DSM Planning: Is It Any Different the Second Time Around?

Ahmad Faruqui, Susan S. Shaffer, Ellen Rubinstein and
Dana Toulson, Barakat and Chamberlin, Inc.
Mark S. Kumm, Potomac Electric Power Company

In 1990, the Potomac Electric Power Company (Pepco) submitted its first comprehensive Least Cost Energy Plan to the District of Columbia Public Service Commission. DSM options were a major element of this plan. Individuals representing the commissioners, commission staff, and several intervenor groups made a variety of suggestions for improving the plan. The commission mandated that Pepco incorporate several refinements in its 1992 study. Recommended improvements included: modifying the DSM measure screening process; reestimating DSM technical potential; redesigning DSM programs; incorporating more primary data into the measure screening and program design analyses; and improving the interface between DSM and supply-side planning.

Pepco responded to the commission's mandates by using building prototype modeling to establish a base case forecast and to screen DSM measures. Two modifications were made to the estimates of technical potential: technical potential was estimated *before* the economic screening, and two estimates of technical potential were developed (instantaneous and phase-in). DSM program designs were improved by incorporating Pepco's field experiences in implementing its existing DSM programs as well as feedback from customer and vendor focus groups. Two major enhancements were made in the interface between demand-side and supply-side options: a probabilistic analysis was conducted of the uncertainty in the DSM analysis, and feedback relationships among DSM programs, marginal costs, electricity prices, and the base case forecast were explicitly modeled.

Nearly every aspect of Pepco's plan was revisited and reevaluated. Not all utilities' least cost energy plan updates will be so elaborate, but updating an energy plan is more than simply revising the numbers used in the last plan. DSM and least cost planning are dynamic, ongoing, continuous efforts.

Introduction

In 1990, the Potomac Electric Power Company (Pepco) submitted its first comprehensive Least Cost Energy Plan to the District of Columbia Public Service Commission (BCI, 1989). Demand-side management (DSM) options were a major element of this plan. Individuals representing the commission, its staff, and several intervenor groups made a variety of suggestions for improvement during the regulatory review of this plan. The Commission reviewed the suggestions and mandated that Pepco incorporate several of the recommended improvements in its 1992 Least Cost Energy Plan (BCI, 1992). The mandated improvements included the following (PSC D.C., 1991):

- **Modifications to the DSM measure screening process.** Pepco was asked (1) to place greater reliance on primary data specific to Pepco's service area; (2) not to exclude a DSM measure from the economic screening process simply because the measure is perceived to have a small potential impact; (3) to modify the economic screening cost-effectiveness calculation to more closely resemble the All Ratepayers Test (or Total Resource Cost test) perspective; and (4) to use on-peak energy marginal costs to calculate the benefits of reduced annual energy consumption

- **Reestimation of technical potential.** Pepco was asked to include all measures, whether or not they pass the economic screen; to include measures with small perceived impacts, such as wholesale trade and miscellaneous commercial buildings; and to provide separate estimates for the multifamily sector, Washington Metro, and streetlighting.

- **Redesign of DSM programs.** Pepco was asked to deter cream skimming, encourage higher penetration rates, and address the needs of Pepco's multifamily customers. Pepco was also asked to investigate programs for the Washington Metro and streetlighting.

- **Improvements in the interface between DSM programs and supply-side planning.** Pepco was asked to better model the interdependence between DSM program cost-effectiveness, marginal costs, the price of electricity, and the base case forecast, and to incorporate the uncertainty in DSM impacts along with supply-side uncertainties in its 1992 Least Cost Energy Plan.

Pepco responded to these mandated improvements in developing its 1992 Least Cost Energy Plan. The major activities involved in implementing these improvements, and the results obtained, are discussed in the balance of this paper. By way of background, some information about Pepco's system is provided in the remainder of this section.

Pepco is a summer-peaking utility that serves the District of Columbia and two counties in Maryland. Over the past ten years, Pepco's system-wide energy sales (measured at the generation level) have increased from 16,577 GWh in fiscal year 1980/81 to 23,932 GWh in fiscal 1990/91, for an average annual growth rate of 3.7%. Over the same period, system-wide summer peak load has increased from 4,142 MW to 5,442 MW, for an average annual growth rate of 2.8%. Over this time frame, the annual load factor has improved by four percentage points from 48.5% to 52.4%. Energy growth is forecast to grow at an average annual growth rate of 1.6% over the next ten years, and summer peak load at 0.8%.

