses. The goal of this project, which was jointly sponsored by the Southern California Edison Company (SCE) and the California Energy Commission, is to investigate a less expensive alternative to metering using 15-minute interval whole-building electric loads. Successful development of such an alternative could reduce the cost of obtaining high quality load shape data by several orders of magnitude. Given the stakes involved in electric utility resource planning, the returns promise to be large.

Our approach is to conduct detailed analyses of SCE data on commercial building characteristics, energy use, and whole-building load shapes, and in conjunction with other data, to develop, test, and apply an integrated method to estimate end-use load shapes (LSs) and energy utilization indices (EUIs). The primary data for the project are on-site surveys, load research data (LRD), and available sub-metered energy use data. Secondary data include other EUI and LS studies, commercial sector mail survey data, and typical and historic southern California weather data.

The project consists of two major parts: the first concerns the development of prototypical buildings and the performance of energy use simulations that lead to preliminary estimates of LSs and EUIs. This part relies primarily on survey data, which are complemented by results from previous EUI and LS studies. The second part entails selective modification of the initial estimates using whole building load research and historical weather data. The methodology is illustrated schematically in the Figure.

Development of a Simplified Tool to Calculate Commercial Sector EUIs

I. Turiel and B. Lebot

This project, supported by the Electric Power Research Institute (EPRI), developed a simplified tool to calculate commercial sector energy utilization indices (EUIs). In EPRI's Commercial Sector End-Use Planning System (COMMEND) model, EUI values are one of the three key market facts. Together with floor stock and market share data, EUI values allow the construction of market profiles that depict energy use patterns at the end-use level. These profiles are important for analysis of the current energy market and they provide a starting point for end-use forecasting. The computer software developed in this project allows utilities to calculate EUIs specific to their

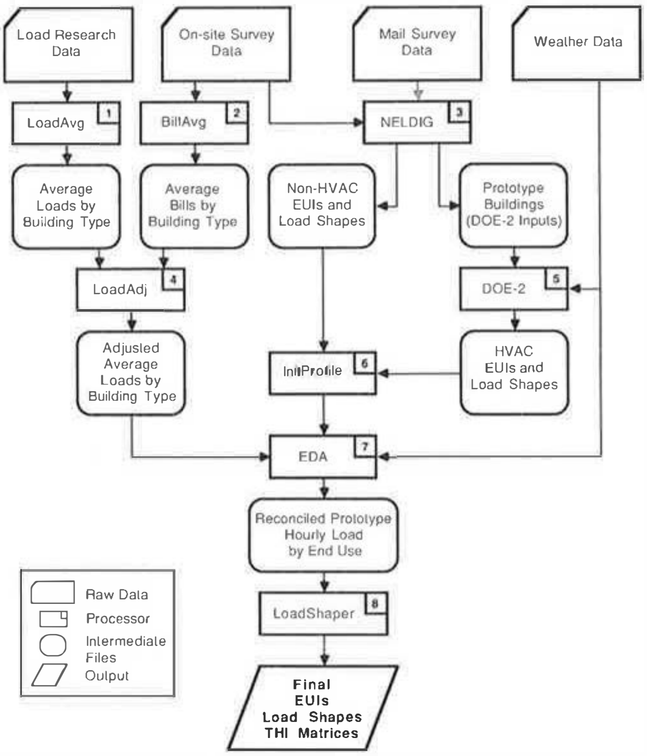

Figure. Integrated LS and EUI Estimation Methodology: The methodology has four major steps: 1) development of initial prototypical LSs and EUIs, using the on-site survey and mail data. Two utility programs, Non-HVAC **EUI/LS** and **DOE-2 Input Generator (NELDIG)** (estimates LSs and annual EUIs for non-HVAC end uses and prepares prototypical building input data for DOE-2 simulations) and initial profile generator, **InitProfile** (combines DOE-2 and NELDIG outputs to prepare initial estimates of hourly end-use loads), are used for this purpose; 2) construction of average hourly loads for prototype buildings using the monthly billing data and load research data. Three programs are developed for this second process: **BillAvg** (computes the average utility bills by building type from the on-site survey billing data), **LoadAvg** (computes the average hourly whole-building loads by building type from LRD), and **LoadAdj** (computes the average hourly whole-building load as normalized by average utility bills); 3) reconciliation of the initial end-use data from the first step with the average hourly loads from the second step using the **E**nd-use **D**isaggregation **A**lgorithm (**EDA**); and 4) summarizing the reconciled hourly end-use data in the form of representative monthly load shapes, using a program called **LoadShaper**. (XBL-8811-3881) service area without undertaking extensive studies such as a conditional demand analysis or end-use metering.

Two approaches were used to develop the EUI specifications for each end-use and business type combination studied. First, previously published EUI studies for the commercial sector were analyzed. An averaging procedure of selected studies yielded the non-weather-sensitive EUIs. Second, the 1979 Nonresidential Building Energy Consumption Survey data set was used to estimate weather-sensitive EUIs. A conditional demand analysis performed with this data set obtained heating and cooling EUIs as a function of building characteristics, operating conditions, and climate parameters.

The end products of this project are a spreadsheet program, a users guide, and an EPRI report.[1] The spreadsheet program, developed with the Lotus 123® software, calculates a matrix of EUIs for eight electrical end-uses for eleven building types. The Figure shows the flow diagram describing how the spreadsheet works. Any utility using this tool can either provide input data specific to the commercial buildings in their service territory or, in the absence of such information, use the default data provided in the software for their census region. The program also allows the user to plot bar graphs of EUIs by building types. The report provides comparisons between the EUI predictions of the program with those EUIs estimated in several electric utilities' conditional demand studies.

The spreadsheet will be used nationwide by utilities already using the COMMEND model. Several improvements have been proposed to the existing program, such as adding sensitivities of the EUIs to new parameters and adding algorithms to calculate EUIs for natural gas use.

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Comparative Assessment of the DSM Plans of Four New York Utilities

C. Goldman and E. Kahn

In April 1988, New York's seven investor-owned utilities filed their first long-term Demand Side Management (DSM) Plans in response to a Public Service Commission (PSC) order. The PSC invited LBL researchers in DOE's Least Cost Utility Planning project to assist Commission staff in reviewing the utility's long-term demand-side resource plans. The principal research objective was to identify the most important least cost utility issues facing public utility commissions based on actual experience gained from working with commission staff.

Comparing the DSM plans of four utilities—Consolidated Edison, Niagara Mohawk, New York State Electric and Gas, and Rochester Gas and Electric—we assessed the potential impact of DSM programs among utilities by the year 2000 (Table). The initial DSM plans of all four utilities are modest in terms of the contribution of DSM options to reducing total system peak load in the year 2000 (3-7%). Expected savings from DSM programs range between 0-50% of the peak load growth projected for that period. However, we believe that the key indicator is "utility commitment," which reflects the utilities' stated willingness or actual commitment of dollars to implement new large-scale DSM programs in the near-term. Several utilities believe that the uncertainties associated with DSM programs are too high to justify major investments.

All four utilities identify commercial lighting as an end-use with cost-effective DSM options. Of the four utilities, only Con Edison identifies other DSM options applicable to commercial buildings (e.g., motors, thermal cool storage, efficient air conditioning replacement, curtailable electric service). In the residential sector, the summer

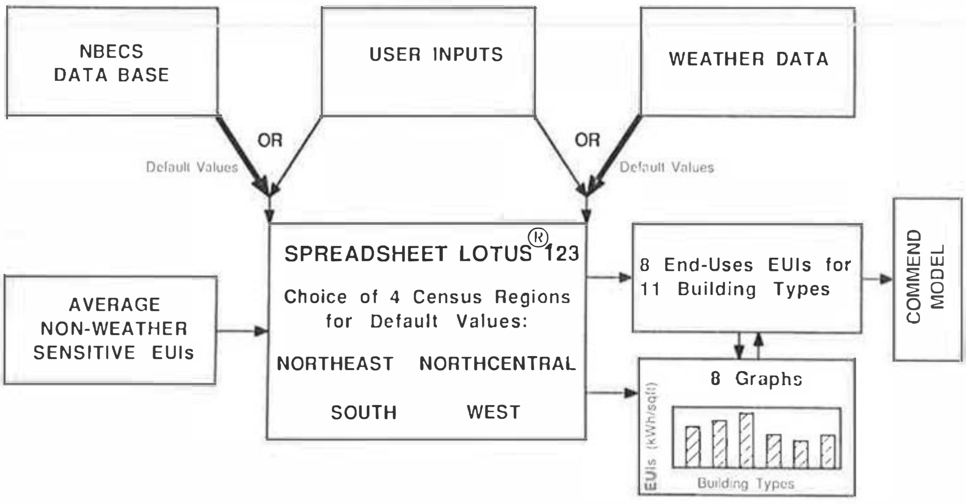

Figure. Flow diagram describing how the spreadsheet works. (XBL-8810-3741)

Table. Potential impact of demand-side management programs

	1987 Peak Load (MW)	Projected Load Growth to 2000 without DSM	DSM Impact Indicators Peak Load Reduction due to DSM (MW)	% of Peak Load Growth	% of Peak Load	Utility Commitment[a]
Con Ed	9400	2092	742	36%	6.9%	A
RG&E	1205	255	0-105	0-41%	0-7.5%	P
NYSEG	2477	769	116	15%	3.6%	A
NiMo	5800	500	0-250	0-50%	0-4.0%	P

Con Ed and RG&E are summer peaking; NYSEG and NiMo are winter peaking utilities.
[a] P = planned; A = action on some programs

peaking utilities (Con Ed and RG&E) found that replacing existing room air conditioners with high-efficiency equipment and peak clipping measures (e.g., direct control of room air conditioners and pool motors) were cost-effective DSM options. Winter-peaking utilities (NYSEG and NiMo) favored load-shifting DSM options (e.g., direct control of water heating and residential thermal storage).

We also identified the most important data and analysis needs for regulators trying to evaluate DSM plans: improved stock characterization, explicit treatment of Qualifying Facilities (QFs) in resource mix, comprehensive assessment of the achievable potential for DSM options for all end uses and sectors, research on customer response and other information relevant to DSM options (load shape impacts, incentives required to achieve certain penetration rates), and projections of avoided costs. More reliable data are available on DSM options for the residential sector than for the commercial and industrial sectors.

Our analysis also suggests that the PSC and utilities must resolve several thorny analytical and methodological problems that hinder DSM program implementation. For example, the utilities used varying economic tests for initial screening and final selection of DSM options. The PSC may need to develop a more explicit treatment of the role of various economic tests in DSM program evaluation. In addition, the utilities were particularly concerned that DSM programs would lead to substantial near-term revenue losses. Thus, the timing of DSM programs is a particularly critical issue: programs and incentives should be selected that meet the twin goals of minimizing short-run negative rate impacts while preparing for long-run expansion of DSM programs. Finally, because New York utilities are members of a centrally-dispatched power pool, DSM options should be evaluated from the perspective of optimizing benefits for the New York Power Pool. Several utilities are assessing the costs and benefits of DSM options from their individual perspectives only; for winter-peaking utilities, this approach understates the benefits of DSM measures that could reduce the Power Pool's summer peak load.

