COMMERCIAL APPLIANCES AS DSM OPTIONS IN COMMERCIAL BUILDINGS

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In the study discussed here, data were developed and analyzed pertaining to the use of commercial appliances as demand side management (DSM) options in the service territory of a west coast utility. From among the universe of available energy efficient commercial appliance technologies, a set of DSM options that appeared to have high impact potential and wide commercial acceptance in the utility's service area were identified. For these selected options, cost and energy savings data were developed that could be used to evaluate the resource potential of the DSM options within the framework of the utility's integrated resource planning. Supply curves were developed for each DSM option that show the estimated reductions either in megawatts or in gigawatthours that might be realized at different levels of incentives offered by the utility for installation of the option. Load profiles were also developed that show the impact of the DSM options.

INTRODUCTION

Although commercial customers are major contributors to most utilities' peak loads, there is comparatively less information on the peak load impacts and resource potential of demand side management (DSM) options for the commercial than for the residential sector. The thrust of this study therefore was to develop data on the costs, load impacts, and resource potential of appliance technologies that can be used as DSM options in commercial buildings.

MARKET SEGMENTS

For purposes of the study, the commercial sector was divided into 28 market segments, which were defined by the product of 7 commercial building types, 2 building vintages, and 2 climate zones.

Building types were defined by grouping together building types that were expected to have similar end use load patterns. Data on the load profiles for various building types were extracted from a data base of load profiles that had been developed in previous work (Alereza et al. 1988). Based upon the inspection of the load profiles, seven types of commercial building market segments were defined:

- High rise offices were grouped with large retail stores to form a large office building/large retail building market segment.
- Low rise office buildings and small retail store buildings were grouped together to form a small office/retail building market segment.
- Restaurants
- Grocery/Refrigerated warehouses (Comparisons show that load patterns for refrigerated warehouses are similar to those for grocery stores, primarily because of the heavy use of refrigeration.)
- Hotels/motels
- Hospitals
- Industrial firms using process equipment, motors, and fans

For this study, large offices were grouped with large retail stores and small offices were grouped with small retail for two reasons. First, HVAC equipment generally used in low rise office buildings is more similar to that used in small retail buildings than in high rise office buildings or large retail stores. That is, packaged HVAC equipment is generally used for low rise office buildings and small retail buildings, while built-up systems are generally used for high rise office buildings and large retail stores. Second, load patterns during peak days for retail stores are more similar to those of low rise office buildings than to those of high rise office buildings.

Because some DSM options are applicable only in newly constructed commercial buildings, while others are applicable as retrofits, buildings within each building type market segment were further segmented according to vintage. Buildings in place as of January 1, 1988 were classified in an "existing" vintage category, and buildings built after that date were classified in a "new" vintage category.

To take account of the effects of climatic conditions on space heating and space cooling loads, geographical location was also used to define market segments. Drawing on previous studies (San Diego Gas and Electric 1988), two climate zones were defined, one for the coastal area of the utility's service territory and the other for the inland area.

SELECTION OF DSM OPTIONS

From among the universe of available commercial appliance technologies, those with potential as DSM options with high load impact and wide commercial acceptance in the utility's service territory were identified through an initial technical and market potential screening. A preliminary list was prepared of DSM technologies that appear to be applicable to commercial in the utility's service territory. Only technologies applicable under the utility's weather conditions were include on the list.

The DSM technologies on the preliminary list were screened according to other technical criteria. A DSM option must not reduce the quality of service to a customer below an acceptable level. For example, a lighting option should not result in intensity too low or light of the wrong color. A DSM technology had to be a reasonable modification for buildings within the utility's service territory. A DSM option had to be commercially available and had to give improvements in energy efficiency and cost that would result in a reasonably short payback period if utility incentives are provided.

For DSM options that satisfied these technical screening criteria, a market potential screening was used to identify applications where there was sufficient resource potential. Preliminary estimates were made of the expected savings in kWh/SF/year and in watts/SF/year that a measure would likely afford. These estimates were used to calculate the expected load factors for the various measures. Estimates were also developed for the likely market potential of a measure in different market segments (defined by building type, vintage, rate class and climate zone location). Data on total market segment size and on current penetration of a measure in a market segment were taken from survey data collected by the utility.