The District of Columbia accounts for 44.1% of Pepco's system energy consumption and 42.7% of system peak demand. In the year 2000, the residential sector, comprised of single-family homes and townhouses, is estimated to account for about 9.2% of the district's energy consumption and 13.1% of peak demand. The multifamily sector, comprised of both individually metered apartments and master-metered apartments, is projected to account for 8.2% of the district's energy consumption and 7.8% of the peak demand. The commercial sector accounts for the bulk of the District's energy consumption and peak demand: 82.6% and 79.1% respectively.

The remainder of this paper focuses exclusively on activities connected with updating the Least Cost Plan in the District of Columbia.

Modifications to the DSM Measure Screening Process

The DSM measure screening process followed in Pepco's 1992 Least Cost Energy Plan is illustrated in Figure 1. The process consists of a qualitative screen, an economic screen, and a technical potential analysis of DSM measures. In order to respond to the commission's concern that Pepco make maximum use of primary data, we incorporated the use of building prototype modeling in the residential, multifamily, and commercial sectors. This is shown in the box in the upper right corner of the figure.

For the residential sector and individually metered multifamily dwellings, we defined six building prototypes. The prototypes varied by building vintage (new or existing) and type of heating system (electric resistance, electric heat pump, and gas furnace). Estimates of energy consumption in these prototypes were developed using the PEAR model developed by Lawrence Berkeley Laboratory for the U.S. Department of Energy (LBL, 1986). Assumptions about key inputs into the PEAR model--such as ceiling and wall insulation levels, building size and configuration, and equipment efficiencies--were derived from a review of Pepco's residential surveys and discussions with Pepco's residential energy services staff. Estimates of prototypical buildings' peak demand base case usage and savings were developed through a review of Pepco load research data, supplemented with load profile information compiled by the New England Power Pool (NEPOOL). Separate analyses were conducted for single-family dwellings and individually metered multifamily dwellings. Three sets of dwelling sizes were examined: 1,200 and 1,500 square feet for single-family dwellings and 800 square feet for multifamily dwellings.

We used a proprietary building simulation model to estimate base case energy consumption and DSM savings potential for master-metered apartment and four commercial building types (private offices; government offices; health care; and lodging). In the commercial sector, building simulation analysis was limited to buildings with average peak demands in excess of 1,000 kW. All customer accounts of this size are included in Pepco's class-load metered load research sample. The master-metered apartment prototype was representative of the entire population of this building type. Because of the large disparity in building characteristics, however, two master-metered prototypes were analyzed: small master-metered apartments (<250 kW) and large master-metered apartments (>250 kW).

In addition to the use of building prototype analysis, Pepco's 1992 study incorporated a revised list of DSM measures. The list was expanded to include additional measures such as chopper cars for the Washington Metro, bivalent heat pumps, and the teletimer customer-operated load control device.[1] In addition, measures were specifically analyzed for the multifamily sector. In identifying opportunities for DSM measures, the 1992 study began with a list of 290 measures (72 in the residential sector,