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Energy Use and Efficiency of Electronic Office Equipment

J. P. Harris

Electronic office equipment, including personal computers (PCs), minicomputers, printers, copiers, fax machines, etc., represents a fast-growing but poorly understood component of the "other" end-use in commercial buildings. This study attempts to establish office electronics as a distinct end-use, by characterizing electricity usage, trends, and efficiency opportunities. We can think of this equipment as the office equivalent to industrial process equipment; in office buildings the main "process" is the production, use, storage, and transmission of information. Except for space conditioning and lighting, information processing is the major user of energy in office buildings (up to 20% of total daytime electricity use).

Typical daytime loads from office equipment (10-20 W/m^2) are about equal to lighting loads in a well-designed new office. We measured actual power use for selected office equipment, and found that it was only 20-40% of nameplate ratings. Thus, estimates of energy use or cooling loads based on nameplate ratings are overstated. Power use varies widely for office equipment with similar functions. In particular, desktop PCs use about ten times the power of equivalent laptop models. It is often the input/output (I/O) devices (terminals, printers, scanners, fax), rather than computers themselves, that are the major power users. Future load growth depends on many market and technical factors. U.S. office equipment electricity use in 1995 could range from 130 TWh ("market saturation," current technology, expanded use of computerized printing), to about 25 TWh if today's most efficient hardware and operating systems become the norm (see Figure).

There is significant potential for improved energy efficiency in both hardware and software. Several policy options could accelerate market and technical trends (e.g., miniaturization, portability). Examples include energy efficiency labeling of hardware and software, and creative use of government purchasing power. In the longer term, better-integrated information management systems may finally introduce the "paperless office," with major impacts on both energy use and office productivity.

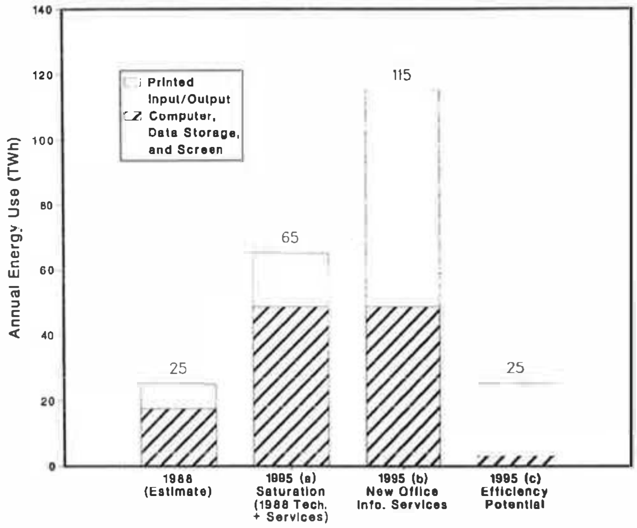

Figure. Alternative load growth scenarios for office electronic equipment in the U.S. The 1988 estimate is based on 25 million "screens" serving 60 million white-collar workers, averaging 200 W/user (equivalent to a PC workstation or shared mini- or mainframe, plus screen and peripherals) and 5000 hours/year operation. The 1995(a) scenario assumes today's hardware efficiencies and usage, with full "market saturation" (65 million screens). The 1995(b) scenario shows the impact of new information services, e.g., increased I/O using computer-generated or -scanned hard-copy. Power requirements for I/O increase from 50 to 200 W/user, nearly doubling total energy use. The 1995(c) scenario ("technology potential") assumes universal adoption of today's most efficient hardware and operating systems. This reduces power from 150 to 15 W/user for computers, and from 200 to 100 W/user for I/O. Better control of idle-time would reduce average operating time to 3000 hours/year, bringing total U.S. electricity use for office electronics back to today's 25 TWh. (XBL-8810-3602)

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EMCS for Utility/Customer Interface

H. Akbari, M. Goralka, and K. Heinemeier

Energy Management and Control Systems (EMCS) are being installed at an accelerating rate in new and retrofitted commercial buildings. We have explored the capabilities of EMCS for use as an interface between electric utilities and their customers for both real-time pricing and end-use data monitoring of commercial buildings. Our research, sponsored by the Pacific Gas and Electric Company, indicates that currently-sold EMCSs are intelligent enough to perform these applications, but lack the necessary software communication features and installed metering capacity for any large-scale effort with real-time pricing or data monitoring.

We have demonstrated the feasibility of the above goals by 1) performing a detailed review of previous LBL studies that demonstrate the concept of remotely collecting data from EMCSs, and 2) conducting a real-time pricing simulation.[1] From these demonstration projects, we developed specifications recommending the necessary EMCS system hardware and software features which could be incorporated into current EMCS.

Typical EMCSs sold today are fundamentally different from machines sold just four to five years ago. A typical large EMCS (see Figure) has three components: a local control module (LCM) which is directly wired to the sensors and relays, a field processing unit (FPU) which makes control decisions, and a personal computer interface. An important feature of the typical system is its modularity. The most powerful EMCS installations have all three components, but often only a FPU or a LCM is necessary for more limited applications such as controlling a single air conditioning unit. Thus, each of these components is capable of stand-alone operation without the other, higher level, components.

The utility's main interest in commercial monitoring is to obtain end-use data for forecasting commercial energy consumption and estimating how this consumption can be predictively modified to decrease the utility's net cost of

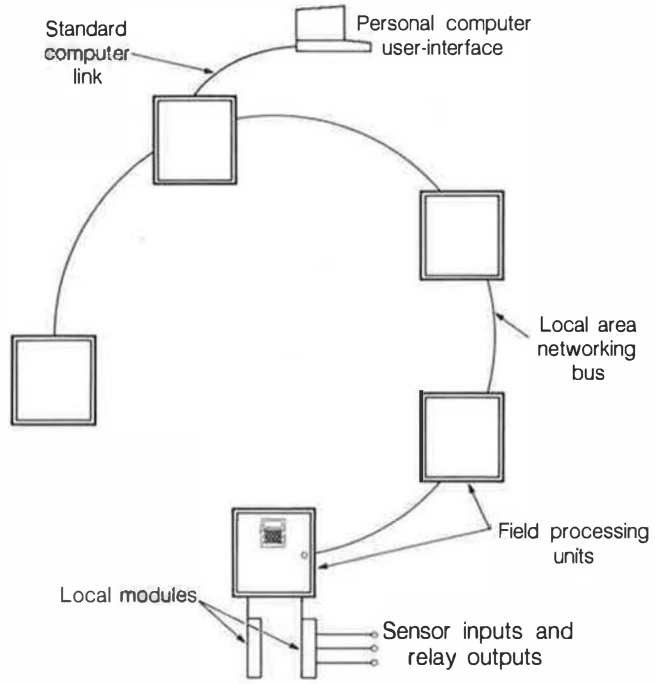

Figure. Architecture of a typical large EMCS. A typical large EMCS has three components: a local control module (LCM), a field processing unit (FPU), and a personal computer interface. (XBL-8810-8581)

services or enhance revenues. Performing this analysis requires end-use intensities and load-shape data for use in utility planning. Utilities use these data in their long- and short-term energy and peak demand forecasts, conservation and load management assessments, marketing assessments of the best end-uses to sell, capacity planning for transmission and distribution, cost-of-service/rate design for profitable end-uses, and modeling the effects of fuel substitution.

EMCSs could easily provide the information required for these analyses. Some modifications of the current systems would be required, however. If these modifications can be accomplished, a wealth of information would be available to a utility. A significant fraction of all commercial buildings already have EMCSs installed to control their HVAC equipment. The data collection process would involve a communications link, where either the EMCS automatically downloads data to a utility over a phone modem, or a utility calls up the EMCS for interrogation of the data.

The use of EMCSs in commercial buildings under real-time pricing would enable customers to adjust their demand automatically in response to fluctuating prices. The process would involve establishing a communications link between the utility and the customer's EMCS. Once a day, the utility would send an hourly price schedule to the building's EMCS. The EMCS would then use the price data to automatically instigate control strategies intended to minimize energy consumption during hours with high prices. In this way, the customer can minimize energy bills with a minimum effort and the utility will see a reduced demand during peak periods and other times when power is most expensive to produce.

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Field Measurement of Heat Island Data

H. Akbari, L. Rainer, and H. Taha

Although the existence of urban heat islands has been known for many years, actual measured microclimate data to quantify this effect has been limited. There has been little simultaneous multiple-site measurement of microclimatic data over long time periods. These long-term data are required to validate and improve the numerical models for predicting the impact of heat islands on cooling energy use.

Two major field studies, one in Davis, CA and one in Sacramento, CA, were carried out by the "Heat Island Project" at LBL.[*] Both studies have yielded valuable heat island data.

In the Davis project, a well-defined tree canopy (i.e., an orchard) surrounded by open space was transected with eleven weather stations that measured dry-bulb and dew-point temperatures, wind speed, and wind direction at 1.5m above the ground. Data were collected at fifteen-minute intervals for two weeks starting on October 12, 1986. The main objective was to quantify the effects of vegetative canopies on micro-climates and in particular their creation of an oasis effect during daytime. Data were studied to analyze the variation of air temperature and wind speed within the canopy. Figure 1 shows a typical daytime air temperature traverse across the orchard. On average, the canopy was about 2°C cooler than the open fields.

Whereas the Davis project dealt with microclimatic changes within a single orchard with a grid spacing of ~100 m, the Sacramento project attempted to extend this measurement to a whole city with a grid spacing of ~1 km. In this study, the weather stations were distributed throughout Sacramento in 15 residential locations with a

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[*] This work was supported in part by a grant from University-wide Energy Research Group, University of California, Berkeley.

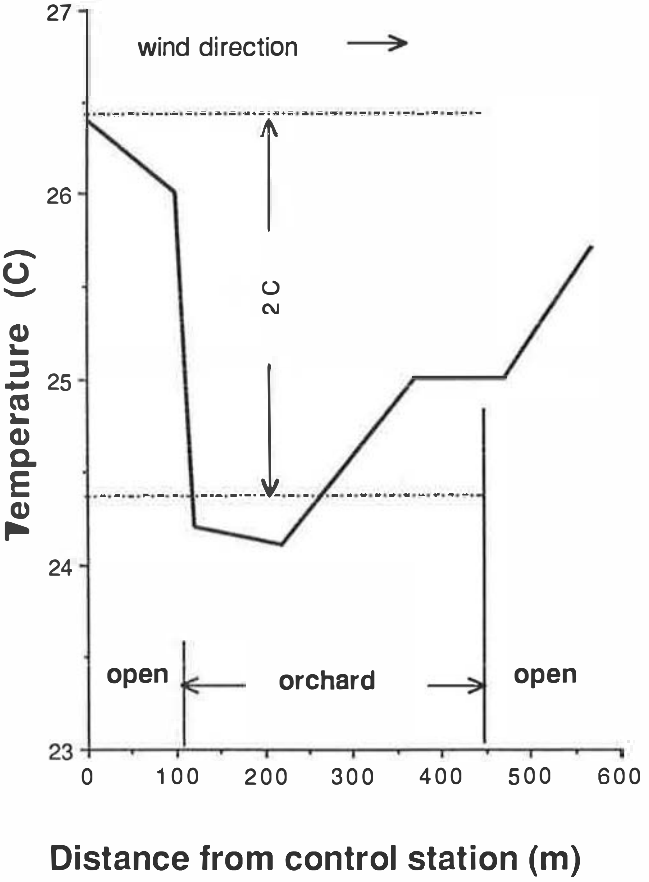

Figure 1. The average effect of trees on the drybulb temperature at 3 PM during October 1986 in Davis, CA. (XBL-8811-3895)

variety of tree cover. Half-hourly data were recorded for each of these sites from July 16 through September 19, 1987. Additional weather data, including cloud cover, were collected using a computer weather monitoring network located at four local airports.

