DSM Potential Studies and Innovative Long-Range DSM Planning

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Defining and measuring potential DSM market opportunities is no simple task. New England Electric System companies worked with Regional Economic Research, Inc. to develop a carefully defined DSM potential estimate. The process made us recognize the need to properly understand what part of DSM potential utilities can affect, the sensitivity of study results to assumptions, limitations imposed by benchmarking models to historic DSM experience, and the pitfalls in comparing utilities' estimates. This paper presents information about what needs to be considered in designing a potential study. Then the paper describes how the potential estimates were used in designing long-range DSM strategies that can be integrated with supply-side options, are flexible enough to adapt to changing utility needs and market conditions over time, and are stable enough to maintain viable implementation infrastructures in all customer markets, by creating market-based DSM resource options.

Introduction

The New England Electric System (NEES) companies[1], like other major utilities, are focusing increasing attention on demand-side management (DSM) as an element of their integrated resource plan. And like many utilities, the NEES companies are attempting to develop long-range DSM options that can adapt to changing utility needs and market conditions over time.

In order to integrate DSM into a resource plan, it is necessary to know the total technical and economic potential for DSM as well as the energy and demand impacts that can be secured under different scenarios. DSM can be implemented through a wide range of utility-sponsored programs. Planners must consider the technical and cost characteristics of these technologies, customer load characteristics, and the utility's marginal energy and capacity costs. A DSM potential study was undertaken by the NEES companies and Regional Economic Resources (RER), Inc., to assemble such information.

The overall goal of this process was to create a better approach for developing long-run options, flexible enough to meet changing business plan needs and higher customer service standards. Meeting business and customer needs requires understanding market opportunities by sector. Developing worthwhile resource options requires up-to-date estimates of potential in the service area and a framework for analyzing naturally occurring and program-induced penetration of DSM technologies.

The size of the DSM resource is limited by its gross technical potential, which is the potential for efficiency improvements based on technology without the influence of other customer, political, or regulatory factors. Some customers will install high efficiency equipment and measures on their own, without the help of utility DSM programs. This customer action is described as "naturally occurring" DSM. The remaining, or net potential for DSM improvements is the target market for utility DSM programs.

Often DSM potential studies have a moment-in-time, technological orientation with little consideration to differentiating markets or customers. Studies fail to consider standards/codes (existing and changing), the need for integration and consistency with load forecast models and assumptions, naturally occurring DSM, the lack of perfect awareness (inertia) on customers' part, the fact that technological and economic potential are not the same, or the fact that competition exists among DSM technologies within single opportunities.

In our study, DSM market potential was subdivided in three major ways: (1) by customer sector (e.g. residential, commercial, industrial); (2) by end-use/technology such as lighting, motors, heating, etc.; and (3) by market activity, either a time-dependent or retrofit opportunity. Time-dependent markets, often described as "market-driven" or "lost opportunities", are essentially time-specific opportunities for DSM actions. Retrofit programs replace inefficient but operating equipment with high-efficiency equipment. Current NEES programs address each of these markets.

The varied characteristics of different customer sectors are key factors in designing and marketing effective DSM programs. Each sub-sector has different technological and payback requirements, (i.e. customer needs,) that require customized marketing and rebate structures.

Determining DSM Potential

Overview of Methodology

The analysis entailed several steps:

- *The scale of the underlying markets* was forecasted annually through 2012, using projections developed by NEES. For residential markets, number of households was used as a scale factor. For commercial markets, floor stock was to represent market scale. Productivity-enhanced employment was used as an indicator of the scale of the industrial markets. These forecasts were developed for key segments within each sector.

- A *list of specific DSM measures* was identified.

- The *characteristics of each technology* were determined for each application. These features included relevant decision types, applicability, feasibility, market competitors, energy and demand savings, and costs .

- The *gross technical potential for DSM* was estimated from the above pieces of information for each market and customer segment. For these purposes, DSM opportunities were separated into time dependent opportunities (new construction and post-failure replacements) and retrofit decisions.

