Impact of Demand Side Management Programs on Peak Load Electricity Demand in North America, 1992 to 2008

By Prachi Gupta*

Introduction

Demand side management (DSM) is a means of using existing energy production facilities more efficiently by reducing price volatility and improving electric grid reliability. The demand for electricity is not steady, varying along a range of different timeframes. Increased demand for energy during the summer peak hours, in particular, puts a strain on the transmission and distribution systems. The primary objective of DSM is to maximize the use of efficient base load generation by managing consumption patterns, shifting consumption from periods of peak demand to off-peak and reducing the need for production capacity that sits idle except during peak demand surges.

The purpose of this paper is to see whether or not there has been a reduction in the peak to base load production ratio in the United States as a consequence of the introduction of DSM programs in the time period 1992 to 2008.

The Department of Energy defines Demand-Side Management (DSM) programs as:

"The planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. It refers to energy and load-shape modifying activities that are undertaken in response to utility-administered programs." [1]

Utilities implement DSM programs to achieve two basic objectives- energy efficiency and peak load management. Energy efficiency is primarily achieved by conservation programs that reduce energy usage on a permanent basis, for example, turning the thermostat a few degrees higher during summer. Peak load management focuses on shifting demand to off-peak periods and has been introduced to different market segments.

The notion of DSM began in the 1970s in response to increasing peak-load electricity demand especially as a result of summer air conditioning. Two laws passed by the federal government in 1978, the Public Utility Regulatory Policies Act and the National Energy Conservation Policy Act, were triggered by rising public awareness of limited energy resources and the need for conservation. These acts marked the beginning of utility conservation and load management programs in the United States. By the late 1990s, a growing number of states had adopted the idea of energy conservation and started allocating DSM budgets. In 1992, the Energy Policy Act (EPACT) amended the NECPA laws to increase clean energy use and improve overall energy efficiency. To promote DSM, the federal government launched another national energy policy initiative in 2005. With the Energy Policy Act of 2005, the federal government took its first steps directly related to DSM. EPACT 2005 included tax incentives for DSM projects that outperformed the minimum energy code.

Year	Total Actual Peak Load Reduction	Energy Efficiency	Load Management
1997	25,284	13,327	11,958
1998	27,231	13,591	13,640
1999	26,455	13,452	13,003
2000	22,901	12,873	10,027
2001	24,955	13,027	11,928
2002	22,936	13,420	9,516
2003	22,904	13,581	9,323
2004	23,532	14,272	9,260
2005	25,710	15,351	10,359
2006	27,240	15,959	11,281
2007	30,253	17,710	12,543
2008	32,741	19,650	13,091

Table 1. DSM Actual Peak Load Reductions by Program Category, in megawatts[2]

To trace the progress of DSM activities across different states, the U.S. Energy Information Administration collects survey data from utilities on actual peak load reduction, the amount of reduction achieved by consumers that participate in utility DSM programs at the time of peak load.

Table 1 summarizes the total actual peak load reduction reported each year from 1992 to 2008, reflecting changes in the demand for electricity during peak periods resulting from deploying programs such as energy efficiency and load management. It is these variations in the peak load reduction that is the subject of statistical analysis in this paper.

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See footnotes at end of text.

Previous Research

The focus of DSM studies is to identify factors that affect the peak demand. These factors include factors such as growth in population and housing units, income growth, and weather.

Whether or not DSM has a significant impact on peak load reduction is a question that has been addressed by a number of researchers. Studies of DSM have principally focused on the gross costs and benefits and have used aggregated data (Loughran and Kulick, 2004; Auffliammer, Blumstein, and Fowlie, 2008; Johnson, 2008; Gillingham, Newell, and Palmer, 2006; Freeman, Intorcio, and Park, 2010). The problem with using aggregate data is that it is difficult to analyze how different consumer groups such as residential, small and medium scale industries and the commercial sector have responded to the introduction of DSM programs. Only few studies have explored the question of how DSM affects peak load at the micro-level (Horowitz, 2007; Faruqui and Sergici, 2008). These studies attempted to estimate end-users response to prices. However, in a complex model with several clusters of consumers, it proved to be impossible to predict how each and every group has responded to DSM programs.

