Section 64

INTEGRATED ANALYSIS OF DEMAND-SIDE PROGRAMS: A CASE STUDY OF THE TEXAS UTILITIES ELECTRIC COMPANY

Joseph H. Eto, Jonathan G. Koomey, James E. McMahon, Edward P. Kahn*

INTRODUCTION

The Lawrence Berkeley Laboratory (LBL) directs economic analysis of residential appliance efficiency standards for the U.S. Department of Energy (DOE). Proposed standards have impacts on manufacturers, individual consumers, electric utilities, and on society, as a whole. This paper summarizes analysis methods directed at electric utilities. These analyses have taken the form of case studies for individual electric utility service territories in recognition of the need to consider company- and region-specific economic circumstances. In the present work, we demonstrate the method with results from our case study of the Texas Utilities Electric Company (1).

We believe that our methods have broad application within the utility industry for evaluating residential demand-side technologies in the pursuit of least-cost planning objectives. For example, an end-use forecasting model allows us to estimate future residential class demands in a fully integrated and consistent fashion. Similarly, the impact of proposed demand-side programs (DSP) on ratepayers is a central component of utility analyses of the comparative worth of demand- and supply-side alternatives. Finally, many regulators require that utility cost/benefit analyses also embody a societal perspective.

The paper has three sections. In the first section, we define the components of the cost/benefit perspectives used in the analysis. In the second section, we describe the computer models that are the basis for our analysis, and give special attention to their integration. The models include the LBL Residential Energy Model, the DOE-2 Building Energy Analysis Program, the LBL Residential Hourly and Peak Demand Model, and the LBL Utility Financial Impact Model. Finally, we illustrate our analysis method with a summary of our case study of the former Texas Power and Light (TP&L) service territory of the Texas Utilities Electric

* The authors are members of the Energy Analysis Program at the Lawrence Berkeley Laboratory, Berkeley, CA, 94720.

Company (TUEC). This summary includes a brief description of TUEC, the appliance efficiency standards evaluated, and the predicted load shape and financial impacts of the standards.

COST/BENEFIT PERSPECTIVES

The analyses described in this paper evaluate appliance efficiency standards from both an electric utility and a societal perspective. Here, we briefly summarize these perspectives.

The electric utility perspective compares the benefits of both long- and short-run avoided electricity production expenses to the under-recovered fixed costs resulting from "lost revenues". Analyses of utility-sponsored programs normally would include the cost of the programs themselves, but our analysis of the impact of federal minimum appliance efficiency standards assumes that no program costs would be incurred by the utility.

The avoided production cost benefits from more efficient appliances can be estimated in several ways. For the TUEC case study, we developed alternative methods for calculating avoided production costs. Both were based on avoided cost filings for the purchase of power from small power producers. In other case studies, the accuracy of our results has been enhanced by the use of production-cost models to calculate avoided production costs instead of avoided cost filings (2).

The cost of load shape impacts to the utility is the under-recovery of fixed costs that results from reduced electricity sales (3). We define this term as the rate impact cost. It is the difference between lost revenues and avoided variable operating expenses. Avoided variable operating expenses are estimated using short-run marginal costs. The rate impact cost can be a benefit, if short-run marginal costs exceed retail rates.

Some measure of rate impacts is commonly included in determining utility costs and benefits (4). It is important, however, to distinguish our definition of this term from its definition in traditional cost/benefit analyses. The under- (or over-) recovery of fixed costs, resulting from less-than-forecast sales, is not a cost (or benefit) from the societal perspective; it is simply a transfer payment. The precise allocation between ratepayers and shareholders is a matter of regulation. Under perfect regulation, the under- (or over-) recovery would be allocated to ratepayers. Short of this ideal, shareholder returns will be affected. Even if we assume perfect regulation, the precise allocation to each rate class is also subject to regulation. Finally, the net impact on retail rates is affected by the rate of sales growth. Increased sales will dilute the impact on rates, and decreased sales will accentuate it.