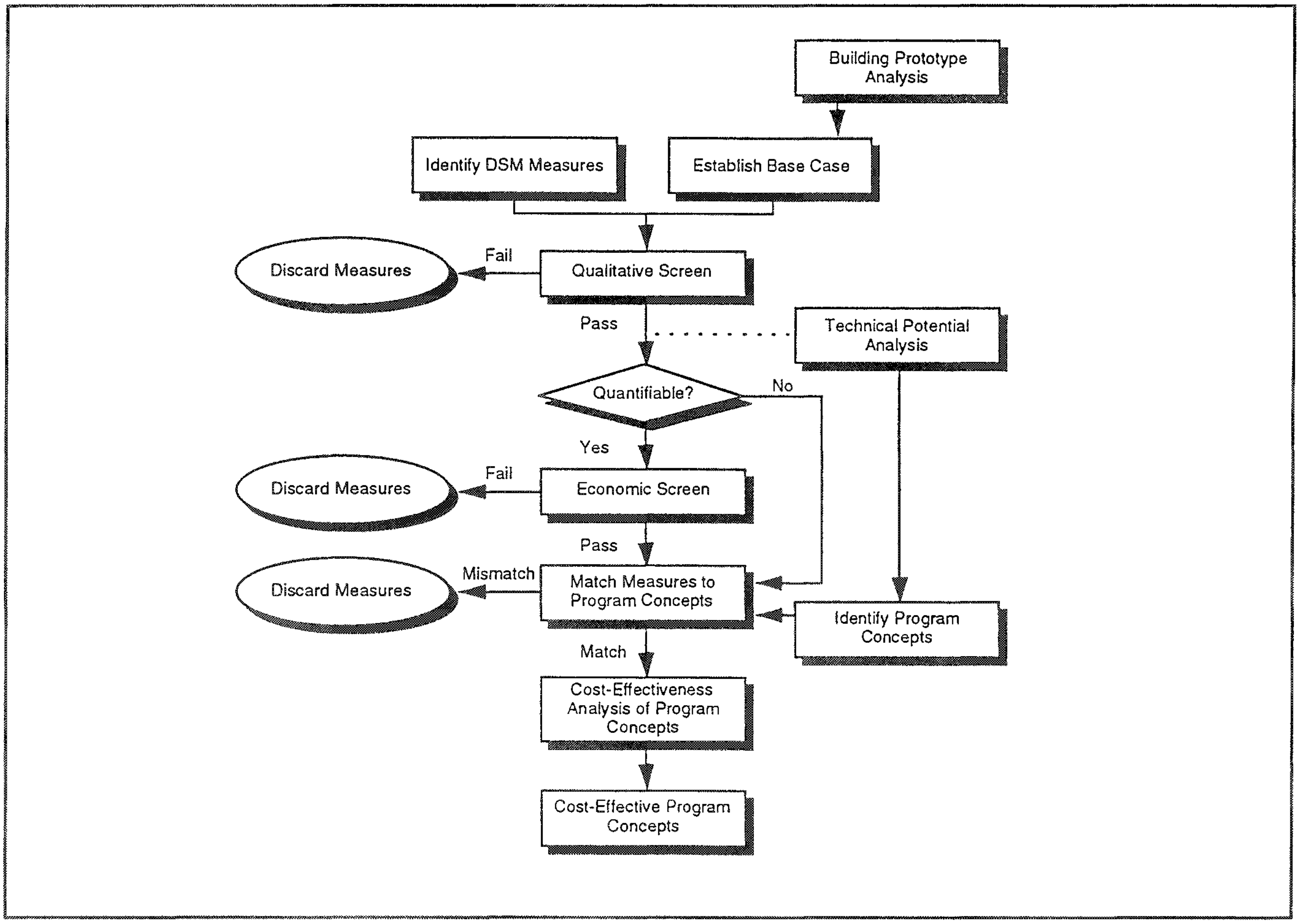

Figure 1. Approach to DSM Planning

72 for individually metered multifamily dwellings, 61 for master-metered apartments, and 85 in the commercial sector). The 290 measures analyzed were further distinguished by customer class, building/equipment vintage, end use, and building type. The residential and multifamily analyses assessed measures in nine major appliance categories (refrigerator, freezer, water heater, dishwasher, clothes washer, clothes dryer, range, microwave, and lighting), four weather-sensitive end uses (resistance heat, heat pump, central air conditioning, and room air conditioning). The commercial analysis assessed measures in four appliance categories (water heating, cooking, refrigeration, and lighting) and three weather-sensitive end uses (heating, cooling, and ventilation). Whenever possible, measures were analyzed by building type (office, government office, restaurant, retail, grocery, warehouse, school, college, health care, lodging, and a miscellaneous building type).

In the 1992 study, the qualitative screen, which identifies specific factors or criteria that may limit the applicability of DSM measures to Pepco's service area, was modified to eliminate the criterion of "small perceived impact." This resulted in several residential shell measures and commercial space heating measures that had been excluded from the previous study being passed on to the economic screen. Measures are passed on to the economic and technical potential screening analysis only if they pass each of the qualitative assessment criteria. Measures that pass all qualitative criteria, but whose savings potential can only be quantified on a site-specific basis are excluded from the economic analysis (although they are included in the technical potential analysis). These measures are passed directly on to the program design stage for consideration in customized rebate programs.

Of the initial list of 290 measures analyzed, 149 were passed on to the economic screen and 167 were passed on to the technical potential analysis; in all, 250 were considered for inclusion in DSM programs. The number of measures considered for inclusion in programs is larger than the number of measures included in the economic and technical potential analyses for several reasons. First, only the "best" measures were included in the technical potential analysis. In addition, because the savings for many measures are quantifiable only on a site-specific basis, many measures cannot be analyzed effectively in the economic screening analysis, but are suitable for customized rebate programs with verifiable savings criteria.

The economic screen was also modified in the 1992 study to resemble the All Ratepayers Test (or TRC), with the exception that program administration costs were not included in the screening process. In addition, the value of savings in annual energy consumption was assessed using on-peak marginal energy costs, rather than a combination of average annual marginal energy costs along with summer and winter on-peak demand savings. On-peak marginal energy costs were used in the economic screen to give potential DSM measures the "benefit of the doubt," so as not to discard potentially attractive DSM measures prematurely.