The DSM options that were selected for further analysis and evaluation from among the list of available technologies are listed in Table 1.

CHARACTERISTICS OF DSM OPTIONS

Estimates for installed equipment costs and useful equipment life were prepared for each selected DSM option for each commercial market segment for which it was determined to be applicable. Initial estimates of the costs of installing the DSM options were derived from extant literature; the initial estimates of the costs were then adjusted by using data available from energy audits performed for various commercial buildings in the utility's service area. Estimates of service life for each option were also developed using similar sources of information.

Load shape and energy use impacts for each DSM option within each market segment were estimated from the results of simulations made with an hourly building energy analysis simulation model (ADM Associates n.d.). Simulations of energy use in a "typical" building of each market segment were made first; separate simulations were made for gas-heated and electric- heated buildings. To define the characteristics of the typical buildings, data collected

Table 1. Commercial Appliance Technologies Selected as DSM Options

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Lighting DSM Options:

   Delamping
   Low wattage bulbs
   High efficiency ballasts
   Metal halide lamps
   Optical reflectors
   Occupancy sensors
   Photo cells
   Daylighting
   HID interior

HVAC DSM Options:

   Energy management system
   High efficiency fan motors
   High efficiency AC
   Variable frequency drives for
   fans
     and pump motors
   Variable-air-volume system
   Roof insulation
   Economizers
   Economizer repair
   Full thermal storage
   Partial thermal storage
   Gas cooling
   Window film

Water Heating DSM Options:

   Low temperature dishwashers
   Change electric booster to gas

Refrigeration DSM  Options:

   Liquid pressure amplifiers
   Unequal parallel compressors

Cooking DSM Options:

   Solid element burner
   Solid state controls

Process DSM Options:

   Variable speed drives
   High efficiency motors
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in surveys of commercial customers and in audits of commercial buildings were reviewed. From this review, typical buildings were defined in terms of their square footage, structural characteristics, and equipment.

Reductions in kW demand and kWh energy use resulting from a DSM option were calculated as the differences between a base case simulation and a simulation for that same building when the DSM option was installed. The estimated reductions in kW demand at time of system peak are shown for each DSM for existing buildings in Table 2 and for new buildings in Table 3. (These estimates represent a weighting average across the estimates for the two climate zones considered, with the weighting based on relative square footage.)

SUPPLY CURVES

A major goal of the study was to determine the potential reductions either in peak megawatts or in gigawatthours for each DSM option in each market segment at various levels of incentive payments that the utility might make for installation of the option. Supply curves showing these potential reductions for the various DSM options were a major product of the study. Such supply curves were developed for five specified years: 1989, 1994, 1999, 2004, and 2009. An analysis of the economics and acceptability of a DSM option to customers provided the conceptual basis for the derivation of the supply curves.

The economics to a customer of installing a DSM option were calculated on the assumption that the

Table 2. Estimated Reductions in kW Demand at Time of System Peak for DSM Options in Existing Buildings (Watts per Square Foot, Weighted across Climate Zones)