The societal perspective compares the avoided electricity production expenses to the incremental capital and labor cost of more efficient appliances.

The utility and society perspectives can be evaluated with separate discount rates. For our case study, however, we followed TUEC's recommendation that the same discount rate be used to evaluate both perspectives. This discount rate is called the rate of disadvantage and is derived from the Company's weighted average cost of capital (5). For this study, we use assumptions consistent with TUEC's estimate of the avoided capital costs associated with deferred generation capacity. At the time of this study, TUEC's rate of disadvantage was 11.5%, while the weighted average cost of capital was 14.0% (6).

EVALUATION METHOD

LBL has developed a four-part method to evaluate the impact of residential demand-side technologies on utility load shapes and finances. The general approach is to link the outputs of existing models to form an integrated DSP analysis tool (see Figure 64-1). The method is general in nature, but the linkages between the models are largely utility-specific. Data availability, for example, affects the degree of disaggregation possible. The components can be divided into two subcategories: load shape forecasts and economics.

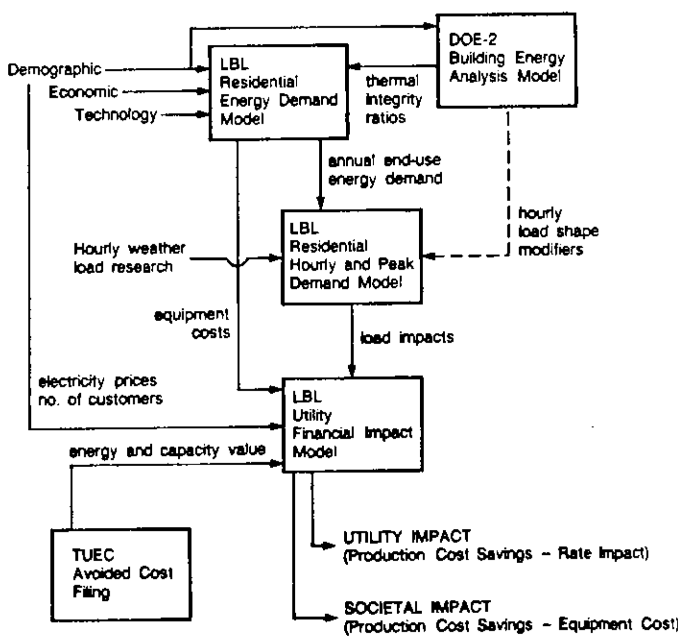

Figure 64-1. LBL DSP Analysis Method.

End-use energy forecasts are crucial to an analysis of the load shape impacts of DSPs. The central component of the first phase of the evaluation is the LBL Residential Energy Model (LBLREM), which is a nine end-use, engineering/economic demand forecasting model (7). LBLREM uses projections of future energy prices, numbers of households, personal income, and housing thermal integrity characteristics to perform five major calculations: future appliance efficiency choices, investments in thermal integrity improvements for buildings, turnover of housing units and appliances, changes in the market share for each technology and fuel (such as numbers of gas vs. electric water heaters), and changes in usage behavior (such as hours of air conditioner usage). These calculations rely on engineering and cost estimates of the range of appliance designs (or thermal integrity improvements) likely to be available, and on relationships describing the influence of energy and equipment prices, as well as income and other factors, on purchase and usage decisions.

For the TUEC case study, we relied extensively on TUEC's own data to develop inputs for an individual service territory within TUEC. To assist in the development of selected inputs on the thermal integrity of buildings, we also used a sophisticated building energy simulation model, DOE-2. The DOE-2 building energy analysis program is a well-documented, state-of-the-art tool for analyzing building energy performance (8). Data limitations, however, require us to use the model in auxiliary capacity; i.e., we do not use the outputs of DOE-2 directly. Instead, we combine data from the utility and other sources with default values from DOE-2's libraries to develop scaling factors. These factors are used to adjust the utility's estimates of space-conditioning energy use for a typical or stock-weighted average residence to that for a new (more efficient) residence.