The Sacramento data have been analyzed in two ways. First, they were analyzed to quantify the effect of local characteristics such as tree cover and skyview factor on the local climate. Regression equations were then developed relating inter-site temperature differences to these local characteristics and daily weather factors such as temperature, wind speed, and wind direction. Secondly, the data were analyzed to extract an overall picture of the summer heat island and its changes throughout the day. As an example, Figure 2 shows the temperature contour on a hot August day. The temperature varies from 35°C downtown to 30°C in some of the outlying neighborhoods. Further analysis of the data shows that heavy tree cover can reduce the effect of urban heat islands by as much as 3°C.

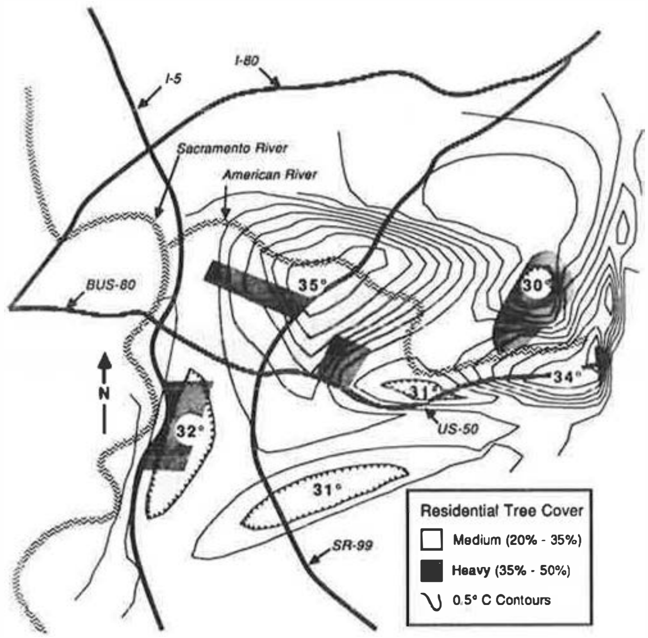

Figure 2. Heat island temperature contours at 4 PM on August 5, 1987 in Sacramento, CA. (XBL-8812-4076)

Analysis of Residential End-Use Load Shapes

H. Ruderman, J. H. Eto, K. E. Heinemeier, A. Golan, and D. Wood

Over the past ten years, the California Energy Commission (CEC) has developed models to forecast electricity demand and peak loads in the state.[1] The models use individual end-use daily load shapes to calculate hourly loads on peak days for both weather-sensitive and non-weather-sensitive end uses. Our project, sponsored by the CEC, analyzes available metered data on end-use load shapes to refine the current estimates used in the CEC peak demand models. Initial emphasis has been placed on residential loads because of data availability; future work will concentrate on non-residential end uses. The project will also assist the Commission in laying the groundwork for transforming their peak demand models into models that forecast hourly loads throughout the year, relying on LBL's experience in constructing and validating its Residential Hourly and Peak Load Model.[2]

Since the project began in the summer of 1987, we have collected metered residential end-use data from the three largest electric utilities in California. End uses were classified as conditioning (space heating and cooling) or non-conditioning (water heating, cooking, refrigeration, etc.); each group was analyzed by different techniques. For non-conditioning end uses, we aggregated the metered data into monthly and seasonal energy consumption profiles and then constructed daily load profiles for weekdays and weekend days for each season (see Figure). For conditioning end uses, we constructed matrices showing average load as a function of time of day and of outdoor temperature (or temperature-humidity index). We devised a new fitting procedure to describe the average load as a function of time and temperature suitable for use in residential load models. To our knowledge, ours is the first analytic expression developed to describe the behavior of space conditioning equipment. A final report to the CEC describing data sources, analytic methodology, and results will be written in FY 1990. Revised load shapes will be incorporated in the LBL Residential Hourly and Peak Load Model.

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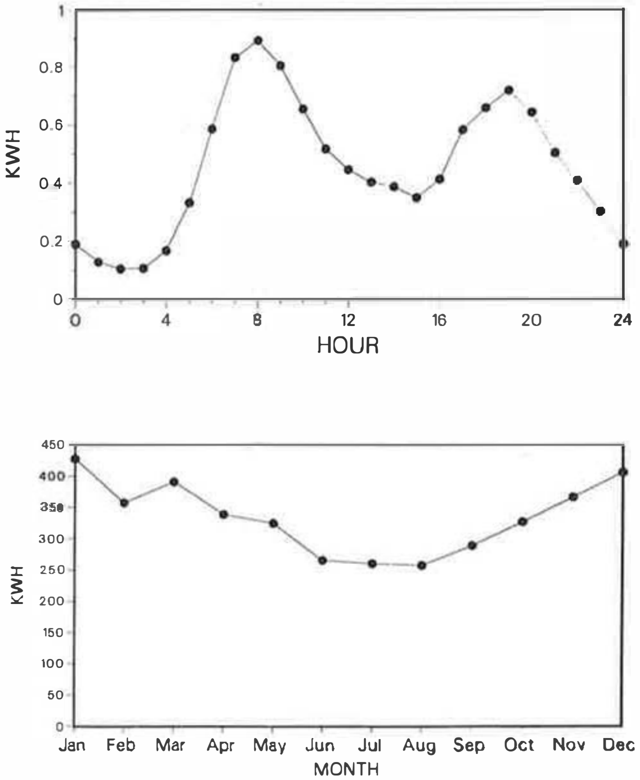

Figure. Average daily and monthly load shapes for water heaters. (XBL-8810-3589)

Analysis of Federal Appliance Efficiency Standards

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

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 provides for periodic update of the standards by the Department of Energy. LBL is responsible for an integrated analysis of the impacts of these appliance efficiency standards. The research involves a detailed assessment of the impacts on consumers, manufacturers, electric utilities, and on the nation as a whole. Work during FY 1988 focused on providing analytic support for DOE's rulemaking on two groups of products: (1) refrigerators, freezers, small gas furnaces, and television sets; and (2) dishwashers, clothes washers, and clothes dryers.

Our analysis has four major components: (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 analysis 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. The Figure shows how the parts of the analysis are interrelated and how they fulfill legislative requirements for evaluating the impacts of standards. The following three articles provide more detailed information on how the Engineering, Consumer, and Manufacturer Analyses are performed.

The analysis of standards on refrigerators, freezers, small gas furnaces, and television sets was completed in the first quarter of FY 1988. We documented the methodology and results of the analysis in the Technical Support Document[2] published by DOE with their Notice of Proposed Rulemaking. Major improvements were made in the utility and environmental parts of the Impact Analysis for refrigerators and freezers. The utility analysis evaluated avoided utility costs, lost revenues, and generating capacity deferrals that would result from imposition of standards. In addition to estimating the reduction of power plant emissions, the environmental assessment examined changes in chlorofluorocarbon use in these appliances. We also focused on the competition between electricity and gas in the small furnace market.

To analyze the impacts of possible amended standards for clothes washers, clothes dryers, and dishwashers, we collected data on the cost and efficiency of design options

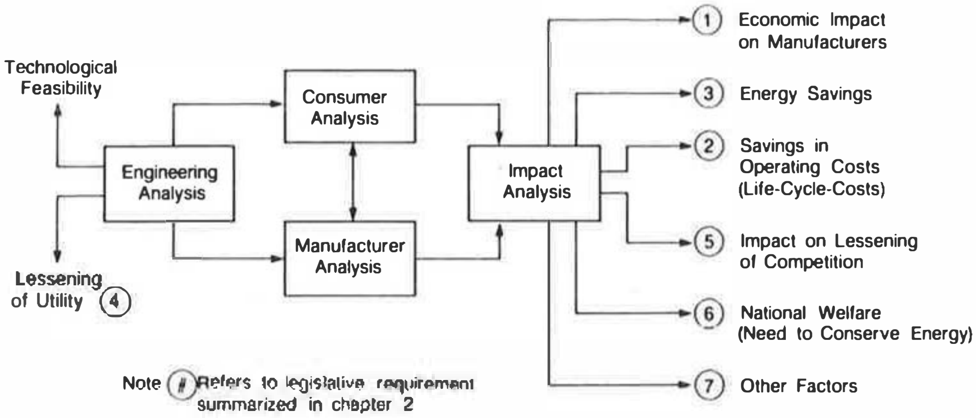

Figure. Satisfaction of legislative requirements through the analysis process. (XBL 856-8918)

for improved efficiency of these products. We modified the LBL Residential Energy Model to take into account changes in water heater energy consumption when the efficiency of clothes washers and dishwashers is increased. Analysis of these three products will continue in the first quarter of FY 1989, emphasizing the estimated reduction in water use and the cost of water and waste treatment that would occur if certain design options were employed.

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Engineering Analyses of Appliance Efficiency Improvements

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

The economic impacts of appliance efficiency standards depend largely on the relation between cost and energy consumption of a consumer product. Our engineering analysis seeks primarily to identify this cost-consumption relation for selected appliances. In FY 1988, we analyzed refrigerators, freezers, televisions, small gas furnaces, dishwashers, clothes washers, and clothes dryers, addressing two legislative requirements: to estimate the maximum technologically feasible efficiency levels that are possible and to ensure that new designs do not lessen consumer utility.

Our analysis selects appliance classes, baseline units, and design options, determines maximum technologically feasible designs and the efficiency improvement provided by each option, develops cost estimates, and generates price-efficiency relationships. We have studied 10 classes of refrigerators and freezers, as well as two classes each of televisions, small gas furnaces, dishwashers, clothes washers, and dryers. Many design options were studied for each product class[1]. For refrigerators and freezers, a computer simulation model was used to estimate energy use under different design options. We also evaluated the energy consumption impact caused by using only those design options that did not increase the baseline amounts of chlorofluorocarbons (CFCs).

We developed energy consumption data for other products by using test data from various sources, manufacturer-provided data, and engineering calculations. Manufacturer costs were obtained from data submitted by manufacturers and from component suppliers. These costs were disaggregated into labor, materials, purchased parts, tooling and capital costs, and shipping and packaging.

The results of the simulation analyses for a top-mount automatic-defrost refrigerator-freezer are shown in the Figure. Simulations were performed under two scenarios. The cross-hatched bars in the Figure show energy use for design options which allow the amount of CFC-11 to increase above that in the baseline case unit. The white bars exclude options 2, 6, 9, and 10, which require increases in CFC-11.