Traditional rationales for DSM programs were threefold: (1) they addressed the problems associated with electricity use, (2) providing an alternative policy response, that was (3) more consistent with environmental objectives. Over the last decade, utility-sponsored DSM programs have encompassed a wide range of activities including direct load management, installation of energy efficient technologies, and attempts to lower emissions as well as to stimulate economic growth (Loughran and Kulick, 2004). Concurring with Loughran and Kulick, Auffliammer, Blumstein and Fowlie (2008) argued that DSM programs can help reduce peak demand through subsidies and various forms of dynamic pricing. Dynamic pricing, such as providing seasonal rates or time-of-use pricing provide an opportunity to consumers to respond to price signals and shift load from on to off peak periods.

DSM programs can be classified into three types, price responsive programs under which consumers can choose how much load they shift from peak to off-peak hours based on electricity prices, triggered programs in which consumers agree to reduce their load based on contractual language, and government mandated programs. Traditional DSM studies have focused on the first two categories and only recently has there been much attention paid to enforcement by federal and state regulators. If there exists government intervention, then how does it affect the growth of DSM?

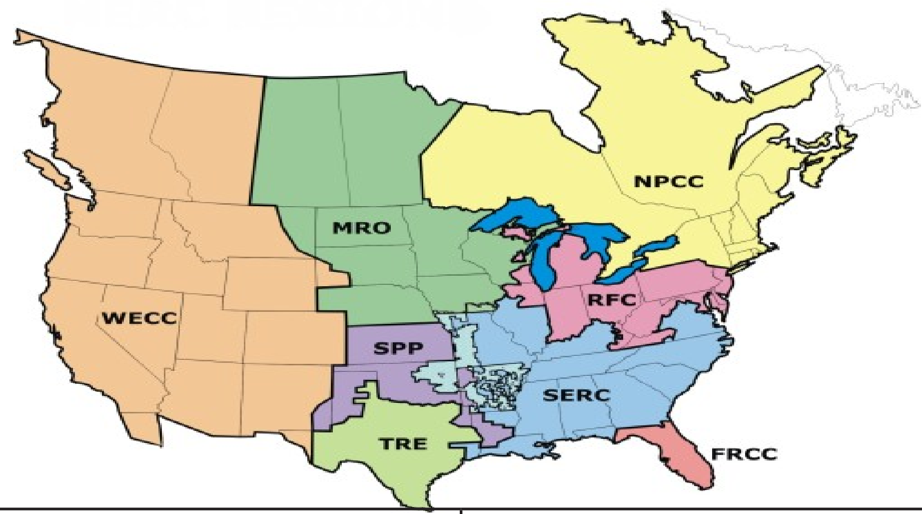
It was after the energy crisis of the 1970s that federal regulators and state commissions began implementing policies that would encourage energy conservation. A growing number of states had adopted the idea of energy conservation. Johnson (1998) highlights the regulatory initiatives that have contributed to the growth of DSM in recent years. State mandated programs stimulate economic growth and increase the effective long-term energy supply by reducing dependence on foreign energy sources (Loughran and Kulick, 2004). This argument was rejected by Freeman, Intorcio, and Park (2010). Some states show greater energy savings with state mandated programs while others saw utilities playing a major role in delivering efficiency programs.

The literature shows that a variety of factors can affect consumption patterns, with only modest positive effects of DSM interventions. As the previous studies indicate, the results of the use of DSM to reduce peak load on the demand-side are ambiguous. Future programs need to be tailored to specific market objectives and to balance both public and private interest.

Research Problem

To what extent did the peak load reduction ratio change with the introduction of DSM programs between 1992 and 2008? The literature offers little guidance to answer this question. I, therefore, develop a regression model in which peak load reduction ratio, a continuous dependent variable, is hypothesized to be a function of a number of categorical independent variables, including years, markets, and end users. The model permits the following questions to be addressed:

- Are there any marked changes in the peak load reduction ratio over time associated with the introduction of DSM programs?
- Does the peak load reduction ratio vary by end-users? Do shifts in consumption patterns vary by type of consumer? Coefficients are calculated by user type.
- Does the peak load reduction ratio vary by market? Dummy variables are entered into the model for each North American Electric Reliability Council region.
- Does the peak load reduction ratio vary by type of consumer in different markets, i.e, is there an interaction between the two previous questions?