Hourly load profiles are essential for linking energy forecasts to financial impacts. The LBL Residential Hourly and Peak Demand Model performs this task by distributing annual end-use electricity forecasts from LBLREM into annual hourly demand profiles for each day of the year (9). The model uses metered data collected by utility-sponsored load research studies. Space-conditioning load profiles are calculated with data from an hourly weather tape and sets of empirically-derived matrices that relate consumption in a given hour to climatic conditions. Each matrix is a series of weights that describes the fraction of the appliance stock that would be running under the conditions specified by the weather tape. These weights are summed at the end of the simulation year and are used to allocate annual energy use to individual hours of the year.

The LBL Residential Hourly and Peak Demand Model plays an important role in calibrating the LBLREM. Before we forecast the impacts of standards, we extensively calibrate the models to both historical and utility projected data. The LBL Residential Hourly and Peak Demand Model increases accuracy by placing additional constraints on the process. We have described these efforts in (1). Figures 64-2 and 64-3 contain samples of our calibrated,

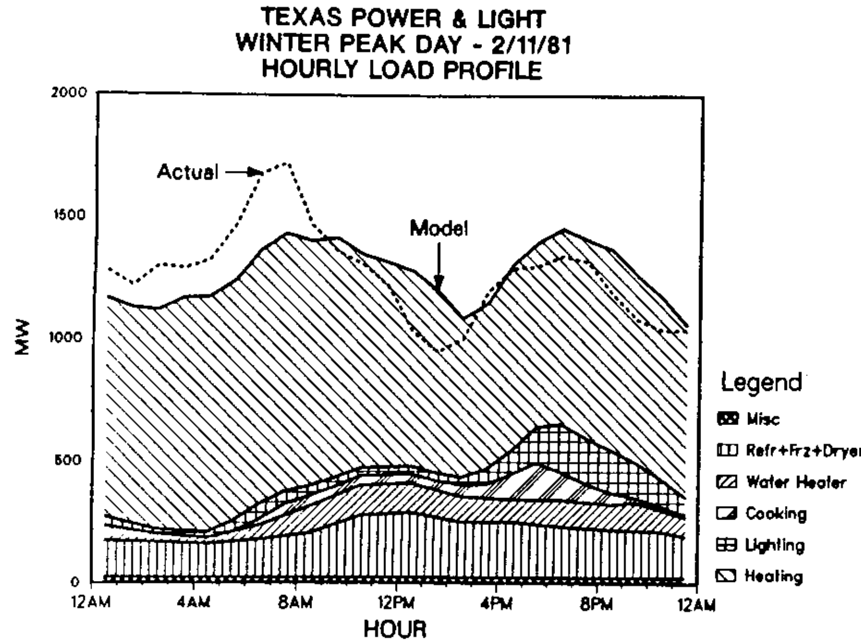

Figure 64-2. Comparision of LBL and Historical Hourly Loads for a TP&L Peak Winter Day.