- The *current naturally-occurring rate of penetration* of each measure in each market was estimated.

- Future *changes* in both gross technical potential and naturally-occurring rate of penetration were projected using RER's DSM Technology Penetration Model.

- *Net technical potential* was derived as the difference between gross technical potential and the portion already being absorbed by existing saturations and naturally occurring market penetration.

- A set of simulations was run to assess the *market potential* for DSM under alternative program designs. Program designs were characterized in terms of rebates and marketing (awareness) impacts. These simulations were used to define bundles of DSM resources to be used in the course of integrated resource planning.

In what follows, we elaborate on some of the central elements of this overall methodology: the choice of DSM measures, the characterization of technologies, the logic of the DSM penetration model, and the use of the model to estimate technical and market potential for DSM.

Choice of Technologies

The list of specific DSM measures to be covered by the study was developed jointly by NEES and RER. It includes 29 distinct residential technologies, as well as 100 commercial and industrial measures (or packages of measures). It was a very comprehensive list, covering the major DSM opportunities in the NEES service area.

Characterization of Technologies

The analysis of the potential for DSM technologies requires several types of information and assumptions, including:

- types of decisions relating to each technology;

- applicability and feasibility of each technology within each segment;

- identification of competing DSM technologies;

- current saturations and naturally-occurring rates of penetration of these technologies;

- time-of-use impacts of each technology within each sector; and

- incremental costs associated with individual technologies for each type of decision under consideration.

Decision Types. Three types of decision are assumed to apply to the DSM technologies listed in the previous section:

- pre-failure retrofit decisions, in which a measure is adopted prior to the failure of its convention alternative;

- post-failure replacement decisions, which entail the choice of a failed piece of conventional equipment; and
- new decisions, in which measures are considered in the course of new construction.

For each technology, relevant decisions were identified. In general, decisions on equipment measures (for example, high efficiency centrifugal chillers) were assumed to be made at the time of failure. Measures that are not contingent on the failure of any piece of equipment (such as water heater blankets, ceiling insulation or the heat pump replacements for resistance space heat) were relegated to the pre-failure decision process. In a few cases, both pre-failure and post-failure replacement decisions were deemed to apply to a specific measure. In these instances, the stock accounting algorithms within the DSM Penetration Model consider the interrelationship between these two decisions. Equipment replaced prior to burnout is deleted from the stock of conventional equipment available for post-failure replacement. The accounting algorithms prevents the double-counting of potential for these measures.

Applicability and Feasibility. In the course of the project, the applicability and feasibility of specific DSM measures were assessed for each customer segment. Applicability is a generic property that varies across specific DSM technologies and often across decision types. It may reflect the presence of an end use (for example, air conditioning), the use of a specific fuel (electric water heating), the presence of a specific system (centrifugal chillers), or the consistency of the measure with basic operational functions (such as the appropriateness of window film in new retail display windows). Feasibility refers to the technical possibility of installing the measure, and is generally a function of structural factors. The determination of feasibility and applicability naturally involved engineering judgment, and was supported by the review of survey data on residential and commercial characteristics. In conducting the analysis, we made use of a composite applicability factor that encompasses both generic applicability and feasibility in specific applications. Of particular note are three specific rules of thumb that should be mentioned here:

- In looking at high-efficiency equipment, applicability was confined to cases in which the basic equipment type was present. For instance, high-efficiency chillers were assumed to be applicable only where chillers are currently used.
- In order to simplify the analysis of space conditioning options, heat pumps were assumed to be applicable to cases in which both electric heating and cooling are already present (or, in the case of new construction, planned), while high-efficiency air conditioning was assumed to be applicable to cases in which cooling is present but electric heating is absent.
- Specific shell options were defined with respect to initial shell states. For instance, for the residential sector, the retrofit of wall insulation was considered for homes with and without some current level of insulation, and the applicability factors for these actions were defined as the proportion of the housing stock falling into each of the initial states.