In FY 1989, we plan to complete the engineering analysis for dishwashers, clothes washers, and clothes dryers. We will also evaluate other design options such as higher spin rpm for clothes washers, simultaneously considering washers and dryers in order to compute benefits. We will also respond to public comments on Notices of Proposed Rulemaking.

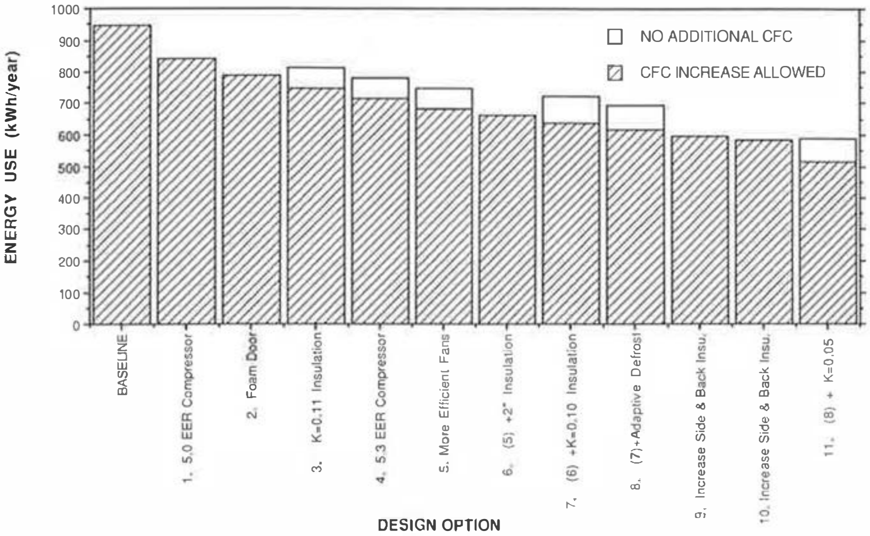

Figure. Energy use of a top-mounted auto defrost refrigerator-freezer for various design options (adjusted volume = 20.8 cu.ft). (XBL-8810-3614)

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Assessment of Impacts of Appliance Standards on Manufacturers

S. Stoft, P. Cunliffe, and J. Hobart

The Manufacturer Analysis determines the impact of appliance standards on the the profitability and competitiveness of the various appliance manufacturing industries. It also provides estimates of retail prices that are used by the Residential Energy Model (LBL-REM) and the life-cycle cost analysis. The Manufacturer Impact Model (LBL-MIM) uses engineering cost and efficiency estimates as well as economic and financial data that we collect to generate the necessary predictions for this analysis. Besides price and rate of profit, these include shipments, revenues, and net incomes, as well as standard errors on of all these.

In the first half of FY 1988, we completed the new version of the LBL-MIM and automated its running. It now does all of the Monte Carlo calculations, scenario evaluation, and production of tables for the Technical Support Document (TSD) automatically. After completion, it was used to analyze impacts of possible standards on the manufacturers of refrigerators, freezers, televisions, and small gas furnaces, and to produce the appropriate tables for the TSD. In general, LBL-MIM showed that approximately all increases in manufacturing cost would be passed on by manufacturers to consumers. For some standards levels, markups were observed to increase slightly, causing an increase in profits, while for other levels a decrease in profits was observed.

During the second half of FY 1988, one major improvement was made which affects the Manufacturer Analysis and, once it has been fully extended to LBL-REM, will allow greater compatibility between LBL-MIM and LBL-REM. This involved changing the demand specification from one that implies constant price elasticity to one that implies constant life-cycle-cost elasticity. Consequently, the price elasticity now changes slightly as both the price and operating cost of an appliance change. Since price elasticity determines the manufacturer's markup, these elasticity effects, though small, can have a significant effect on a manufacturer's profits.

We also collected data on the dishwasher and laundry products industries. This included a survey of the industries, developed by us and administered by AHAM, a meeting with consultants from the dishwasher industry, and a visit to a major manufacturer. Finally, we completed our initial analysis and the initial draft of the TSD for these products.

Residential Energy Demand Forecasting

J. E. McMahon and P. Chan

The LBL Residential Energy Model (LBL-REM) provides estimates of the impacts on consumers of federal policies affecting energy consumption by home appliances, including furnaces and air conditioners. LBL-REM combines engineering estimates of possible appliance designs with a simulation of market behavior for the purchase of appliances, including fuel choice, efficiency choice, and usage behavior (see Figure).

The LBL-REM has been improved this year by: incorporating the effects of the National Appliance Energy Conservation Act (NAECA) of 1987 into the base case; modeling the interactions between internal loads (e.g., waste heat from refrigerators) and space conditioning energy use (heating and cooling); directly using discrete design options from engineering analyses, without any smoothing or curve fitting (new data became available for refrigerators, refrigerator-freezers, freezers, and some new sub-markets listed below); and explicitly modeling the individual sub-markets for small gas furnaces, dishwashers, clothes washers, and televisions (none of which were previously analyzed).

The model was used to perform several analyses of impacts of federal policies on consumers and on national energy consumption, including: regional impacts of the NAECA; possible new conservation standards for small gas furnaces, televisions, and dishwashers; and possible updates to conservation standards for refrigerators, refrigerator-freezers, freezers, clothes washers, and clothes dryers.

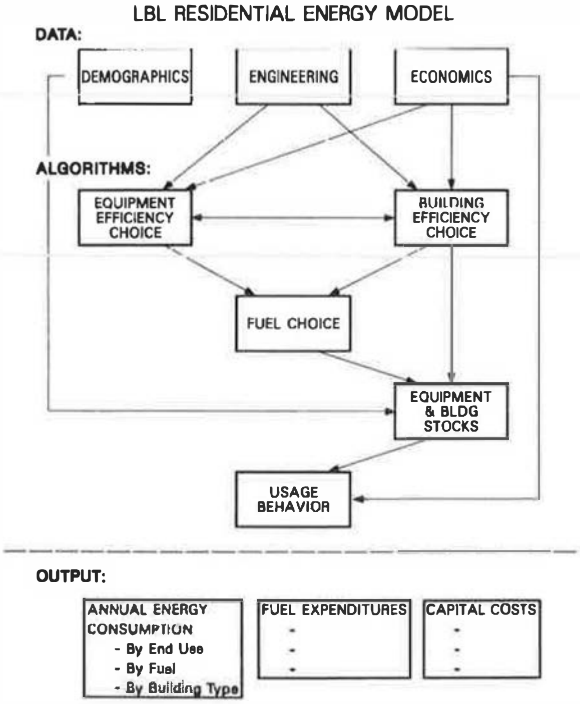

Figure. Logic diagram showing major components of LBL Residential Energy Model. (XCG 8412-13510)

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

We plan to continue to model impacts of any proposed federal conservation standards, including incorporating into LBL-REM any new data from public comments on the proposed rules for dishwashers, televisions, and small gas furnaces, and on updated standards for refrigerators, refrigerator-freezers, freezers, clothes washers, and clothes dryers. A new water heater algorithm will be formulated to take into account hot water use by clothes washers and dishwashers. A new feature will be estimates of impacts of federal energy conservation standards on residential water consumption and on water and sewage costs. The future analysis of room air conditioners, water heaters, direct heating equipment, and pool heaters will be performed on a regional basis. We will continue improving the consumer analysis and forecasting capabilities of LBL-REM.

The Regional Energy and Economic Impacts of Appliance Efficiency Standards

J. H. Eto, J. E. McMahon, J. G. Koomey, P. T. Chan, and M. D. Levine

While nationwide analyses performed by LBL overwhelmingly support the cost-effectiveness of appliance efficiency standards, the regional impacts of the standards have never been examined. These impacts will vary greatly due to regional differences in climate, appliance stocks/saturations, energy costs, and demographic trends. In the present work, we use an end-use energy demand forecasting model to assess the energy, peak demand, and economic impacts of the standards for the ten DOE planning regions of the continental U.S.

We find that the standards will save the nation nearly \$25 billion (in 1987 dollars) in cumulative net present benefits to 2015. The savings consist of reductions in electricity generation of 800 TWh and in direct fuel use of almost 2 Quads.

We find that the largest absolute and percentage electricity savings will occur in the South Atlantic and Southwest DOE regions due to both the high saturation of air conditioning and the relatively greater cooling loads found in these climates. Conversely, we observe the lowest percentage electricity savings in New England due to lower air conditioning saturations and smaller cooling requirements.

Percentage savings for all other fuels are relatively modest and uniform across all regions with the exception of the Northwest region where we predict fuel use will increase slightly. In the Northwest, NAECA has the effect of reducing the attractiveness of electricity as a heating fuel because heat pumps (25% of electric heating appliances) become too expensive relative to expected annual heating requirements. In this situation, fossil fuel furnace sales increase, leading to increasing consumption of other fuels.

The analysis is of special significance to electric utility planners because the end-use model we employ shows how the structure of demand will be affected by the standards. For example, we find that, while overall air conditioning equipment sales will change only slightly, sales will shift away from central air and heat pumps in favor of room air conditioners. For water heating appliances, we find that electric water heating sales will increase at the expense of other types of water heating equipment. These effects are small nationwide, but can be significant in some regions.

The end-use detail of our forecasts also allows us to provide guidance to utilities considering rebate programs to stimulate the purchase of even more efficient appliances. We find that only modest rebates ($50-$100/unit) will be needed to stimulate the purchase of more efficient central air conditioners, but that utilities must distinguish between models that do and do not save electricity peak demands. In order to encourage purchases of more efficient refrigerators, we find that a rebate must offset almost the entire incremental cost of the efficiency improvement.

Research and Policy Studies to Promote Building Energy Efficiency in Southeast Asia

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

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

Several on-going assistance programs have continued through this past year. First, workshops in building energy audit procedures have been given in ASEAN for several years by LBL consultants. Second, assistance has been provided to several countries in developing energy conservation standards for new commercial buildings. Malaysia is in the process of adopting a new building standard for implementation. Thailand is also evaluating a similar standard that will be voluntary.

A policy options paper has been prepared to define a wide range of policy approaches that could be pursued in addition to building energy standards to reduce energy use in buildings.

The most important new activity of the project has been the development and implementation of research activities on building energy conservation in each of the ASEAN countries. These research efforts are summarized in the accompanying Table. These research activities, as they progress in each of the countries, will yield a deeper understanding of energy use in ASEAN buildings. This in turn will provide a sound technical basis for effective policies to reduce energy use in buildings.

[†] The countries are Indonesia, Malaysia, the Philippines, Singapore, and Thailand.