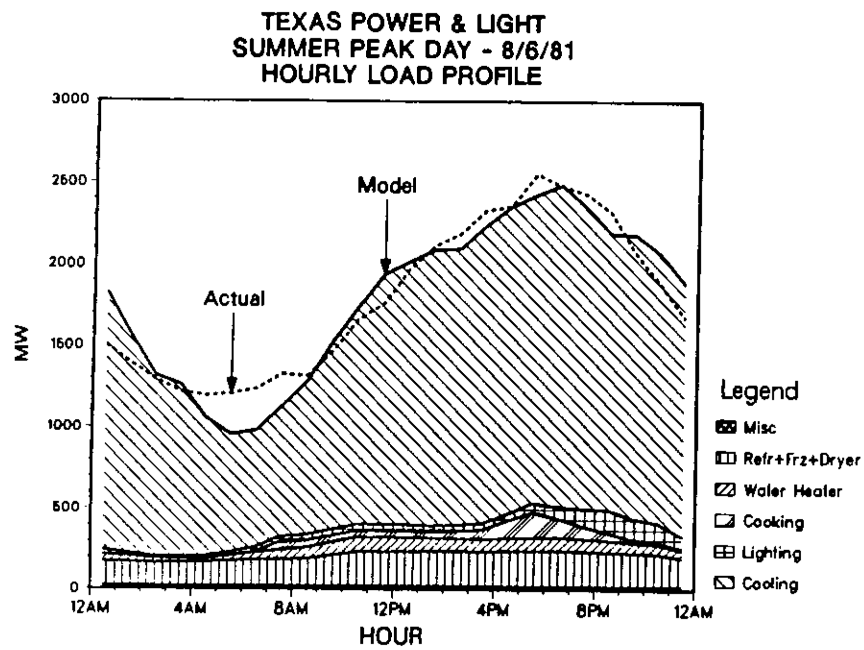

Figure 64-3. Comparision of LBL and Historical Hourly Loads for a TP&L Peak Summer Day.

benchmark results for historical TUEC winter and summer, peak day, hourly energy use. Note that, in lieu of better information, we have assumed a flat load shape for the miscellaneous category of end-uses.

The cost/benefit calculations are performed by the LBL Utility Financial Impact Model (1). The model is essentially an accounting tool for combining data on avoided production costs and revenues with the forecast load shape impacts. The source of these values and the valuation procedures employed by the model are, however, unique to our analyses. We will summarize major features of this evaluation, but direct the interested reader to longer, more detailed reviews (10).

For the TUEC case study, we developed two procedures for valuing load shape changes based on company-sponsored offers to purchase power from small power producers and cogenerators. The first followed a literal interpretation of the terms and provisions approved by the Texas Public Utilities Commission for payments to independent power producers (6). We will refer to this method as the TUEC avoided-cost methodology or TUEC method. The second took the cost data supporting the development of the State-approved offers and applied them in a manner more akin to those used in other states (11). We refer to this method as the energy-related capital avoided-cost methodology or ERC method.

TUEC offers to purchase power from small power producers and cogenerators are based on the cost savings resulting from a hypothetical two-year deferral of the Forest Grove 1 generating plant scheduled to go on line in 1989. Two quantities are calculated, an avoided energy component and an avoided capital component. The fuel component is the price of the avoided fuel (in this case, coal) times the average heat rate of the plant. To calculate the capital component, the TUEC method compares the annual revenue requirements for the plant for two on line dates, 1989 and 1991, and takes the difference to be the value of the deferral. A small amount is also subtracted from the difference to account for irreversible costs associated with such a deferral.

The ERC method distinguishes two categories of investment within the capital component, in recognition of the principle that the decision to built a new plant is motivated by two considerations. On the one hand, a utility chooses to build coal plants because there are fuel savings associated with the investment. We call this aspect of the investment the energy-related capital component. On the other hand, building another plant also means that system reliability will be enhanced. We call this aspect of the investment the capacity- or reliability-related capital component. We estimated the value of the reliability related component using a combustion turbine proxy (12). The difference between this proxy and the original capital component, then, is the energy-related capital component of the investment decision.

For the TUEC method, we imposed TUEC's performance requirements on the energy saved by our appliance standards to derive imputed capacity values. Imputations were made for the summer and average annual performance criteria. In addition, the actual peak summer hour change in demand was also considered, and the lowest of the three values was used. For the ERC method, we took the differences between the average of the highest 500 hourly loads as a conservative measure of capacity value. We will illustrate the effects of these different measures of capacity in discussing our case study results.

The rate impact cost is measured by the difference between lost revenues and avoided variable operating expenses. TUEC's residential rates are tiered. Therefore, to calculate lost revenues, we used the Block-adjustment procedure to estimate total lost revenues (13). Avoided variable operating expenses were estimated using short-run marginal costs.