Competition among DSM Options. Some DSM measures compete with each other as well as with conventional options. In these cases, the measures were assigned to a competition group, and were forced to share the same markets. For the purposes of the estimation of *gross technical* potential, the market is conceded to the most efficient of the competing options. For instance, if high-efficiency T-12 fluorescent lamps with energy-efficient magnetic ballasts compete with T-8 lamps coupled with electronic ballasts, the former measure is suppressed and the latter measure is assumed to be adopted wherever applicable and feasible. However, for the analysis of naturally occurring penetration and market (program) potential, competing technologies are modeled jointly in order to avoid double-counting of adoptions within single opportunities and the associated impacts.

Saturation and Penetration Rates. The next step entailed assembling information on the *current rate of saturation* and the *baseline penetration rate* of each measure in each market. These rates were developed for each of the three types of decisions covered by the analysis: post-failure replacement, prefailure replacement, and new/remodel decisions. All saturation and penetration rates were specified as proportions of applicable cases (that is, the bases for the rates are confined to cases where the technology in question is applicable). Saturation rates refer to the proportions of such cases where the technology is already present as of the period being examined, whereas penetration rates refer to the annual rate of adoption of the technology when the decision is confronted. For instance, a post-failure penetration rate for high-efficiency air conditioning indicates the percentage of post-burnout conventional equipment replacements that are replaced with the high-efficiency technology.

Information on saturations and penetrations is traditionally scarce. While NEES was able to provide some data on saturations and new construction penetrations of DSM technologies, this information had to be supplemented with information from other sources as well as informed judgment. While the information assembled for saturations and for new construction and post-failure penetrations is fairly reliable, estimates of pre-failure replacement rates are subject to considerable uncertainty. As is common in studies of this sort, very little data are available on customers' prefailure replacement rates; as a result, judgmental estimates generally need to be used to fill in this portion of the database.

Technology Impacts. The hourly energy impacts associated with the adoption of specific DSM measures were estimated by RER for each customer segment. RER then summarized these hourly effects in the form of *annual energy and summer/winter demand savings* for the purposes of analyzing potential and penetration of the subject measures. Two aspects of the estimated impacts should be noted. First, these impacts were based on engineering analysis, but calibrated to observed levels of end-use consumption in the NEES service areas. Second, impacts were allowed to change over time as baseline efficiencies changed due to evolving efficiency standards.

Technology Costs. DSM technology costs are characterized in terms of incremental capital and O&M cost per unit relative to the conventional alternative. All residential costs were converted to a per-household basis, while all commercial and industrial costs were transformed into per-square foot and per-employee values, respectively, for use in the penetration model.

The DSM Penetration Model

Projections of future technical potential and rates of naturally occurring penetration were developed using RER's DSM Penetration Model. The model is a discrete choice framework that relates adoptions of specific technologies to a variety of economic and non-economic factors. Model inputs include information on segment scale (number of households, floorstock, and employment), DSM measure incremental costs, time-of-use energy and demand impacts, forecasted electric and gas rates, applicability factors, feasibility factors, awareness rates, and current saturation and penetration rates. Model outputs include forecasts of penetration rates by decision type, saturation rates, annual and cumulative energy and demand impacts, annual and cumulative customer costs, annual and cumulative utility costs, and various cost-benefit tests for specific measures/programs.

The model has the following useful feature:

- It describes the penetration of user-defined DSM technologies in user-defined market segments. These segments were defined in terms of residence types, building categories and industrial sectors.

- It covers all three kinds of DSM activities: pre-failure replacement (retrofit), post-failure replacement, and new construction.

- It recognizes competition among DSM technologies through the use of a multinominal logit specification. Specific DSM measures that are applicable to the same opportunity are assigned to a competition group.

- Within the model, penetration is modeled as a function of the rate of return on the measure and its competitors, awareness of the competing options, and market inertia.

- It automatically calibrates the penetration model to naturally occurring rates of penetration.

- It can be used to model the effects of DSM programs. Rebate programs are introduced through the specification of rebate levels. These rebates affect the covered measure's rate of return and influence the rate of penetration. The impacts of informational programs can be introduced into the model through changes in awareness.