Table. ASEAN in-country research projects

Country	*Project Title*	*Description*
Indonesia	Policy	Review existing building regulations; conduct building audits; develop energy conservation policy for buildings.
Indonesia	Survey of Energy Use In Hotels and Simulation Studies	Audits of hotels and other commercial buildings; energy analysis using computer simulation tools (DOE-2 and ASEAM.2) to determine cost savings.
Indonesia	Weather/Solar Radiation Data	Collect hourly solar and weather data in Bandung and Jakarta; analyze weather data; develop typical weather year and prepare in DOE-2 format.
Indonesia	Control and Monitoring of Commercial Buildings	Review existing buildings with energy management and control systems (EMCS) in place; review economies and energy savings of retrofit measures; upgrade existing EMCS with new controls and monitoring equipment and monitor building energy use.
Malaysia	Utility Policy	Measure building hourly load profiles using UPLAN simulation code; analyze short- and long-term marginal costs for utility; analyze commercial conservation/load management effects on load shapes; conduct financial analysis of costs, tariffs, and marketing strategies; analyze overall implications for future utility policy.
Malaysia	Chiller Optimization and Control	On-site study of buildings with building automation systems (EMCS) in place; simulate performance of these buildings; compare simulation results with actual.
Malaysia	Energy Audit Studies and Development of Energy Conservation Requirements for Malaysian Buildings	Analyze results of audit survey of 10-12 buildings using ASEAM.2; analyze and revise OTTV equation using solar radiation data; perform DOE-2 studies; assess economics of implementation of standards on existing buildings.
Malaysia	External Shading of Windows	Survey and tabulate use of external shading devices on existing buildings; build physical model to analyze effectiveness of shading devices; correlate results to those of DOE-2 simulations for selected devices; develop shading schedules for DOE-2.
Malaysia	Administration and Policy Studies	Survey 25+ existing government buildings and analyze results; identify possible targets for energy conservation measures; study effect of implementation of policy on existing government buildings.
Philippines	Lighting and Daylighting	Survey and compile results of actual lighting and daylighting conditions in 20+ buildings, including survey of behavioral response to daylight and artificial light; study daylight geometrics, such as glare and brightness imbalance; develop DOE-2 daylight simulations; set up controlled physical models for monitoring.

Country	*Project Title*	*Description*
Philippines	Forced and Natural Ventilation	Survey and compile results of actual air conditions and thermal comfort in 12 buildings; correlate ESPAIR computer simulations with findings of survey; prepare design guidebook for natural ventilation.
Philippines	Air Conditioning Equipment	Survey component cooling equipment in 50+ commercial buildings; study effects of air conditioning efficiency improvements using ASEAM.2, and for selected buildings, DOE-2.
Philippines	Performance of Typical Building Insulating and Reflective Materials	Perform correlation studies to determine heat transfer values of materials in non-air conditioned buildings and potentials for comfort conditioning and energy efficient design; establish U-values for typical building cross-sections of materials and components commonly used in the Philippines but not covered by ASHRAE; build test cell to test materials.
Philippines	Analysis, Assessment, and Policy	Survey building characteristics and energy use and also building managers' attitudes toward energy conservation investment; perform detailed energy audits of 50 buildings; study performance of cogeneration systems and investigate utility pricing policy affecting cogeneration use; perform DOE-2 and ASEAM.2 simulations in support of policy development including development of building energy conservation standards; analyze policy issues.
Singapore	Lighting and Daylighting	Extend existing lighting survey of 200 buildings to include industrial buildings and obtain more detailed data from existing 200.
Singapore	Energy Analysis Using DOE-2	Prepare new weather data for Singapore for use in DOE-2; evaluate OTTV equation and develop simplified expression for estimating energy use; assess and validate simplified energy estimation methodologies using survey data; develop algorithms for revised energy standards.
Singapore	Energy Management	Conduct energy measurements in existing buildings; compare results with simulation studies; evaluate energy conservation options; produce manual on energy management.
Singapore	Assessment, Analysis, and Policy	Verify solar correction factors based on a full year of solar data; study conductance heat gains through glass; verify ETDQ values for classification of construction—light, medium, and heavy. revise OTTV handbook; develop approach to the revised standards.
Thailand	Natural Ventilation	Collect and analyze weather data including solar data for Chiang Mai; Using ESPAIR simulation code, conduct natural ventilation studies; produce design guidebook on natural ventilation; organize dissemination workshop.

Country	*Project Title*	*Description*
Thailand	Lighting and Daylighting	Perform daylighting studies with DOE-2; evaluate daylighting availability in Bangkok; investigate various design methodologies; conduct experiment to compare effectiveness of installed daylighting controls in an office environment; organize in-country workshop.
Thailand	Air Conditioning Research	Perform parametric study of air conditioning system performance via simulation; evaluate actual performance of air conditioning equipment.
Thailand	Assessment, Analysis, and Policy	Perform audits and analyze data; formulate policies, develop standards and implementation package.

Global Biodiversity: Habitat Change and Species Extinctions*

W. E. Westman

Current concern about the global loss of species arises in part from the rapid rate of clearing of species-rich tropical forests. We are using satellite remote sensing to quantify rates and patterns of tropical deforestation, and are linking this information to predictions of species endangerment by use of field data and predictive models. Current efforts in a pilot study are focused on two tropical rainforest regions: southern Uganda, and northern Queensland, Australia.

In our work in Uganda,[1] using LANDSAT multispectral scanner (MSS) data, we found a net removal of 29% of the forest area in Mabira Forest Reserve during the period 1972-1988 (see Figure). During the same period, the edge-to-area ratio of the forest increased by 29%, and a maximum of 7% of the forest regrew in cut areas. We could also differentiate heavily-logged from lightly- or moderately-logged areas of forest using the MSS data. By linking this information to field-based studies, we could identify which two of seven primate species in the area were expected to thrive differentially under current patterns of forest disturbance.

In Queensland,[2] we conducted field work on the Atherton Tableland to examine how vascular plant species, and an indicator arthropod species (a giant centipede), respond to forest fragmentation over time. The research included an investigation of differences in attributes of plants growing on newer forest edges vs. forest interiors.

In future work, we plan to examine the impacts of forest clearing in Uganda on a larger regional scale using Advanced Very High Resolution Radiometer satellite data (1 km resolution), and to use predictive models from biological theory to predict regional impacts on the biota.

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

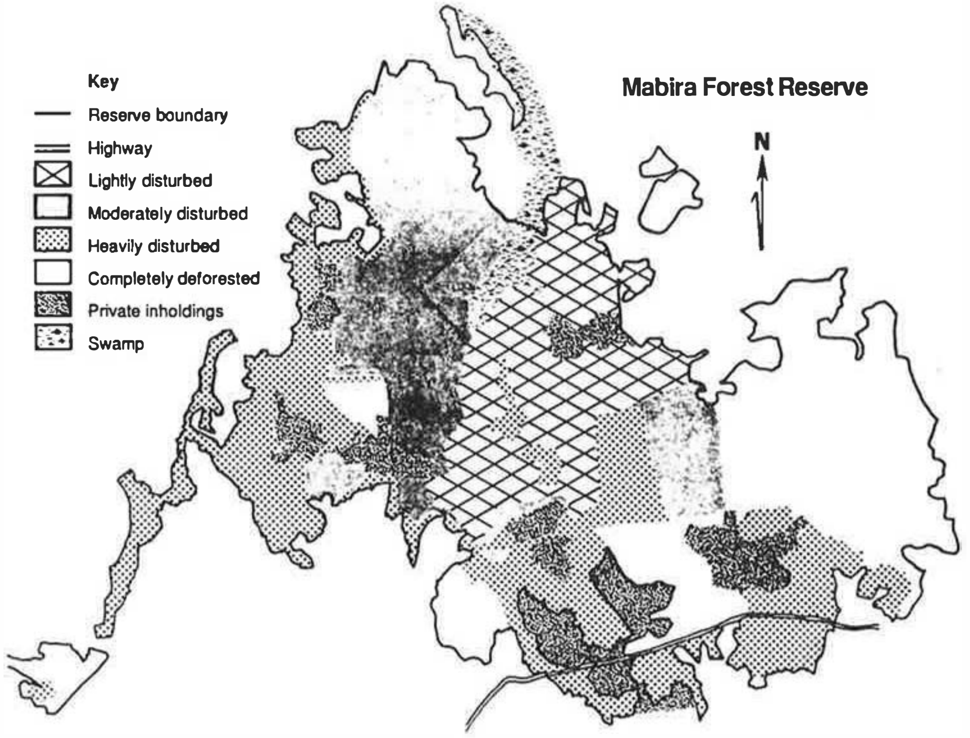

Figure. Mabira Forest reserve in southeastern Uganda, showing disturbance observed during a field survey in 1987-1988. (XBL-8810-3674)

Effects of Climate Change on Vegetation in California and Baja California*

W. E. Westman

General circulation models of global climate predict that California's climate will become warmer and wetter with continued buildup of carbon dioxide over the next century. By observing predicted climate changes for California in relation to existing climatic tolerances of vegetation, we made predictions of vegetation change using direct gradient analysis. We predicted that chaparral elements would expand at the expense of southern oak woodland and blue-oak digger pine woodland; that yellow-pine/mixed conifer and red fir forest elements would expand at the expense of subalpine forests in the Sierra Nevada, and that inland prairie and sage elements would expand into areas now supporting coastal sage and succulent scrub vegetation.

Higher summer temperatures imply an aggravation of ozone formation in coastal southern California. The effects of increased precipitation, increased temperature, and increased ozone levels on the coastal association (Venturan) of coastal sage scrub were examined under varying fire frequency regimes using a simulation model (FINICS).[1] Simulations of the combined effect of these changes (see Figure) indicate that long fire-return intervals (30-40 years) would be needed to maintain mixed-species shrub dominance. This could intensify conflicts between biodiversity goals and current fire hazard reduction practices involving prescribed burning at shorter return intervals.

Some early warning signs of changes in Venturan coastal sage scrub under increased evapotranspirative stress and elevated ozone may be inferred by comparing ecophysiological and morphological changes along a gradient in these parameters in the Santa Monica Mountains. As sites of elevated temperature and ozone are approached, early season leaves of the dominant black sage (*Salvia mellifera*) become larger and less dense, nitrogen and lignin concentrations increase, and the chlorophyll (a/b) ratio decreases. At both coastal and inland sites, reduced shrub cover increases the opportunity for growth of annuals, including exotic grasses.

We plan to expand our simulation modeling to include the behavior of the evergreen shrublands (chaparral) of California, and examine the relative abilities of the evergreen and drought-deciduous shrublands to thrive under future climatic alteration.

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*George P. Malanson, Dept. of Geography, Univ. of Iowa, collaborated in this work, which was sponsored by the Environmental Protection Agency.