The incremental equipment cost of more efficient appliances is calculated by LBLREM and passed directly to the Financial Model. Our forecasting model accounts for the effects that the higher cost of efficient appliances have on consumer's purchase decisions (14).

TUEC CASE STUDY

The subject of our case study is the residential class of the former Texas Power & Light (TP&L) service territory of the Texas Utilities Electric Company (TUEC). In 1984, Texas Power & Light, Dallas Power & Light, and Texas Electric Service were merged into the present TUEC. Through this consolidation, TUEC has become one of the largest electric utilities in the country. Sales in 1985 were forecast to be 77,049 GWh and with a peak demand of 15,595 MW. Total residential class sales account for 33% of system generation. TUEC is located in the northern half of the state of Texas. The TP&L service territory under examination is that portion of TUEC that surrounds, but does not include, the cities of Dallas and Fort Worth in the northeastern portion of the state.

TUEC anticipates continued strong demand growth into the 1990's. Electricity consumption is expected to increase at 3.3%/year from 1985 to 1999, and peak demand is expected to grow at 2.9%/year over the same period (15). Growth should improve the TUEC system load factor, which is currently 56.4%. In general, the large fraction of TUEC sales accounted for hy the residential class means that the load shape impacts of appliance efficiency policies will have important consequences for future system load factors.

TUEC costs are lower than national averages. In 1985, residential electric rates for 1,000 kWh/month were 0.070 \$/kWh as compared to the national average of 0.076 \$/kWh (16). The utility is also in the process of phasing lower cost coal plants into the generation mix. Between 1985 and 1999, TUEC expects coal-fired generation to reduce the fraction of electricity generated by oil and gas from 52% to 18%. We expect that these relatively lower costs will have equally important consequences for our economic analyses of load shape modifications.

Table 64-1

COMPARISON OF APPLIANCE EFFICIENCY STANDARDS

Appliance	1985 * Existing	1985 * New	Level 8	Level 8/12	Level 12/AC
Space Heating (AFUE%)					
gas	63.79	70.18	85.72	85.72	--
oil	73.93	78.61	90.98	90.98	--
Air Conditioning					
room (EER)	6.54	7.17	8.87	8.87	8.87
central (SEER)	6.91	7.32	8.42	12.00	12.00
Water Heating (%)					
electric	80.75	81.31	93.60	93.60	--
gas	50.50	56.96	81.75	81.75	--
Refrigerators (ft^3/kWh/d)	4.88	6.35	11.28	11.28	--
Freezers (ft^3/kWh/d)	9.22	11.61	22.34	22.34	--
Ranges (%)					
electric	39.64	43.73	47.51	47.51	--
gas	16.29	29.27	20.27	20.27	--
Dryer (dry lbs/kWh)					
electric	2.72	2.88	2.96	2.96	--
gas (3413 Btu/kWh)	2.22	2.63	2.61	2.61	--

AFUE - Annual Fuel Utilization Efficiency
EER - Energy Efficiency Ratio
SEER - Seasonal Energy Efficiency Ratio

*1985 values are those forecast by LBLREM; they are not measured data.

We examined three separate residential appliance efficiency standards. The standards are modeled by imposing a minimum efficiency requirement for new equipment, starting in 1987. Table 64-1 compares the efficiencies mandated by each standard to existing appliance efficiencies. Existing efficiencies for 1985 are described by both an existing appliance average efficiency and a marginal (or new) appliance efficiency. The first policy, Level 8, consists of a set of minimum efficiencies that are cost-effective based on a life-cycle analysis using national data. Note that, for TUEC, the minimum efficiencies required for gas ranges and gas dryers are lower than the efficiencies of new appliance purchases; the standard will, consequently, have no effect for these appliances. The second policy, Level 8/12, incorporates tbe minimum efficiencies called for in the first standard, but in addition specifies an extremely high minimum efficiency level for central air conditioners and heat pumps (namely, SEER=12). The third policy, Level 12/AC, refers to the isolated case of increasing only room and central air conditioner efficiencies.