Reestimation of Technical Potential

Two modifications were made to the technical potential analysis in the 1992 study. First, we estimated the technical potential *before* the economic screening of measures. Second, we estimated two kinds of technical potential: instantaneous and phase-in potential. (We had estimated only the instantaneous technical potential in the 1990 study.) Instantaneous technical potential is theoretical, because it assumes that equipment can be instantaneously and continuously upgraded to the most efficient equipment available. Phase-in technical potential estimates instead limit the calculation of technical potential by substituting the best commercially available equipment for new, inefficient equipment. This perspective assumes that equipment efficiency measures will be adopted only by customers purchasing new or replacement equipment. In the phase-in technical potential analysis, only new growth plus equipment that has worn out and is ready to be replaced is upgraded to the most efficient equipment available.

Eventually, over time, the phase-in technical potential converges to the instantaneous technical potential, as more and more equipment and building stock turn over. In our experience, because the instantaneous technical potential analysis is theoretical in nature, phase-in technical potential estimates provide a better indication of the likely upper limits to energy efficiency that can be achieved through DSM programs.

Redesign of DSM Programs

Improvements were made in designing Pepco's potential DSM programs, based on the experience Pepco gained through actual field implementation of full-scale and pilot DSM programs and through feedback from customer and trade ally focus groups. Recent experiences of other utilities were also incorporated into this study (Berry, 1990; and Nadel, 1990). Examples of program design enhancements included in the 1992 study are:

- A sliding scale of rebates was created to encourage customers to purchase the highest efficiency residential cooling equipment.

- Builders of new homes and commercial buildings were provided rebates equal to 100% of the incremental costs of efficiency improvements.

- Market penetration rates were raised for several programs, based on Pepco's experience to date and the experience of other utilities with similar program concepts. For example, the equilibrium cumulative penetration rate for Water Heater Retrofit program was increased from 27% to 60%, and the equilibrium annual penetration rate for the High-Efficiency Residential Cooling program was raised from 33% to 50% of the eligible replacement stock each year. The Small Commercial Shop Doctor program was redesigned to be a "blitz" program,[2] and that program's maximum cumulative penetration rate was raised from 21% to 50% accordingly.

- Market penetration rates were raised for some programs based on Pepco's own experience. For example, Pepco's experience with alternative delivery mechanisms for the Compact Fluorescent program suggested that the equilibrium annual penetration rate be raised from 2.5% to 10%.

- Program participation eligibility criteria were expanded for several programs. For example, all commercial new construction became eligible for incentives offered through the New Building Design program; only buildings greater than 75,000 square feet had been eligible in the 1990 study. Similarly, customers up to 500 kW are eligible to participate in the Small Commercial Load Reduction program; only customers below 125 kW had been eligible in the previous study. Pepco's experience indicates that larger customers are more capable of participating in this program.

In addition, two new program concepts were created to supplement the 14 concepts developed in the previous study: a Residential Weatherization program for electrically heated homes, and a High-Efficiency Water Heater Rebate program. These additional program concepts were developed for three reasons: (1) the measures to be offered through these programs were not excluded a priori by the qualitative screening process; (2) the measures included in these programs passed the economic screen; and (3) the new programs addressed target markets sufficiently distinct from the markets of other programs that an entirely new program seemed warranted.

Interface With Supply-side Options

In Pepco's 1992 Least Cost Energy Plan, two major enhancements were made in the interface between demand-side and supply-side options. First, a more detailed probabilistic analysis was conducted of the uncertainty in the DSM cost-effectiveness analysis. Second, explicit allowances were made in the least cost planning analysis for the feedback relationship among DSM programs, marginal costs, electricity prices, and the base case forecast (Hill, 1991).

Uncertainty Analysis

Regarding the uncertainty analysis, we replaced the single-variable sensitivity analysis approach used in the 1990 study with a probabilistic analysis that allowed for simultaneous uncertainty in three key variables of the cost-effectiveness equation. These three uncertain variables were unit impacts for energy and demand, market penetration rates, and free rider rates. The uncertainty analysis was first used to assess the validity of the program's pass/fail cost-effectiveness decision and then to estimate the likely range of program's energy and demand savings. We assessed the validity of the pass/fail decision by confirming that programs are cost-effective even taking uncertainty into consideration. This verification process involved estimating the probability that a program will be cost-effective (i.e., has a benefit-cost ratio greater than 1), and selecting a probability "threshold level" such as 75% or higher.[3] For example, a DSM program may have a benefit-cost (B/C) ratio of 1.5 and its probabilistic sensitivity analysis may indicate that the program has an 80% probability of being cost-effective. Another DSM program may have a B/C ratio of 1.2 and a 50% probability of being cost-effective. If the probability threshold level is set at 75%, then the first program would be cost-effective even taking uncertainty into consideration, but the second program would not.