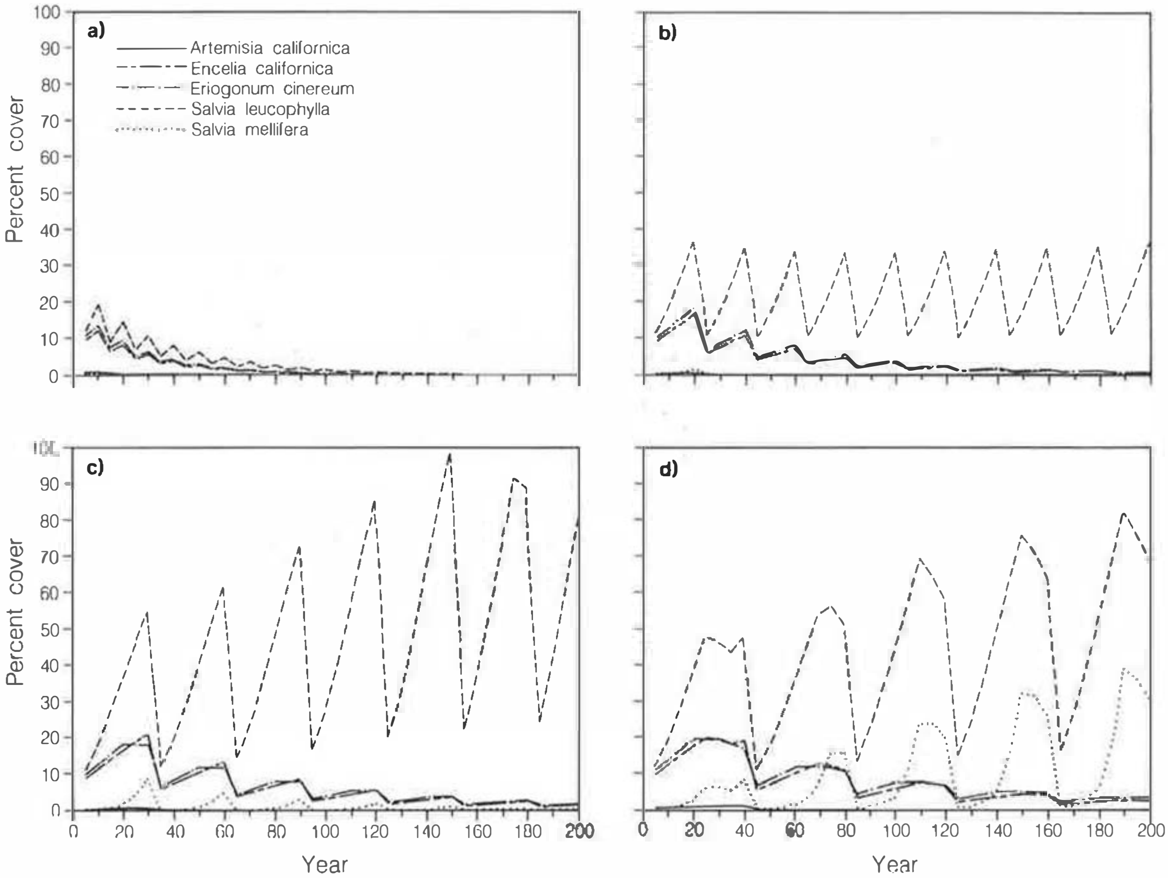

Figure. Changes in percent cover (y-axis) of five species of coastal sage scrub over time (x-axis) under FINICS model simulation, assuming plant growth under the altered climate of doubled carbon dioxide levels, increased ambient ozone, and higher fire intensities. a-d show responses to fire return intervals of 10, 20, 30, and 40 years respectively. (XBL 889 10424)

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Contribution of LDC Energy Use to the Global Climate Problem

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

Over the last century, the global atmospheric concentration of carbon dioxide and other "greenhouse gases" has increased substantially. This may have serious consequences for human well-being over the next century. Emissions from energy consumption are the single largest contributor to this effect. An examination of possible trends in energy consumption and the potential for its reduction is therefore crucial to any attempt to prevent or delay global warming.

We have explored the contribution of developing countries (LDCs) to the demand side of the problem.[1] We use information about energy and economic activity in the developing and developed countries to construct two basic scenarios for the year 2025 in five regions: Asia, China, Africa, Latin America and the Middle East. These are based on assumptions about economic growth rates, energy price trends, and population growth. We also construct two policy cases to examine the effect policies could have in reducing energy intensity and activity levels in the two basic scenarios. In analyzing energy demand, we examine five sectors in each region: industry, transportation, residential, commercial and agriculture. We establish measures of energy intensity (energy consumption per unit of activity) for each sector, and seek to understand the changes in structure of that sector that influence its energy intensity. We also examine the changes in the mix of fossil fuels (taken as a group), biomass, and electricity in each sector.

The Table gives the overall results by region for the rapid economic growth scenario. The results for non-LDC regions are derived from basic assumptions consistent with those used for the LDC scenarios. The results show the large shift in share of energy consumption from the industrialized to the developing countries. About half of world energy use takes place in the LDCs in 2025. Modern fuel use increases at 3.4% annually in the LDCs between 1985 and 2025. Almost 80% of the increase in fossil fuel combustion in this scenario occurs in the LDCs. Their contribution to carbon dioxide also increases in similar proportion.

It is estimated that such an increase in energy consumption will lead to a realized temperature increase of 2.5°C by 2050. To place this in perspective, the anticipated temperature rise of 1.5-4.5°C over the next 100 years is equivalent to the temperature increase that has taken place over the last 18,000 years.

We also construct scenarios where strong policies are adopted to control growth in energy use. These would lead to a temperature increase of about 1.5°C by 2050.

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European Electric Power Generation: The Role of Oil

D. Hawk and L. Schipper

Annual primary oil demand in European member countries of the Organization for Economic Cooperation and Development (OECD) declined by approximately 25% between 1973 to 1986. Nearly one-third of this decline is the result of the phasing-out of oil for use in electricity generation. In 1973 in France, Germany, Italy, England & Wales, and Sweden, oil was the first- or second-most important energy source for electricity generation—

Table. Energy demand in 1985 and 2025, all regions

		2025					
	1985	Rapid Scenario		R/Policy Scenario		GDP/Cap.	Pop.
Region	EJ*	EJ	% AAGR**	EJ	% AAGR	% AAGR	% AAGR
C-Planned Asia	29	96	2.9	77	2.4	3.8	1.0
Middle East	9	42	3.7	36	3.3	2.0	2.3
Africa	8	43	3.4	32	2.7	1.7	2.4
Latin America	19	72	3.3	56	2.7	2.8	1.5
S and E Asia	22	85	3.3	66	2.7	3.6	1.5
LDC Total	90	337	3.3	266	2.7	4.5	1.5
World Total	354	642	1.5	514	0.9	2.1	1.3

* 1 EJ is 10^{18} Joules, or about 23.9 MTOE, 0.5 MBDOE, or 0.95 quadrillion BTU.
** % AAGR = % average annual growth rate.
Note: Energy demand includes that for modern and traditional fuels.

generating between 14% to 59% of electricity produced. By 1986, oil use for electricity generation had declined to between 1.5% and 5.6% in all countries except Italy (39.4%), where oil is still being used for base-load generation. However, the oil generation facilities existing in 1973 are still in place and are operable (in various stages of reserve) and some oil-fired generation is used, primarily to meet peak load. Thus, the infrastructure that enables oil-based electricity generation remains in place, but the *intensity* with which oil is used has changed. This sector could trigger a large and quick rise in the demand for oil: a potential 25% increase in the total oil demand for these five countries. The Figure shows the huge increases in oil use by the power sector that would result if the oil-using capacity in each of these countries was used at its highest feasible level (capacity factors between 60% and 79%). The case 1 potential is calculated using only oil capacity. The case 2 potential is calculated using all of the oil-using capacity, which includes capacity with multi-fuel capability.

In England & Wales and Sweden, oil-based generation may soon increase above 1986 levels. In Sweden, oil-based generation will be used to bridge a supply gap that will result from the de-commissioning of nuclear power plants in the absence of new generation capacity to replace it. In England & Wales, a competitive environment introduced through privatization, the relative youth of the oil capacity, and the current low oil prices may cause oil-based electricity generation to have a competitive advantage, even replacing some coal-fired generation. Continued delays in the nuclear program would encourage the use of oil to bridge supply gaps until the nuclear capacity comes on-line or a different generation source is selected. In Italy and Germany, oil-fired electricity generation will likely remain relatively constant. Unless German law changes, no additional oil-based generation will occur. Only in France will oil-based generation decline.

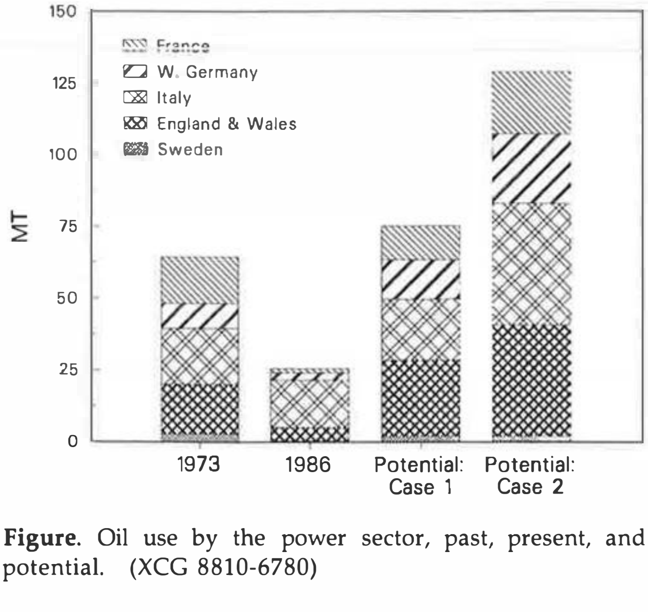

Figure. Oil use by the power sector, past, present, and potential. (XCG 8810-6780)

Although oil-fired electricity generation may increase above 1986 levels in the near future in some countries, the maximum potential levels of oil-based generation calculated in this report will not be attained in any of the countries *unless* a major electricity generation resource or technology suffers a severe, unforeseen disruption. In the absence of such a disruption, institutional barriers against dependence on oil will preclude the realization of the existing potential. Nonetheless, the "hidden" potential for oil use in the power sector, represented by the existing oil-fired capacity, must be borne in mind. As institutions and political agendas evolve, so too might attitudes regarding oil use.

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Residential Energy Conservation Policy and Programs in Six OECD Countries

D. Wilson, L. J. Schipper, S. Tyler, and S. Bartlett

In response to the impacts of high international oil prices in the 1970s and early 1980s, the governments of many countries implemented policies and programs for the purpose of reducing household energy consumption. Through these policies and programs, governments sought to improve the residential energy market (by removing perceived market barriers), change that market (by offering subsidies, charging taxes, etc.), and alter the make-up of items on the market (appliances, heating equipment, etc.). The tools they used to meet these goals were information, subsidies, regulations, and price manipulation.

The current low price of oil has offered governments a reprieve: time to pause and look back. That process is currently taking place within several governments as they anticipate the necessity of moving forward with new programs motivated by changes in energy prices and/or other concerns such as the negative environmental impacts of energy supply and consumption processes. In this study, we describe and compare policies and programs that were implemented in Denmark, France, Japan, Sweden, West Germany, and the U.S. We present them along with contextual factors which determine both policy and program goals and the range of feasible measures/methods for achieving them. Contextual factors include: energy supply and demand structure; political and social environment; economic environment; institutional structures of relevant government agencies; and physical environment (climate, age and thermal quality of the housing stock, etc). Each of the above-mentioned topics is then discussed individually, using the specific experiences of the study countries to highlight and illustrate our observations with regard to their use.