Table 64-2

SUMMARY OF LOAD SHAPE IMPACTS
Texas Power and Light, Residential Class

Case	Growth (1987-1996)		Impact by 1996 *				
	Energy (%/yr)	Demand (%/yr)	Class Load Factor (%)	Energy (GWh)	Energy (%)	Peak Demand (MW)	Peak Demand (%)
Base	3.48	3.07	42.7				
Level 8	2.84	2.28	43.5	827	(6.4)	269	(7.8)
Level 8/12	2.30	1.30	45.6	1469	(11.3)	566	(16.4)
Level 12/AC	2.67	1.52	46.1	1031	(8.0)	502	(14.5)

* Energy and peak demand impacts are calculated relative to the base case.

The load shape impacts of the three standards are summarized in Table 64-2. Level 8 and Level 12/AC standards produce reductions in sales of 6.4% and 8%, respectively. The Level 8/12 standard reduces sales in 1996 by 11.3%. Examination of projected class peak demands gives a different picture of the effects of the policies. Level 8 standards reduce the 1996 peak by 6.4%. The Level 12/AC standard, while saving approximately the same amount of energy as the Level 8 standard, reduces load growth much more, by 12% in 1996. Level 8/12 decreases load growth by 13.5% by 1996, which is only slightly more than the reduction due to the Level 12/AC standard.

Reductions in sales and loads vary substantially by season, as shown in Figure 64-4. For all cases, sales reductions are greater in the summer months than in other seasons. For the Level 8 standards, monthly sales are reduced approximately 2.5% in winter and 7.5% in summer. For the Level 12/AC case, sales are slightly higher in winter due to increased sales of electric heat pumps, but are reduced 15% in summer. For the Level 8/12 case, winter sales are reduced approximately 1.5%, and summer sales are reduced 18%.

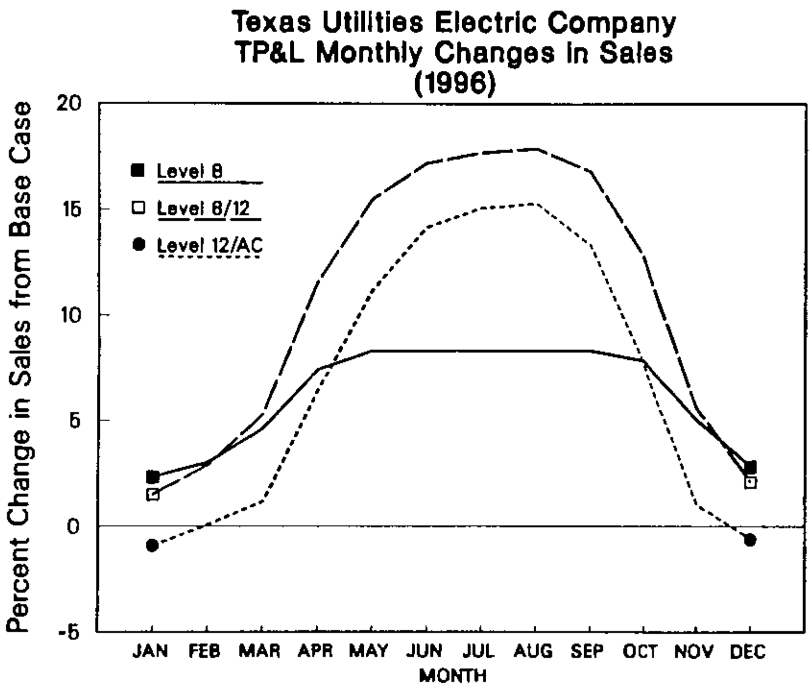

Figure 64-4. Monthly Percent Savings for Residential Appliance Efficiency Standards.