Estimating the likely range of DSM program impacts involved reviewing the probability distribution of the energy and demand savings estimates. Confidence intervals at the 90% range were developed to assess the likely range of impacts.

We used triangular distributions to represent the uncertainty in the three key elements, and Latin Hypercube sampling with 200 iterations to develop the output probability distributions. The minimum and maximum values used to define the triangular distributions for each variable were based on the experience of other utilities with similar DSM programs (BCI, 1990). The most likely values were always set at the values used in the deterministic analysis of program cost-effectiveness for Pepco.

Feedback Relationships

The second enhancement relating to demand- and supply-side options dealt with feedback relationships among DSM programs, marginal costs, electricity prices, and the base case forecast. Pepco relied on an iterative full-loop integration technique to identify the combination of future supply- and demand-side resources with the lowest total revenue requirement. The full-loop technique incorporated a feedback mechanism that measures how preliminary resource selections will affect long-run marginal costs, electricity prices, and the base case forecast.

Figure 2 summarizes the full-loop integration process used by Pepco in this study. Pepco developed an initial base case forecast (excluding DSM program impacts) using an initial assumption about the future growth rate in electricity prices. Load reductions associated with the cost-effective DSM program concepts developed in this study are subtracted out of the base case forecast to derive two net load forecasts. The first net load forecast (LF') reduced the base case forecast by half of the savings expected from DSM programs. The second forecast (LF-C) reduced the base case forecast by 100% of the anticipated DSM load reductions.

Pepco's least cost planning process consisted of two loops. In the first loop, Pepco developed a supply-side-only plan (using the EGEAS model) that satisfied the resource requirements of the LF' load forecast (including 50% of DSM impacts). We used the marginal costs associated with this plan to assess the cost-effectiveness of DSM program concepts under the All Ratepayer Test.