DSM Option	Watts Reduced per Sq. Ft., by Building Type						
	Large Office Retail	Small Office Retail	Restaurant	Hospital	Grocery/Rfr Warehouse	Hotel Motel	Industrial
Lighting:							
Delamping	0.54	0.43	0.19	--	0.27	--	--
Low wattage bulbs...	0.24	0.45	0.13	--	0.37	--	--
High efficiency ballasts..........	0.27	0.34	--	--	0.27	--	--
Metal halide lamps .	0.00	--	--	--	--	--	--
Optical reflectors..	0.35	1.52	--	--	1.27	--	--
Occupancy sensors ..	0.05	--	--	--	--	--	--
Daylighting	0.11	--	--	--	--	--	--
HID Interior........	--	--	--	--	0.18	--	--
Delamping & low wattage bulbs.....	--	--	--	0.33	--	--	--
Hotel lighting package...........	--	--	--	--	--	0.04	--
HVAC:							
Energy management system............	0.41	--	--	0.07	--	--	--
High efficiency fan motors............	0.05	--	--	0.05	--	--	--
Variable frequency drive fan & pump..	0.00	--	--	--	--	--	--
Variable air volume system............	0.73	--	--	--	--	--	--
Roof insulation.....	0.02	0.26	--	--	--	--	--
Economizers.........	0.00	-0.03	0.07	--	0.00	--	--
Economizer repair...	0.00	-0.03	0.07	--	0.00	--	--
High efficiency AC..	0.29	0.91	1.73	0.17	2.15	0.09	--
Gas cooling	1.60			0.74		0.10	
Full thermal energy storage...........	2.72	--	--	2.38	--	--	--
Partial thermal energy storage ...	1.36	--	--	1.19	--	--	--
Window film.........	0.04	0.04	--	--	--	0.02	--
VAV/window film package...........	--	--	--	0.03	--	--	--
Water Heating:							
Low-temperature dishwashers.......	--	--	1.25	--	--	--	--
Change electric booster to gas....	--	--	0.98	--	--	--	--
Refrigeration:							
Liquid pressure amplifier.........	--	--	--	--	0.05	--	--
Unequal parallel compressor........	--	--	--	--	0.00	--	--
Cooking:							
Solid element burner & solid state controls package..	--	--	0.25	--	--	--	--
Industrial:							
Variable speed drivers...........	--	--	--	--	--	--	0.07
High efficiency motors............	--	--	--	--	--	--	0.05

Table 3. Estimated Reductions in kW Demand at Time of System Peak for DSM Options in New Buildings (Watts per Square Foot, Weighted across Climate Zones)

DSM Option	Watts Reduced per Sq. Ft., by Building Type						
	Large Office Retail	Small Office Retail	Restaurant	Hospital	Grocery/Rfr Warehouse	Hotel Motel	Industrial
Lighting:							
Delamping	n/a	n/a	n/a	--	n/a	--	--
Low wattage bulbs...	0.16	0.41	0.06	--	0.26	--	--
High efficiency ballasts..........	0.05	0.32	--	--	0.20	--	--
Metal halide lamps .	n/a	--	--	--	--	--	--
Optical reflectors..	0.25	1.31	--	--	0.81	--	--
Occupancy sensors ..	n/a	--	--	--	--	--	--
Daylighting	n/a	--	--	--	--	--	--
HID Interior........	--	--	--	--	0.11	--	--
Delamping & low wattage bulbs.....	--	--	--	0.18	--	--	--
Hotel lighting package...........	--	--	--	--	--	0.02	--
HVAC:							
Energy management system............	0.14	--	--	0.06	--	--	--
High efficiency fan motors............	0.04	--	--	0.04	--	--	--
Variable frequency drive fan & pump..	n/a	--	--	--	--	--	--
Variable air volume system............	n/a	--	--	--	--	--	--
Roof insulation.....	n/a	n/a	--	--	--	--	--
Economizers.........	n/a	n/a	n/a	--	n/a	--	--
Economizer repair...	n/a	n/a	n/a	--	n/a	--	--
High efficiency AC..	0.19	0.20	0.42	0.11	0.29	0.02	--
Gas cooling	0.98			0.57		0.07	
Full thermal energy storage...........	2.64	--	--	1.58	--	--	--
Partial thermal energy storage ...	1.32	--	--	0.79	--	--	--
Window film.........	0.08	0.11	--	--	--	0.02	--
VAV/window film package...........	--	--	--	0.82	--	--	--
Water Heating:							
Low-temperature dishwashers.......	--	--	1.25	--	--	--	--
Change electric booster to gas....	--	--	1.00	--	--	--	--
Refrigeration:							
Liquid pressure amplifier.........	--	--	--	--	0.00	--	--
Unequal parallel compressor........	--	--	--	--	0.00	--	--
Cooking:							
Solid element burner & solid state controls package..	--	--	.06	--	--	--	--
Industrial:							
Variable speed drivers...........	--	--	--	--	--	--	0.07
High efficiency motors............	--	--	--	--	--	--	0.05

present value of the savings in energy costs that would result from the use of a DSM option represents the maximum price that a customer would pay to install the option. (This approach is similar to the cost requirements approach used by Brown and Spanner 1989.) The dollar savings from installing a DSM option were estimated by factoring data on projected gas and electricity rates with the energy savings data for the option to arrive at estimates of dollar savings over each year of the service life of the option. For each of several discount rates, the stream of yearly dollar savings was reduced to a present value. A regression equation was then calculated that summarizes the relationship between the present value of the accumulated dollar energy savings over the lifetime of the option and a discount rate that measures a customer's evaluation of future savings.