Table 64-3 illustrates the effect of our valuation method on the system-level, capacity value of standards. As expected, when the 500 highest residential class hourly load impacts are averaged (for the ERC method), the capacity savings are less than the impact at the residential class's peak hour. Similarly, the annual average load savings and the summer average load savings, when calculated using the performance criteria required of cogenerators by TUEC (the lower of the capacity values implied by a 65% annual average capacity factor or a 75% summer capacity factor), also reduce the system-level capacity value of residential class load shape changes.

Table 64-3

1996 CAPACITY VALUE FOR STANDARDS
Texas Utilities Electric Company

	Class Peak Hour (MW)	ERC-Method * (MW)		TUEC-Method ** (% of peak)	
Level 8	269	222	(83)	145	(54)
Level 8/12	566	466	(82)	258	(46)
Level 12/AC	502	413	(82)	181	(36)

* Based on average change for highest 500 residential hourly loads.

** Based on the lower of the capacity values implied by a 65% annual capacity factor or a 75% summer capacity factor.

Tables 64-4 and 64-5 summarize the cumulative financial impacts of the standards by 1996 for the utility and societal perspectives, using both the TUEC methodology and the energy-related capital methodology. In fact, both benefits and costs will continue to accrue beyond this date. The impact of the policies on the utility is positive for Level 8 using the TUEC methodology, and is positive for both Level 8 and Level 8/12 for the energy-related capital methodology. From a societal perspective, only the Level 8 standard yields positive benefits in both cases. Both Level 8/12 and Level 12/AC have large negative impacts from a societal perspective. Recent cost estimates collected by the California Energy Commission for efficient central air conditioners suggest that our costs may be overestimated by 20-50% (17). Revised cost estimates may make even the Level 12/AC standard cost-effective to society. Such revisions, based on new engineering analyses, are currently being incorporated into LBLREM.

Table 64-4

SUMMARY OF IMPACTS - UTILITY AND SOCIETAL PERSPECTIVE
TUEC Methodology
(in million 1985$; discount rate = 11.5%)

	Utility Perspective			Societal Perspective	
	A	B	A - B	C	A - C
Standard	Avoided Cost	Rate Impact	Net	Equipment Cost	Net
Level 8	261	246	15	196	65
Level 8/12	463	481	(18)	672	(209)
Level 12/AC	325	394	(69)	605	(280)

Table 64-5

SUMMARY OF IMPACTS - UTILITY AND SOCIETAL PERSPECTIVE
Energy-Related Capital Methodology
(in million 1985$; discount rate = 11.5%)

	Utility Perspective			Societal Perspective	
	A	B	A - B	C	A - C
Standard	Avoided Cost	Rate Impact	Net	Equipment Cost	Net
Level 8	273	246	27	196	77
Level 8/12	510	481	29	672	(162)
Level 12/AC	390	394	(4)	605	(215)

SUMMARY

This paper has described an integrated analysis method to evaluate the load shape and economic consequences of a DSP for residential appliances. The method employs a "bottom-up" approach that includes end-use forecasts of annual energy use for all fuels and of hourly loads for electricity. The forecasts are based on an engineering/economic model that uses energy prices and demographic data. The financial analyses rely on avoided production costs based on utility avoided cost filings. These benefits are compared to costs for both the utility and society. The utility's costs are the under-recovered fixed costs resulting from "lost" and society. The utility's costs are the under-recovered fixed costs resulting from "lost" electricity sales. Society's costs are the incremental labor and capital costs of the demand-side activity. Our method is particularly well-suited to analyses of energy conserving demand-side technologies, but is not presently capable of modeling other important DSPs such as time-of-use pricing and direct load-control technologies.

We demonstrated the analysis method in a case study of three sets of residential appliance efficiency standards in the former Texas Power and Light service territory of the Texas Utilities Electric Company. These minimum efficiency standards for new equipment, were assumed to take effect in 1987. The first standard, Level 8, consists of moderate minimum efficiencies for all appliances. The second standard, Level 8/12, modifies Level 8 by specifying, in addition, very high minimum efficiencies for central air conditioners and heat pumps (namely, SEER=12). The third standard, Level 12/AC, consists of minimum efficiencies for only space-cooling appliances.