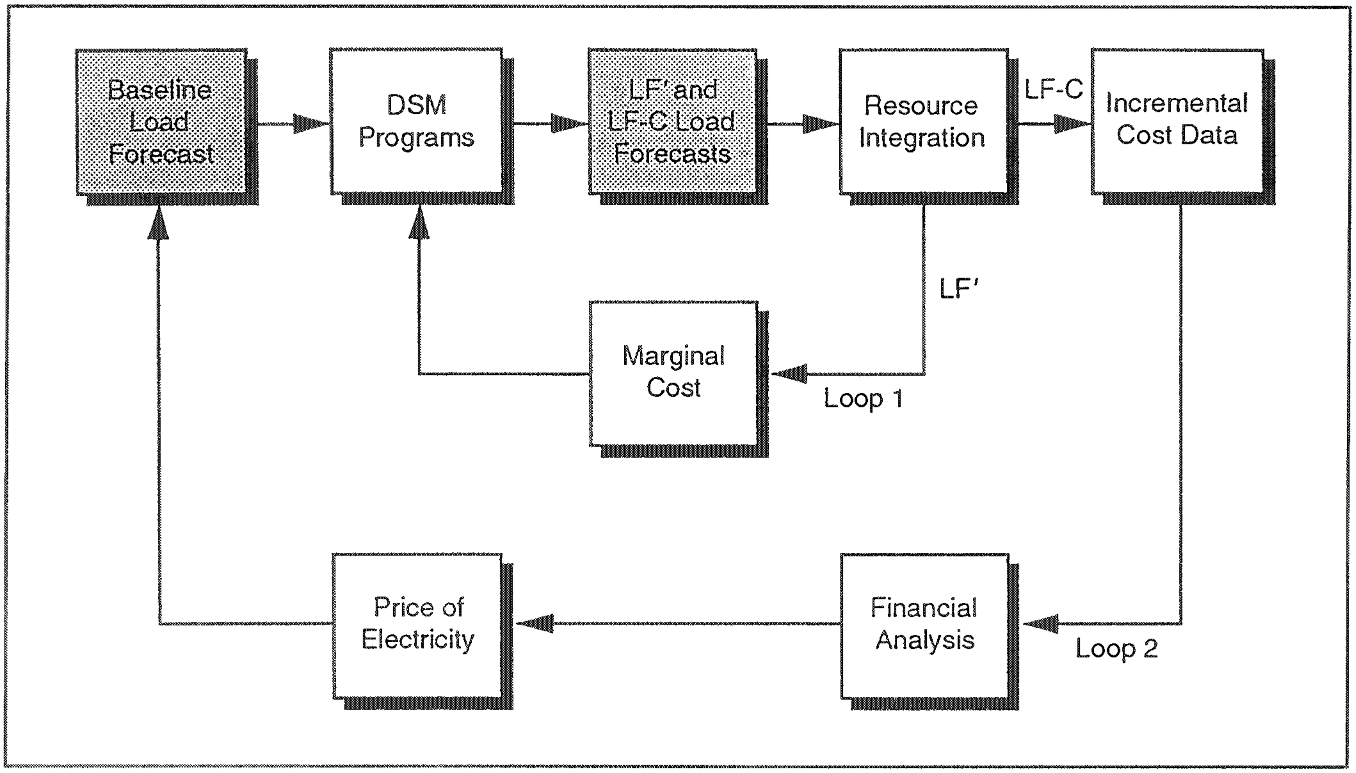

Figure 2. Feedback Loops Between DSM and SS Planning

Demand and energy reductions associated with the cost-effective DSM program concept were then fed back into the net load forecasts. Marginal costs were then recalculated and DSM programs reevaluated for cost-effectiveness. If the selection of DSM programs changed, the net load forecast was adjusted again through the first loop. This cycle continued for several iterations until the adjustments had no further effect on the selection of cost-effective DSM programs.

The second loop considered the relationship between electric rates and customer demand for electricity. After identifying all cost-effective DSM programs, we developed a supply-side plan (using EGEAS) that met the capacity requirements of the last iteration of the LF-C forecast (including 100% of DSM impacts). We estimated future electricity prices by combining the incremental costs associated with the resulting supply- and demand-side resource mix with Pepco's embedded costs. If the growth in the real price of electricity differed significantly from the assumptions made in the initial base case forecast, we computed the changes in electricity use and made adjustments to forecasting equations. This revision ensured that the price of electricity was consistent with the specific supply- and demand-side resource plan under consideration.

With this adjustment made, we produced an updated base case load forecast and the, process preceded back through loop 1 again. We developed new resource plans through loops 1 and 2 until the price of electricity reached equilibrium. At this point, both the least cost plan and the load forecast were fully defined and internally consistent.

The full-loop integration process was carried out with respect to three scenarios of future economic activity and inflation rates. Each scenario made different assumptions about Pepco's future operating environment. The low case scenario assumed a sluggish economy plagued with high inflation (7%) throughout the planning period. The base case scenario assumed a moderate economy and a 5% inflation rate. This was the "most likely" forecast. The high case scenario assumed a booming national and regional economy and a 4% inflation rate over the planning period.

Results

Fifteen of the 16 DSM program concepts analyzed in the 1992 study were found to be cost-effective in the District of Columbia from the All Ratepayers Test perspective. These programs, along with the impacts of Pepco's existing full-scale programs, are projected to reduce

Pepco's energy consumption by about 8% and summer peak demand by about 15% in the year 2000. Figures 3 and 4 show these impacts alongside the estimates of instantaneous and phase-in technical potential for the year 2000.

The cost-effective DSM program impacts developed in this study are higher than their 1990 counterparts, especially for annual energy consumption. The 1992 study's estimate of 8% savings in energy consumption compares with a 5% savings estimate for the 1990 study; and the 1992 study's estimate of 15% savings for summer peak demand compares with a 14% estimate for the 1990 study. Much of the difference in impact is due to revisions in the projected program penetration rates, brought about by program redesigns based on a review of Pepco's DSM program experience and the experience of other utilities.

Based on these projected results, Pepco's DSM package compares very favorably with the most aggressive DSM packages in the nation. Compared with the DSM savings projections reported by the top 25% of a sample of utilities surveyed, Pepco's 8.0% energy savings projection compares to an average energy savings of 4.1% of the utilities surveyed. Pepco's 15% peak demand savings program compares to an average demand savings of 7.8% of the utilities surveyed.[4]

To assess the validity of the program pass/fail decision, we estimated the probability that a program is cost-effective (i.e., has a B/C ratio greater than 1). Of the programs that pass (15 of the 16 considered in the analysis), all had a probability of 80% or higher of being cost-effective, except for the multifamily components of two residential programs. For the one program that failed, the probability that its B/C ratio is greater than 1 is nil, based on the 200 simulations that we carried out.

Conclusions

Updating Pepco's Least Cost Energy Plan was an intensive effort. In addition to addressing issues mandated by the commission for consideration, the update had to consider the dynamic nature of the DSM planning process. Information on efficiency standards, technology development, and program evaluations is continuously changing. In addition, as Pepco gains more experience in implementing its full-scale DSM programs, more primary data are available to be analyzed and incorporated into future planning studies. As a result, nearly every aspect of Pepco's plan was revisited and reevaluated. Given the scope of the issues included in the update, the 1992 study proved to be at least as complex as the first study.