These analyses have resulted in several fundamental conclusions regarding residential energy conservation program design. The first of these is that the most far-reaching programs take an integrated approach, using more than one tool to achieve a well-defined policy goal. An important example of this took place in Denmark where a program package of subsidies, home audits, and a home labeling program were used to attempt to improve the thermal quality of the existing housing stock. The specific tool or set of tools to be used in a program should be chosen based on both program objectives and context. The implementation of program tools commonly requires combined efforts of a variety of government institutions. The relationships and interactions between these institutions should be directly addressed as part of every program design, and where possible should be enhanced. In addition, relationships between government and non-government institutions (such as industry and academia) should be nurtured. These relationships can provide important channels to consumers and an infrastructure for supporting program implementation. Wherever possible, existing infrastructures should be used to implement programs. Both the Swedish retrofit subsidy plan that was melded into the existing national home loan program and the program in Germany that supported the publication of energy efficiency information through a well-known and widely-read magazine provide examples of this. A multitude of examples of problematic programs that attempted to create and rely exclusively on new institutions and infrastructures also exist. Finally, program evaluation should be part of every program design. Evaluations should be used both as part of the implementation process (i.e., learning and adapting as you go along) and after programs are completed (i.e., enhancing the learning curve effect). Although program evaluations have become more common in the U.S., they are still relatively sparse in other countries (except Sweden). Removing the many barriers to program evaluations should be a high priority goal of policy- and decision-makers responsible for initiating and/or planning residential energy conservation programs.

Home Electricity Use in OECD Countries: Recent Changes

L. Schipper, D. Hawk, A. Ketoff, and N. Hirt

The Home Electricity Use Study[*] has been recently updated to study changes through 1987.[1] These changes suggest that the wave of increased efficiency seen in our earlier study has peaked. Except for the heating market, inter-country differences are shrinking. The inter-country comparison suggests that many factors besides price and income influence the levels and patterns of residential electricity use in homes of the Organization for Economic Cooperation and Development (OECD) countries.

The Figure shows per-capita use in 1986 divided into end uses. The most important difference among countries is the use of electric space heating, a dominant component of sales growth in France, Sweden, and Norway. Secondary use of electricity for heating, i.e., in combination with other main heating systems, has grown in Denmark and is now a leading component of growth in electricity in Japan, where heat pumps reach the 50% saturation level.

The historical evolution of the countries shown in the Figure reveals that once homes reach a level of consumption corresponding to about 1000kWh/cap. for lighting, appliances, and cooking, then household electricity use only grows significantly if electricity makes significant inroads against fossil fuels in the space and water heating markets. In Sweden and Norway, such gains drove strong increases in household electricity use in the late 1970s and 1980s. In these countries, electricity heats 35% and 65% of all homes, respectively. In the Netherlands, by contrast, electricity heats almost no homes: instead cheap gas provides space heat, hot water, and cooking for over 90% of homes.

Differences in structural features, such as housing and appliance characteristics, incomes, and habits and lifestyles are not insignificant but many of these differences have diminished over time. This is particularly true for electric appliances. As the number of major international appliance manufacturers has declined, appliances have become more homogeneous.

If the differences in use patterns shown in the Figure are analyzed further, significant differences in intensity, or use per household, are found. For example, homes with electric water heating in Germany use considerably less

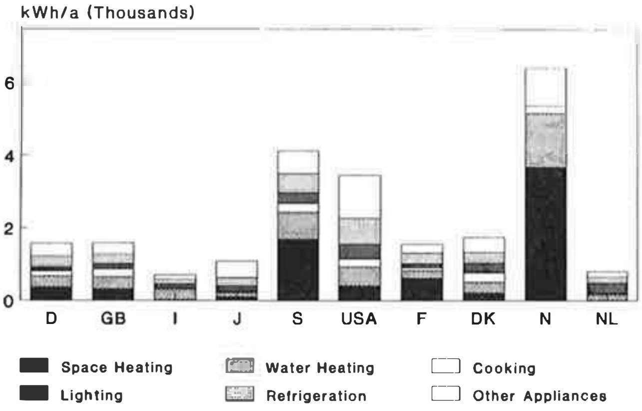

Figure. Electricity use per capita in 1986, climate corrected. D = West Germany, GB = Great Britain, I = Italy, J = Japan, S = Sweden, F = France, DK = Denmark, N = Norway, and NL = Netherlands (XBL-8811-3856)

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[*] This work was additionally supported by the International Energy Agency, Paris, France and Oslo City Light, Oslo, Norway.

electricity per home for that purpose than those in the U.S., Sweden, or Japan. German homes use instant water heaters with almost no tank losses, while Japanese, American, and Swedish homes use large tanks.

The efficiency of electric appliances has increased markedly in most of the study countries. These improvements limited the growth in appliance electricity use caused by increased saturation levels; in a few countries (Denmark, Sweden, United States), growth in use per household was very slow or even negative after 1978. Appliances sold in 1988, while far more efficient than similar ones sold in the early 1970s, may not be significantly more efficient than those sold in 1985. If this "efficiency plateau" proves lasting, then electricity use for appliances could begin to grow again as larger and more fancy models appear in households. Our comparisons also suggest that there are slight differences in the sizes and efficiencies of appliances within European countries; in countries with high electricity prices, such as Denmark and Germany, efficiency is slightly higher than in countries with lower prices. Appliances in North America are larger and less efficient than their European counterparts.

The price of electricity is an important determinant of the level of demand in the long run. If cheap compared to fossil fuels, electric heating gains a high market share (as in Norway), and water heating becomes attractive as well. Prices also influence comfort and lighting levels, and have some impact on appliance size and use. Income is an important determinant of the level of demand while stocks of major appliances are growing, but becomes less important thereafter, particularly in countries where the most expensive appliances are often the most electricity-efficient ones. Technology—the choice of heating system and insulation and the actual design of appliances—is certainly influenced by electricity prices, but other factors, such as climate, the presence of central space- and water-heating, and the traditions of the housing industry also influence the design and use of appliances.

Work in FY 1989 will focus on four areas. First, we shall continue our dialogue with the major appliance manufacturers to better quantify the savings in electricity use since 1973 that have arisen from greater efficiency. We will also explore the factors driving the future appliance market, and how new appliance features will influence electricity consumption. We will extend the comparison of household electricity use to 1987, with special emphasis on a Scandinavian comparison. Thirdly, we will explore the impact of certain kinds of lifestyle changes on future electricity use. Finally, we will extend our analyses to cover important end uses in developing countries, based on direct experience with surveys in Venezuela and Indonesia as well as information generated from our urban energy use network.

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Electricity in the LDCs: Trends in Supply and Use Since 1970

S. Meyers and J. Sathaye

The share of world electricity production accounted for by the less developed countries (LDCs) grew from 11% in 1970 to 20% in 1986. The average annual growth rate for LDC electricity production in this period—8.4%—was over twice the rate of 3.8% in the "developed" countries. Growth in the 1980s—6.7%/year through 1986—has been less than the rate of 9.4%/year in the 1970s, mainly due to slower economic growth in Latin America and Africa.

Electricity production has grown fastest in Asia (9.5%/year between 1970 and 1986), followed by China (8.8%/year), Latin America (7.7%/year), and Africa (6.4%/year). Among the 13 countries in our study, growth ranged from 5.2%/year in Argentina to 13.2%/year in South Korea. Indonesia, Malaysia, and Thailand averaged growth in excess of 10%/year, and Pakistan, Taiwan, and Brazil were close to this.

Electricity generation is much higher in China (450 TWh in 1986) than in any other LDC. Brazil (212 TWh) and India (202 TWh) are also major producers of electricity. The next largest—Mexico, South Korea, and Taiwan—are well below India.

The share of total LDC electricity production derived from fossil fuels has remained at about 65% since 1970. The share of fossil fuels in 1986 was 77% in China and Africa (56% if South Africa is excluded), and 70% in Asia. In Latin America, the hydropower share increased from 51% to 61% between 1970 and 1986. Hydro's role has increased in China since 1970, but has declined in Asia and Africa.

The LDCs have experienced a shift away from oil to coal, natural gas, and nuclear power (mainly in Asia). Coal dominates power generation in China and India, and is also prominent in South Korea and Taiwan. Natural gas plays an important role in Pakistan, Thailand, and Venezuela. For 12 major LDCs, the combined share of oil in total public generation declined from 27% in 1970 to 17% in 1986. The share of hydro fell from 48% to 44%, coal grew from 15% to 22%, while nuclear went from 2% to 9%.

The extent to which electricity consumption grows faster than the economy depends in part on the stage of economic development in which a country finds itself. The ratios between average growth in electricity consumption and growth in real GDP in the 1970-86 period in the 13 study LDCs were mostly between 1.6 and 1.9. The ratio was lower in Taiwan and Malaysia, reflecting their more mature level of economic development.

The industrial sector dominates electricity consumption in nearly all LDCs, but its share of total consumption has generally declined in the face of faster growth in the residential and commercial sectors (see Figure). Residential electricity use per capita has grown at more than 10%/year in most of the countries due to increase in the

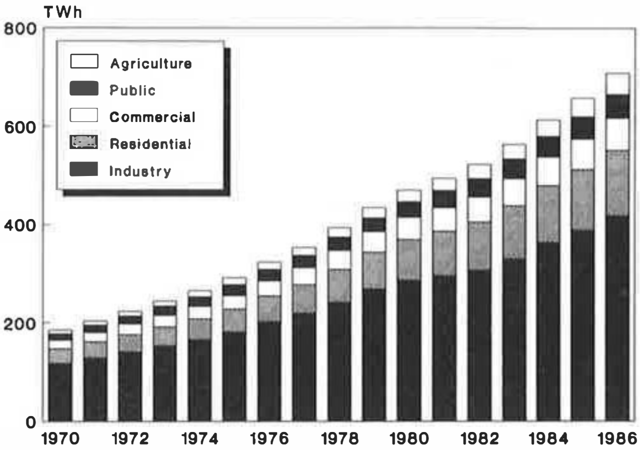

Figure. Electricity consumption by sector for 12 LDCs. (XBL-8810-3591)

number of homes that have electricity and rising ownership of appliances.

As electricity demand grows, many LDCs face increasing difficulty as they seek to expand supply and maintain existing systems. Power shortages are critical in many countries and environmental issues are becoming more important. Measures that are receiving closer attention include reform of tariffs to better reflect costs, reducing demand through end-use efficiency improvement, encouraging private power generation, and improving technical and managerial aspects of electric utilities.

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Production, Consumption, and Trade of Natural Gas: Western Europe and the Developing Countries

J. Sathaye, A. Ketoff, and G. Pireddu

World-wide, natural gas is assuming growing importance. It is being discovered in increasing quantities in the developing countries and it is also the fuel of choice to substitute for oil in oil-importing countries. It is environmentally more benign than other fuels and emits less "greenhouse gases" relative to those associated with the use of oil and coal. For these reasons, its use will be highly valued in the future.