We found that each standard increased residential class load factors and that, for both perspectives, the Level 8 standard was cost-effective. We also found that the choice valuation method can affect utility and society preferences. Under the energy-related capital methodology, the Level 8/12 standard was cost-effective to the utility, but not to society. The Level 12/AC standard was not cost-effective from either perspective. The results for our analysis of the societal perspective depends strongly on the cost associated with efficient appliances.

ACKNOWLEDGEMENT

The work described in this paper was funded by the Assistant Secretary for Conservation and Renewable Energy, Office of Building and Community Systems, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098. We also acknowledge the cooperation of the Texas Utilities Electric Company in developing our case study.

REFERENCES

1. J. Eto, J. Koomey, J. McMahon, and P. Chan. *Financial Impact on Utilities of Load Shape Changes Project: The Texas Utilities Electric Company,* Lawrence Berkeley Laboratory report #21598, April, 1986.
2. J. Eto, J. Koomey, J. McMahon, and P. Chan. *Financial Impact on Utilities of Load Shape Changes Project: The Nevada Power Company,* Lawrence Berkeley Laboratory report #21597, April, 1986.
3. M. Minick, and J. Runnels. "Load Management Assessment - An Oil Burning Utility's Perspective," *IEEE Transactions on Power Apparatus and Systems,* Vol. PAS-101, No. 10, October 1982.

4. Economic Assessment Subgroup of the IEEE Load Management Working Group. "Economic Issues Related to Assessing Load Management in Electric Utilities," *IEEE Transactions on Power Apparatus and Systems,* Vol. PAS-102, No. 6, June 1983.
5. R. Brealy, and S. Myers. *Principles of Corporate Finance,* 2nd ed., New York, McGraw Hill, 1984.
6. Texas Utilities Electric Company. *Exhibits C and D, Docket No, 6065-Settlement Agreement,* Public Utilities Commission of Texas, 1985.
7. J. McMahon. *The LBL Residential Energy Model,* Lawrence Berkeley Laboratory report #18622, January, 1986.
8. R. Curtis, B. Birdsall, W. Buhl, E. Erdem, J. Eto, J. Hirsch, K. Olson, and F. Winkelmann. *The DOE-2 Building Energy Use Analysis Program,* Lawrence Berkeley Laboratory report #18046, April, 1984.
9. G. Verzhbinsky, H. Ruderman, and M. Levine. *The LBL Residential Hourly and Peak Demand Model: Description and Validation,* Lawrence Berkeley Laboratory report #18698, August, 1984.
10. E. Kahn. *Proxy Plant Valuation Methods for Demand Side Utility Programs,* Lawrence Berkeley Laboratory report #21525, May, 1986.
11. Montana Public Service Commission. *Order No. 5017 in Docket No. 83.1.2,* 1984.
12. National Economic Research Associates, Inc. *How to Quantify Marginal Costs,* Electric Power Research Institute report # EURDS-23, March, 1977.
13. E. Kahn, C. Pignone, J. Eto, J. McMahon, and M. Levine. *The Effects of Conservation Programs on Electric Utility Earnings: Results of Two Case Studies,* Lawrence Berkeley Laboratory report #21098, August, 1984.
14. U.S. DOE. *Supplement to March, 1982 Consumer Products Efficiency Standards Engineering Analysis and Economic Analyses Documents,* DOE/CS-0045, July, 1983.
15. Public Utilities Commission of Texas. *Long-Term Electric Peak Demand and Capacity Resource Forecast for Texas, 1984,* 1984.
16. U.S. DOE. *Typical Electric Bills,* DOE/EIA-0040 (85), December, 1985.
17. California Energy Commission. *Staff Report on Proposed Revision of Appliance Efficiency Standards for Central Air Conditioners Under 65,000 BTU/Hour,* Docket 84-AES-2, November, 1984.