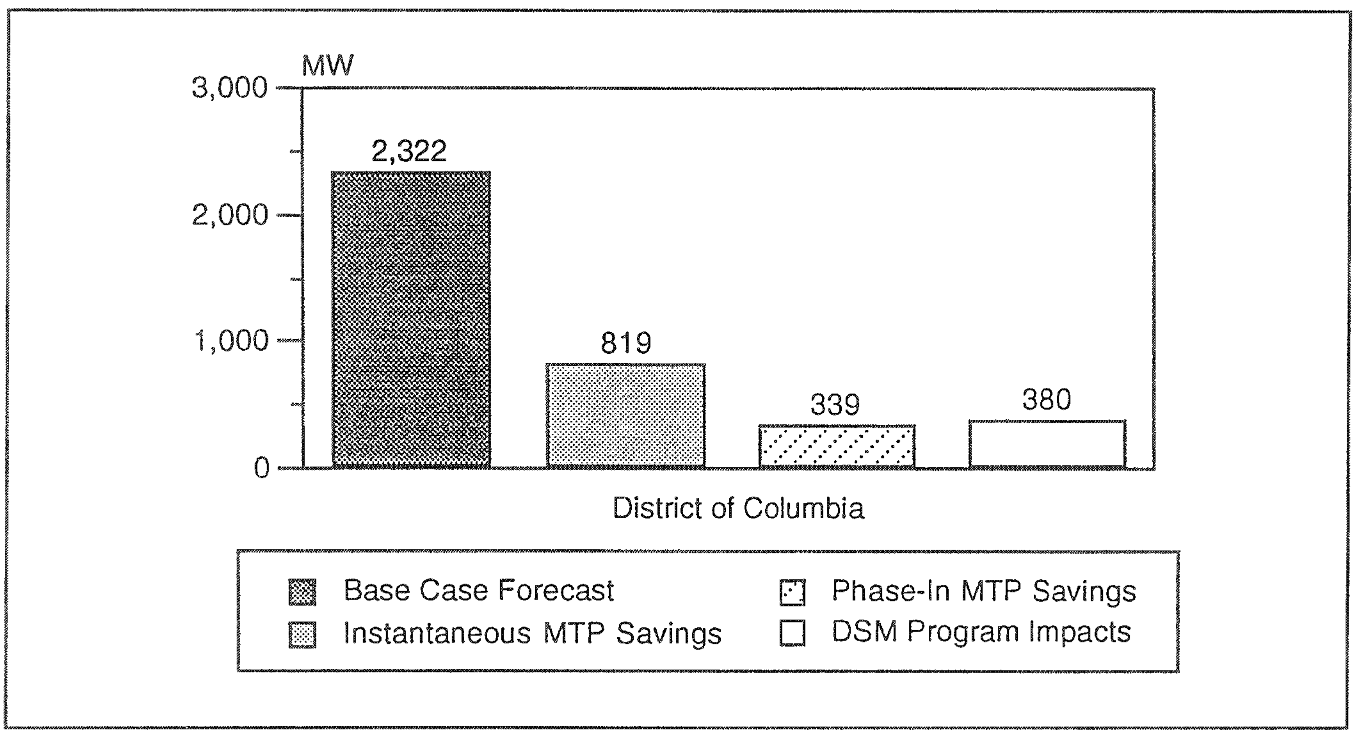

Figure 3. Base Case Summer Peak Demand and Alternatives: District of Columbia - Year 2000