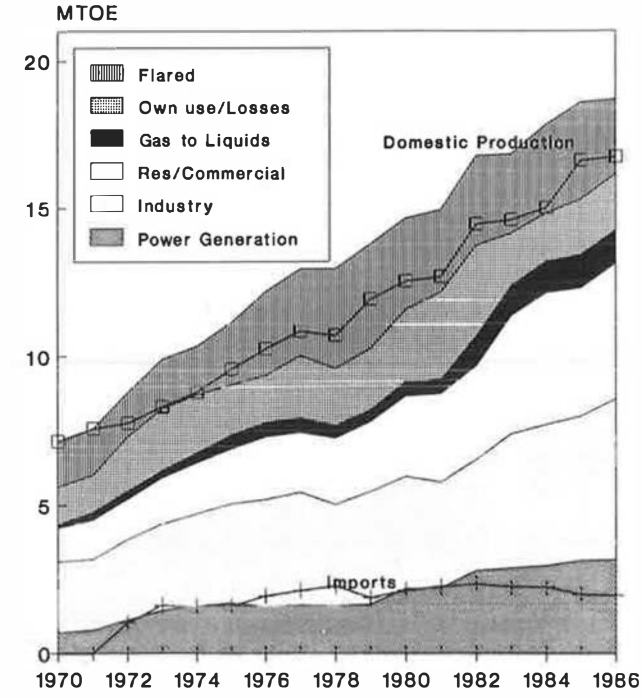
This work is intended to describe the current and potential use of natural gas in several regions of the world—Western Europe, Asia, Latin America, and the Middle East. Within each region, we focus on a few countries that are in a position to export, or are already exporting, natural gas to other countries.

In Western Europe, natural gas demand is not expected to increase by more than 10-20% by the end of the century. The major uncertainty is whether the Scandinavian countries will use more of the abundant gas available in that region for power generation and space heating. The long-term demand for gas could increase considerably if environmental policies forced additional displacement of other fuels.

The Asian region (not including the Soviet Union) accounts for about 6% of the world's natural gas reserves. Indonesia, Malaysia, Brunei, and Afghanistan have deposits large enough with respect to domestic demand to export natural gas. Taiwan and Japan have smaller and dwindling deposits of natural gas. The region is far from fully explored and new discoveries have been reported in Papua New Guinea and India. Asian reserves are expected to increase over the next two decades. Natural gas utilization will depend on the location of the natural gas deposits within a country and the level of reserves relative to the country's needs. Countries that discovered natural gas recently have used it in industry and power generation. Residential use occurred in countries that had heating needs and those that discovered gas some decades ago. Exports of gas, either as LNG or methanol, from Malaysia and Indonesia will remain a long term option; those from other Asian countries are unlikely given their current reserves and indigenous demand for natural gas.

Natural gas in Latin America has changed from being a by-product of the petroleum industry in the 1960s and the early 1970s to become an important energy source for the indigenous market. The prospect for export of natural gas from this region is limited. Demand is growing in the three major producing countries—Argentina (Figure), Mexico, and Venezuela—and is likely to expand in the others, particularly in Brazil. Increasing demand can be expected in the residential sector as a result of both an increase in the number of users (in Venezuela and Mexico) and an increase in comfort levels (in Argentina). Use in transport will remain minimal, although it might grow considerably in certain markets if strong government programs are launched. Industrial demand will remain dominant, particularly as the use of gas is seen as beneficial either to the environment (e.g., in Mexico), or to the international competitiveness of local industry (e.g., in Venezuela). With both Venezuela and Mexico pushing the use of gas as raw material for petrochemicals, demand in this sector is bound to increase considerably. Both countries would rather export higher-valued petrochemicals than LNG. Given present trends in demand patterns in Latin America, reserves of natural gas appear insufficient to allow export in the long run. Furthermore, since most of the gas is associated with oil, gas for export would be available only when demand for oil, and therefore production of oil, is high.

The cost of natural gas in the Middle East is minimal, since its production is associated with oil. Final users are



Source: IES/LBL.
Own use/Losses includes gas reinjected.

Figure. Natural gas in Argentina. (XBL-8812-4249)

charged low prices to favor its use over other, more exportable, petroleum products. Gas demand (in producing countries) will continue to expand as petrochemicals, power generation, and large industries switch off oil products. The uncertainty of the international oil market will push governments (in particular, Saudi Arabia and Kuwait) to seek non-associated resources to be tapped in case of shortages of associated gas. Capital availability might be a constraint, but the priority is high as countries prefer to keep oil underground in a period of low oil prices. In Iran, additional marketable production requires considerable amounts of capital, as major fields are scattered in the southern regions of the country. The end of the Iran-Iraq war is likely to boost industrial demand as well as residential use in newly reconstructed cities, which might justify increased efforts on the production side. As local use of gas becomes a key element of economic development, exports are not likely to be sought by any of the countries examined, with the exception of Qatar and Abu Dhabi. In the other countries, we can expect natural gas to be used in petrochemicals, fertilizers, and other energy-intensive products which will be marketed locally and/or exported.

With increasing discoveries of natural gas world-wide, the likelihood of additional gas becoming available for export in the form of LNG or, after transformation, in the form of methanol is strong.

Energy Markets and Energy Demand: China and the U.S.

J. Sathaye, L. Schipper, and M. D. Levine

Knowledge abroad about China's energy demand patterns and its likely future growth of demand is limited. Likewise, Chinese planners are eager to seek additional information and knowledge about energy use and government policy in the U.S. In order to exchange information and viewpoints, a symposium was sponsored jointly by the State Planning Commission of China and the Office of Policy, Planning and Analysis of the U.S. Department of Energy. The Chinese-American Symposium on Energy Markets and the Future of Energy Demand was organized by the Energy Research Institute of the State Economic Commission of China, and Lawrence Berkeley Laboratory and Johns Hopkins University from the United States. It was held in Nanjing, China in late June 1988. It was attended by about 15 Chinese and an equal number of U.S. experts on various topics related to energy demand and supply.

The Chinese papers provide an excellent overview of the emerging energy demand and supply situation in China and the obstacles the Chinese planners face in managing the expected large increase in demand for energy. Topics discussed by speakers included energy demand modelling, energy pricing reform, air pollution and energy use, and patterns of energy use and conservation in buildings, transportation, industry, and power generation.

The huge rate of economic growth in China has brought with it a dramatic increase in energy use. Energy conservation, however, has not yet surfaced as a common concern or practice among the populace, and lack of price incentive for conserving energy has allowed a huge incremental increase in energy use to accompany China's approximately 10% annual rise in GNP. Of great concern to China's leaders is that country's energy pricing structure, which encourages inefficiency and discourages conservation. "Planned" (i.e., subsidized) prices are replaced in practice by locally derived prices, which in turn often yield to black-market prices. Representatives of the Chinese government expressed their eagerness to reform pricing and to develop and implement conservation techniques and policies.

Conference participants also discussed China's efforts to control indoor and outdoor pollution, especially in urban areas. In China, almost all cooking is done using low-quality coal that is not cleaned (cleaning reduces substantially the sulphur content of the coal). In addition, scrubbers are not yet used by coal-fired power plants. Acid rain has resulted from these practices, and damage caused by acidic pollution is glaringly evident: a slide presentation at the conference depicted two sides of a monument, its windward side pitted and its leeward side, smooth.

Future work with the Chinese is likely to involve collaborations on such topics as energy pricing reform, energy demand and global warming, and building energy conservation. A follow-on conference in which the Chinese researchers travel to LBL is envisioned in FY 1991.

Competition in Electricity Generation

E. Kahn

Competition in the generation of electricity began with the Public Utilities Regulatory Policy Act (PURPA) of 1978. PURPA required regulated utilities to purchase the output of certain private, unregulated suppliers at prices based on the cost of equivalent power. Producers who met the technology specifications embodied in PURPA, essentially cogenerators and users of renewable energy, were called Qualifying Facilities (QFs). The response to PURPA was very substantial in regions which offered favorable terms. In some cases, the response overwhelmed utilities and their regulators, creating a need to ration or limit QF supplies. This unanticipated development spurred interest in reforming the PURPA process to make it more efficient. The principal reform which has emerged from these concerns is the creation of auction or bidding systems in which PURPA suppliers compete for the right to sell under long-term contracts. PURPA auctions raise many design and implementation questions. These have been studied in detail previously.

The Federal Energy Regulatory Commission (FERC) has taken the initiative to broaden the PURPA auction process initiated in individual states. In a series of Proposed Rules, the FERC has suggested expanding the scope of competitive bidding to include all sources of supply instead of only the QFs. The principal effect of the proposed FERC rules would be to create a new class of unregulated suppliers, called Independent Power Producers (IPPs) who would compete with the QFs and regulated producers for the right to provide new generating capacity. The far-ranging nature of the FERC proposals raises a number of policy and technical questions.

We examined the welfare impacts of the FERC proposals in light of prospects for regulatory policy. PURPA and the FERC initiatives have arisen in part out of dissatisfaction with the performance of regulation, particularly with regard to inducing efficient investment in generation facilities. Three scenarios for future regulatory policy were delineated and used as a background against which to evaluate the FERC proposals. These scenarios are: 1) capital minimization, in which utilities avoid investment due to hostile regulation, 2) joint responsibility, in which regulators share planning authority explicitly with utilities, and 3) optimal risk aversion, in which utilities avoid risky investment, but there is no sharing of responsibility with regulators. The balance of costs and benefits varies in each scenario. Depending on the degree of competition between the IPPs and regulated suppliers, there will be no differences in bargaining power and flexibility. Efficiency gains will be obtained, but at the price of higher transaction costs. On balance, the FERC proposals appear beneficial. Details are available.[1]

The FERC proposals imply major changes in the structural organization of the electric utility industry. The underlying assumption that the wholesale generation market is workably competitive implies that the traditionally vertically-integrated and regulated firm will be altered significantly. The key element in these long-run changes is the evolution of the transmission system. The FERC proposals do not explicitly take up the questions raised about transmission under wholesale competition. Any system which evolves must provide for system security, efficient pricing of transmission services in the short-run, and capacity expansion in the long run. Achieving all three objectives will require some kind of cooperative arrangement between the buyers, who will probably end up operating the system, and the sellers, who may have to bear the financial burden of expanding capacity to reach new markets.

The planning and operating environment will also change substantially under wholesale competition. Contractual arrangements will play a larger role in unit commitment and economic dispatch. The utility's obligation to serve will be tested as its "supplier of last resort" function gets defined more precisely. It is plausible that the overall level of wholesale generation reliability may degrade somewhat. Storage technologies, which provide an inventory function, will play a larger role in smoothing out these problems.

There can be expected to be major re-allocations of assets among firms. Some of this will involve divestitures that move particular resources to higher valued uses. More important will be consolidations that will help to make the market operations more efficient. On the buyers' side, small distribution companies can achieve important efficiencies through merger. One problem is that many of these companies are publically owned, and lack the financial incentives to consolidate. Mergers among suppliers will not be harmful as long as monopoly power does not accumulate. The prospects are good that these abuses can be prevented. Detailed results are available.[2]

Future work on these issues will focus on implementation problems of designing all source competitions for bulk power and the resource planning problems these must address.

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