- It embodies a complete stock accounting system. This logic tracks adoptions made under the three types of decisions and adjusts the stock of DSM measures annually throughout the forecast period.

The model offers a useful framework for predicting the levels and impacts of DSM under alternative assumptions.

Use of the Model to Estimate DSM Potential and Future Penetration

The DSM Penetration Model was used in several modes in order to develop estimates of technical, economic and market potential. These applications are discussed below.

Estimating Gross Technical Potential. Its first mode of operation was designed to estimate *gross technical potential.* To accomplish this objective, the following assumptions were implemented:

- rates of return on all technologies were defaulted to 1000%;

- inertia factors were set equal to 0;

- awareness was set equal to 100%;

- in the case of competing technologies, only the highest-efficiency electric option was allowed to be chosen (although current saturations of less efficient DSM options were taken into account in defining remaining DSM opportunities); and

- the decay of DSM measures was assumed to be offset by immediate replacement.

Given these restrictions, the model generates maximum applicable/feasible adoptions of the highest-efficiency electric options as decisions are made. Specifically:

- All pre-failure replacements are made in the first forecast year.
- Post-failure replacements are made as failure occurs.
- New and remodel adoptions occur at the time of construction or renovation.

Another measure of potential, *incremental gross technical potential,* was derived by subtracting the impacts of DSM measures already in place as of 1992 from gross technical potential.

Estimating Naturally Occurring Penetration. Second, the model was used to forecast the impacts of *naturally occurring adoption* of DSM measures. In this application, the following steps were taken:

- Rates of return were developed for each year of the forecast period using information on incremental costs and energy/demand savings. NEES rate forecasts were used to convert energy and demand savings into dollar savings.
- The model was calibrated using estimated current naturally occurring adoption rates. This calibration process involves estimating inertia factors consistent with current rates of adoption.
- Unlike the case of technical potential, more than one option within each competition group was allowed to penetrate the market. While these assumptions may seem inconsistent, they are necessary to recognize both maximum technical potential as well as actual market behavior. Moreover, the apparent inconsistency between these two treatments is minimized by our practice of splitting the market through the use of applicability factors where reasonable (which minimizes the number of cases of competition).
- The model was run under these assumptions in order to develop an annual forecast of naturally occurring adoptions over the forecast period.

Estimating Net Technical Potential. Third, the results of the last two simulations were used to construct estimates of *net technical potential.* Net technical potential was estimated by subtracting naturally occurring penetration from incremental gross technical potential.

Estimating Market (Program) Potential. Fourth, the model was used to simulate the market potential for NEES DSM programs. Market potential was based on our assessment of the impacts of rebates and marketing programs. Rebates were assumed to influence customer adoptions of DSM through their effects on technology rates of return. In developing these estimates of rebates impacts, alternative levels and timing patterns of rebates were used to characterize general program options. Marketing was assumed to influence DSM adoptions through its effects on awareness of DSM opportunities. Estimates of these changes in awareness were made on the basis of the preliminary results of our 1993 programs. That is, the awareness changes were developed in a way that yielded first-year market potential close to NEES's estimate of actual program impacts in 1993, given the rebates offered during that program year. The model was used to forecast adoptions under these assumptions, and the associated impacts were adjusted for naturally occurring penetration of the subject measures, thereby yielding estimates of the *net market potential* for programs with the specified characteristics. These levels of market potential were then grouped into DSM resource bundles and provided to Resource Planning for use in the integrated resource planning process. This process is described in the section entitled "Developing DSM Resource Options."

The Limitations

Calibration to Historic DSM Experience

It is extremely important to calibrate penetration model results to historic performance, but the process has limitations. Technology impacts were based on engineering analysis, but calibrated to observed levels of end-use consumption in the NEES service areas. Rebates were assumed to influence customer adoptions of DSM through their effect on technology rates of return. Yet rebates are not the only factor which influences customer adoptions of DSM. There are other events that cannot be quantified into model inputs, often because they are only indirectly connected to DSM program marketing, such as: (1) over-anticipated customer interest, which causes early closure of programs; (2) manufacturer failure to stock qualifying DSM measures in the region; and (3) the ubiquitous utility re-organization occurring in the middle of the DSM marketing season, which results in significant marketing personnel changes.