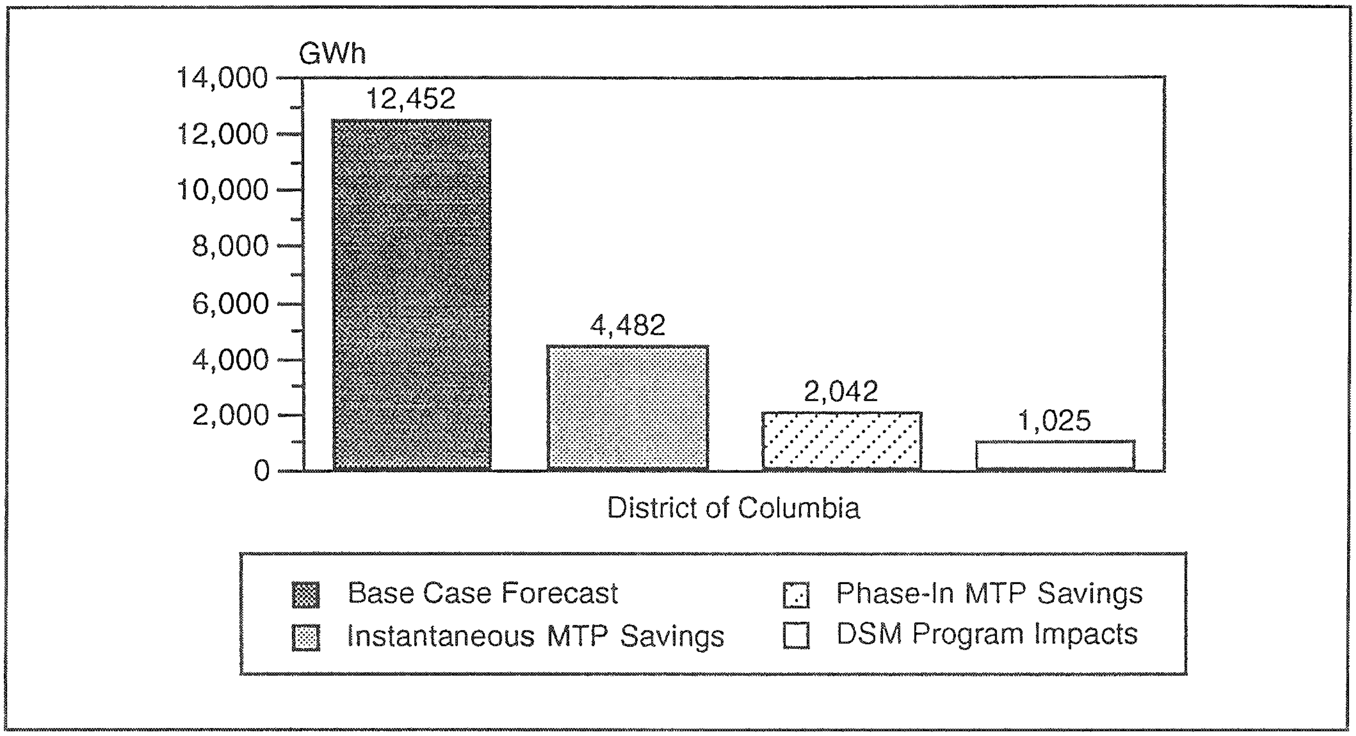

Figure 4. Base Case Energy Consumption and Alternatives: District of Columbia - Year 2000

The results of Pepco's 1992 Least Cost Energy Plan differ from those of the 1990 study. Many factors contribute to these differences: changing economic forecasts, base case energy forecasts, efficiency standards, new DSM measures, and existing DSM program impacts. The results of future plans may differ as well, and they are also likely to be even more realistic. As more DSM program implementation experience is gained and program evaluation and market research efforts occur, utilities will be able to rely less on the experiences of others during the planning process. Instead, estimates of DSM program potential will need to be refined to reflect the utility's actual experiences.

Not all utility least cost energy plan updates will be as elaborate as Pepco's. Updating an energy plan, however, is more than a simple update of the numbers used in the last plan. Pepco's experience in updating its DSM and least cost plan is not unique. Utilities are finding that DSM and least cost planning must be viewed as ongoing, continuous efforts. Because of the rapidly evolving nature of DSM options and efficiency standards, DSM plans are quickly outdated. As Winston Churchill once said, "the plan is nothing; planning is everything."

Acknowledgements

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Endnotes

1. A *chopper car* is a regenerative breaking car for subway systems. The heat that is usually lost during breaking can be recovered and used to power the chopper car. A *bivalent heat pump* is a burner-assisted heat pump. In its most common configuration, a bivalent heat pump consists of a standard air source

heat pump installed as a retrofit to an existing fossil fuel furnace. This configuration is typically referred to as an add-on heat pump. A *teletimer* is a telephone-activated controller that allows customers to turn equipment in their homes on or off via the telephone.

2. A blitz program entails aggressive promotion of direct installation of an energy efficiency measure. In this case, the direct-installation lighting measure was reduced from a 15- to a 5-year program.

3. The probability threshold level of 75% was selected based on professional judgment.

4. Utility DSM program energy and demand savings projections were obtained by Barakat & Chamberlin, Inc., from published utility documents and informal discussions with utility staff. Information on projected energy savings was obtained for 41 utilities. Information on projected peak demand savings was obtained for 50 utilities. Only the results of the top 25% of utilities in each category surveyed were compared with Pepco's results.

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