A customer acceptance function was formulated to relate the share of the market that would be captured by a DSM option to the discount rate used by firms. Essentially, this curve represents the distribution of firms according to the returns that they require from an investment. The empirical formulation of the customer acceptance function was based on assumptions about the maximum market share attainable by a measure or option and the payback period at which a measure or option would attain 50% of the market in 1989. The assumptions used were arrived by reviewing studies that the utility had conducted on the acceptance of conservation/load management technologies by commercial firms within its service territory.

For the base case analysis, it was assumed that a DSM option would attain 50% of the market in 1989 if the payback period were 1.8 years (i.e., a rate of return of about 55%). However, it was also assumed that incomplete information among potential adopters would prevent any option from attaining 100% of the market even under the most favorable payback considerations, but that the limit on the percentage of the market that was attainable would increase over time. For 1989, it was assumed that the maximum market share attainable would be 68% even for an option that paid back instantaneously. The market share limit was assumed to increase year by year, reaching 76% by 1994, 84% by 1999, 92% by 2004, and 100% by 2009. In effect, the customer acceptance function was parametrically shifted outward to represent the spread of information regarding DSM technology.

Given the customer economics relationship and the customer acceptance function, the effects of different utility incentive payments on the market acceptance of a DSM option were determined by analyzing the consequences of changes in the cost of the option. An incentive payment was interpreted as a lump sum payment that lowers the cost of installing an option. With the cost to the firm of installing the option lowered, the rate of return that it can realize from investing in the option is higher. From the form of the customer acceptance function, a higher rate of return implies a higher market share for the DSM option.

To determine the reduction in system peak megawatts or in gigawatthours that is associated with a DSM option, a market share, as determined from the customer acceptance function, was multiplied by the amount of square footage in the market segment for which the option was considered applicable and by the amount of energy use reduction per square foot. Applicable square footage could be less than total square footage in the market segment for several reasons. First, some buildings in the market segment could already have installed the particular DSM option and no longer be candidates for installation. Existing saturations of each option were estimated from data collected by the utility in surveys of its commercial customers (San Diego Gas and Electric 1987). Second, the potential for installing a DSM option generally differs between customers who own the space they occupy and those that lease or rent. Based on audit experience with the utility's customers, it was assumed that all of applicable owned space offered potential for installing a DSM option, but only about 20% of leased space was assumed to offer such potential. Third, it may not be physically possible to install the option in all buildings in a market segment. Engineering judgment on this factor was used to reduce the applicable square footage for a option.

By varying the level of the incentive payment, a supply curve was traced out that relates reduction in peak megawatts or in gigawatthours to incentive level. (Because these supply curves focus on the potential available from a single option at different levels of incentive, they differ in concept from the conservation supply curves introduced by Meier et al. 1983, which show the potential achievable from successively higher cost measures.) The form of the supply curves is shown in Figure 1, using optical reflectors as an example. (Only the supply curves for 1989 and 1994 are illustrated, although similar curves were developed for 1999, 2004, and 2009.) As this example shows, the supply curve represents the relationship between estimated reductions in kW demand at time of system peak and different levels of incentives offered by the utility (expressed as payments made per kW reduced). Similar curves were developed to show the reductions in gigawatthours at different levels of incentives expressed as payments made per kWh reduced.

Factors that cause the supply curve for a DSM option to shift over time were addressed through shifts in the functional relationships. For example, the customer economics relationship was shifted through changes in the starting year for the price projections. The relationship between maximum price and discount rate for 1989 was determined using a price projection series that begins in 1989 to calculate the present value of savings from an DSM option. For 1994, the relationship was determined using a price projection series that begins in 1994. Because prices increase over time, the customer economics relationship between present valued savings and discount rate shifts out over time. The cost of installing an DSM option was escalated over time by applying a factor that measures the expected rate of price increase over time.