Sensitivity of Results

The results of the DSM market assessment are influenced by a variety of assumptions. Standard assumptions relate to general market trends, DSM impacts and costs, current DSM activities (both saturations and naturally-occurring penetrations), sensitivities of DSM decisions to arguments of the penetration function, technology awareness, and influences of DSM programs on awareness. There is clearly some uncertainty with respect to all of these assumptions. The lack of information on DSM decision-making is particularly troublesome in this regard. Unfortunately, it is impossible to estimate the likely range of errors associated with this uncertainty in any systematic way, due to the lack of standard errors for most of the individual assumptions. However, the modeling system appears to yield sensible estimates in two ways. First, its application to recent historical data calibrates to actual program performance with reasonable assumptions with respect to program impacts on awareness. Second, it yields reasonable estimates of changes in program impacts given variations in rebate levels. If we were forced to estimate a likely error range for resource potential on judgmental grounds, we would expect it to be in the vicinity of ±25% at some reasonable confidence level, with most of the error relating to difficulties in forecasting customer acceptance. While this may be relatively large for the purposes of integrated resource planning, it is characteristic of work in this area. For most of the technologies covered by NEES programs, such errors in program impacts (which would primarily affect administrative cost per unit of delivered resource) would have little impact on cost-effectiveness.

Clearly, more research is needed to identify current DSM activities and to quantify the relationships between these activities and market conditions. This research will entail extensive data collection on customer characteristics and activities, market research on the impacts of DSM program features on customer behavior, and closer integration of the results of program impact evaluations into the analysis of measure effects. NEES is currently conducting such research in order to facilitate the integration of DSM into the resource planning process.

Keeping up with the Joneses

There seems to be a prevalent desire to compare DSM potential study results among different utilities. We have experienced a general uneasiness with these casual comparisons. Obviously, differences in present and historic electric rates, regional DSM measure costs, climates, prevailing regional standards, and industrial base will result in variable levels of DSM potential for different utilities relative to sales. Another difference that should be obvious is DSM program history-has a utility been aggressive in DSM in the past, and thus have less to go after in the future? Some potential estimates still rely on savings relative to a “frozen efficiency” baseline and hence overestimate technical potential. This is one of the most potent reasons potential studies vary significantly. In our study, impacts were allowed to change over time as baseline efficiencies changed due to evolving efficiency standards.

Potential estimates will always be limited by the number of technologies studied, and the inclusion of technologies with highly uncertain data can skew the results of any study. The technologies available to capture efficiency improvements cover a wide range of end-use categories, beyond that which can be effectively managed in a model, forcing the user to focus on a certain number of technologies. DSM monitoring and evaluation efforts have also shown us that estimated incremental savings based on engineering judgments can differ significantly from actual evaluated program results, and depending on which is used as the basis for a potential estimate can result in diverging estimates. Finally, given that there is more than one potential in any study (i.e., gross technical, incremental gross technical, net technical, total economical, or net market potential), only like potentials should be compared across studies.

Despite its limitations, we believe a potential study is the best starting place for developing long-range DSM planning options or at least we have not been introduced to a superior alternative.

Developing DSM Resource Options

A key objective of integrated resource planning is to compare demand-side and supply-side resources in order to make good and balanced resource planning decisions. The days are over when integrated resource planning meant the “appropriate” level of DSM was decided first, subtracted from the load forecast, and then subsequent analysis was completed with supply options. NEES Resource Planning assesses alternative combinations of DSM programs and the risks and risk-reduction associated with implementing DSM programs in conjunction with supply alternatives. To make the integrated resource planning function as proposed required us to provide Resource Planning with a variety of DSM resource bundles for dispatch modeling. These bundles or blocks must be comparable to and combinable with supply-options and provide different levels of DSM “plants” to match to different resource scenarios. Using the results of one model to provide the inputs to another needs to be handled with caution so as not to cascade imprecision from one model to the next.