LOAD SHAPES

Load shape data were developed for each DSM option in each applicable market segment. For each option, a 24-hour load shape was developed for each of 7 types of day for each month of the year. These day types include 1 peak day, 4 weekdays, and 2 weekend days.

As with the calculation of energy savings, load shape differentials were calculated as the difference

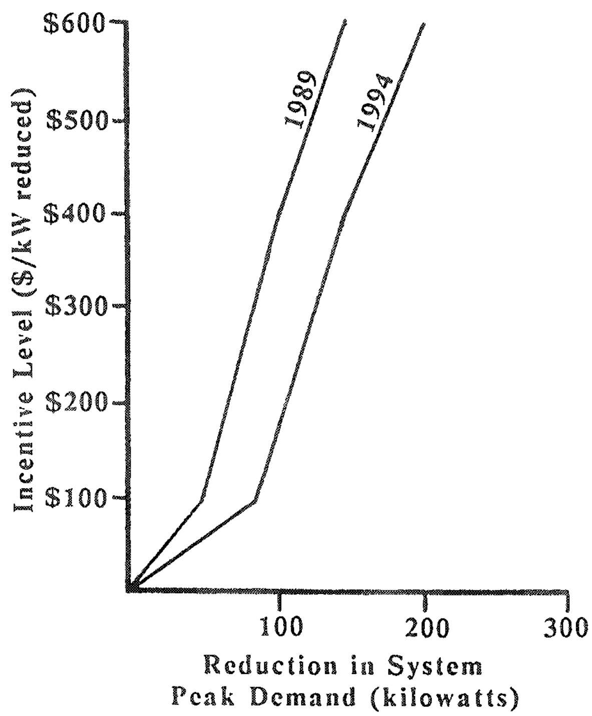

Figure 1. Example of Supply Curve for Single DSM Option (Optical Reflectors)

between a base case load shape without the option and the load shape with the option. To normalize load differentials, a scaling procedure was used in which all values within a load shape file were divided by the value for the utility's system peak hour (assumed to be an August weekday at 2:00 P.M.). These scaling factors represented the reduction in demand during the August 2:00 P.M. hour that resulted from installation of a particular DSM option.

While load shapes for individual DSM options are of interest themselves, in an integrated resource planning exercise it is desirable to have DSM options whose aggregate impacts on system loads are of a magnitude comparable to the supply side resources with which they are being compared. Accordingly, the DSM options were grouped into 18 different groupings that could be considered as DSM packages in the integrated resource planning process.

LIMITATIONS OF ANALYSIS

The commercial appliance technologies selected for evaluation in this study were chosen from among technologies that have been demonstrated to be cost-effective and/or commonly-used in the utility's service territory. Options were not included if they were perceived as unlikely to achieve significant market penetration or if the energy savings they offer could be obtained more cost-effectively through other technologies.

The methodology used to forecast the market penetration of a DSM option is based on a customer acceptance function that effectively represents a distribution of commercial firms by the rate of return they require in an investment. The customer acceptance function that was used is limited in that it was assumed to apply to all market segments and to all DSM options. Moreover, the empirical basis for the assumed customer acceptance function is somewhat ad hoc, as is the manner in which competing technologies are handled. In the current approach, for example, competition among gas cooling, partial thermal storage and full thermal storage were handled through judgmental adjustments to the model outputs. Further work could be directed toward addressed the competition among such technologies more explicitly.

APPLICATION

The data base produced in this study included data on the costs, service lives, energy savings, and market potential for over 200 DSM options for commercial buildings. The intent of the study was to prepare data that could be used by the utility's resource planners to develop cost curves to represent the technical, market and resource potential of the DSM options. Clarke (1989) provides a discussion of the use of the data for the utility's integrated resource planning.

CONCLUSIONS

This study represented a first step in the utility's efforts to evaluate DSM options as resources within the same resource planning framework as generation resources. As such, it provided an initial indication that a significant data development effort is required to evaluate DSM options within that context. Based on the results of this study, a more comprehensive study is being undertaken by the utility to develop additional data to support its DSM market planning and design process.

ACKNOWLEDGMENTS

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