Recognizing the value of flexibility and the desire to incorporate option theory into resource selection, we revamped our approach to developing long-run DSM planning options based on the Marketing (Program) Potential results from the Penetration Model.[2] The results were used to develop DSM blocks representing different marketing approaches for each marketing sector based on plausible futures.

The first block set created describes the "minimum viable" blocks for each market sector. The NEES companies are publicly committed to continue to offer DSM as a customer service, and DSM is also considered one method of attaining environmental goals, At the minimum level, commitment is considered to be sufficient to maintain a core staff of experienced personnel to maintain technical and marketing expertise to allow future ramp up of program activity; ensure customers' access to accurate information on energy efficiency issues and opportunities; maintain customer service across all customer classes and markets; and maintain contacts with vendors, manufacturers, and distributors. A minimum viable level is also a recognition that DSM programs cannot emerge quickly from zero activity to full-fledged programs to meet emerging need.

Additional DSM resource blocks depict growing market activity targeting different customer markets, and the associated end-uses, and penetration levels. One penetration level presents moderate marketing activity and the other scenario reflects an aggressive DSM response given unforeseen economic growth, environmental crisis, power supply scarcity or other significant resource need. This variety of DSM blocks provides planning options which can be fitted to changing utility needs and market conditions over time. These blocks are described in Table 1.

While a nearly infinite number of incremental DSM resources could be added to the minimum level, only a limited number of options can be effectively managed. For our most recent planning needs, these blocks were combined into six scenarios for both the business sector and the residential sector that were made available to Resource Planning, described in Table 2. Each scenario assumes that marketing will be undertaken in time-dependent markets before a higher intensity of retrofit marketing is attempted. The resource planners were required to choose one option from both business and residential scenarios, thus ensuring that programs continue at least at the minimum viable level for all sectors.

Final Thoughts

We have discussed the efforts to improve and overcome the limitations of DSM potential studies, and put the results into actual use in long-run resource planning. The one thing that should be clear is that DSM potential study results and the DSM resource bundles will never be perfect. Our attempt here was to improve the process with consistency and analysis. The process clarified our need for good current customer and end-use survey data and verified the importance of DSM post-installation program evaluation. Equally important we were able to use the DSM potential results to complement business-planning needs. Finally, the process remains flexible enough to expand with new information and new questions that will arise before the turn of the century.

Table 1. DSM Resource Blocks sorted by Market Sector and Activity

Marketing Sectors & Activity	**Minimum Viable**	**Moderate Marketing**	**Aggressive Marketing**
Residential Time-Dependent Retrofit **Commercial** Time-Dependent Retrofit **Industrial** Time-Dependent Retrofit	The minimum level of DSM in the six market sectors required to meet customer and trade-ally expectations and retain in-house expertise.	Six additional DSM resource blocks for each market sector.	Six blocks representing more difficult and expensive DSM that requires aggressive marketing programs. Modelled as all time-dependent economic potential and all retrofit economic potential available in late 1990's.

Table 2. DSM Planning Scenarios

Market Activity Time-Dependent Blocks	Retrofit Blocks Minimum Viable	Moderate	Aggressive
Minimum Viable	Scenario 1		
Moderate	Scenario 2	Scenario 4	
Aggressive	Scenario 3	Scenario 5	Scenario 6

Endnotes

1. The NEES retail companies consist of Massachusetts Electric, Narragansett Electric, and Granite State Electric.

2. The Resource Planning group of the NEES companies has adopted financial "Options Theory" analysis in the integrated resource planning process. This is a form of analysis that quantifies the value of flexibility in specific resource alternatives. The value of smaller, shorter lead-time projects is quantified relative to large, irreversible projects requiring early investment of substantial funds. See paper by Lowell, J. 1994. "Applying Financial Option Theory to Utility Resource Planning", *Proceedings from the ACEEE 1994 Summer Study on Energy Efficiency in Buildings.* American Council for an Energy Efficient Economy, Washington, D.C.