FRCC - Florida Reliability coordinating Council **MRO** - Midwest Reliability Organization **NPCC** - Northeast Power Coordinating Council **RFC** - Reliability First Corporation	**SERC** - SERC Reliability Corporation **SPP** - Southwest Power Pool **TRE** - Texas Regional Entity **WECC** - Western Electricity Coordinating Council

Figure 1: North American Electric Reliability Council Region Map (US)

The Data

To estimate the effectiveness of DSM programs, the data on actual peak load reduction is collected by end-users and by NERC regions. Data aggregated at the end-user level includes industrial, commercial, residential, and transportation sectors. The regional level data are collected by eight North American Electric Reliability Corporation (NERC) regions as shown in figure 2. NERC is a nonprofit organization established to maintain mandatory reliability standards for the bulk electric system in North America.

The data is utilized from the Energy Information Administration (EIA) data form EIA-861. Form EIA-861 is a mandatory annual census of approximately 3,200 electric utilities in the United States which was implemented in January 1985.

Estimation Methodology and Empirical Results

This study began with the question of whether or not any significant changes have taken place with the introduction of DSM policies. To address this question, I formulated the model that tests peak load reduction as a function of end-users, regions, years, and the interaction of end-users and regions. In the usual notation, the overall function can be written as follows: $Y = f\ (U, R, T, I)$ where Y is the percentage of peak load reduction, U represents dummy variables for the end-users. R includes eight regional dummy variables for regions, T denotes dummies for years from 1992 to 2008, and I captures the $U * R$ interactions.

The model has the following form:

$$Y_{urt} = \alpha + \beta_u U_u + \beta_r R_r + \beta_t T_t + \beta_{ur} I_{ur} + \varepsilon_{urt}$$

$$Y_{urt} = P_{urt} / S_{urt}$$

The dependent variable is constructed by dividing actual peak load reduction (P_{urt}) by the summer peak load (S_{urt}), measured in megawatts. Summer peak load represents the maximum load during the summer months from June to September. The set of independent variables, obtained from EIA data, includes dummy variables for end-users (U_u), 8 regional dummies (R_r) and dummies for years (T_t).The base cases are Industrial end-user, the Texas Region (TRE), and year 1992.

In order to generate empirical evidence relating to the hypothesis that peak load reduction varies by years, end-users, and regions, we regress peak load reduction ratio function of end-users, regions, years. It was found that DSM did have a positive effect; however the extent of response mainly varied from one region to another. These results are quite robust in the summer peaking regions that have employed DSM programs to offset the heavy use of air-conditioning. A notable end-user variability of reductions in peak demand also is discovered. The greatest sectoral response to peak load management initiatives has been in the commercial sector, followed by the residential and industrial sectors. Controlling for other variables, regions with the greater peak load reductions are populous regions such as MRO and WECC with sharp summer peaks. Active government involvement, as shaped by state regulations in these regions, has had positive outcomes in terms of achieving prescribed energy savings targets. The least progress has been made by the NPCC region, a winter-peaking region with less cooling demand during summer months. Interaction variables that were entered into the model to test whether or not there have been behavioral shifts by end-users in different NERC regions seem to demonstrate positive results in the commercial sector that occurred in the NPCC region. It can be explained by the market mechanisms in the Northeast that have encouraged significant development of DSM programs.

None of the NERC regions reveal substantial peak load reductions by the transportation sector. The transportation sector is heavily dependent on petroleum, primarily in the form of gasoline and diesel. Energy use in the transportation sector might be improved and diversified in several ways: improving the energy efficiency of the vehicles and the transportation system, by expanding the range of fuel and engine options available to motorists, including alternative fuels and electricity/battery operated vehicles, and diverting traffic from individual vehicles to mass transit are all examples.

We also witness a possible DSM-related uptick in the recent years which indicate that we may have finally started to see a strong uptick with the government intervention to support DSM programs in 2005. Significant end-user shifts are also traceable in the WECC and MRO regions in the years after 2002, when government-embraced DSM measures were introduced to combat the U.S energy crisis of 2002 and 2001. These efforts to reduce peak load and increase energy awareness have been proliferating, as indicated by an uptick in peak load reductions in the years 2008 and 2009.

Summary

Indeed there is evidence that by 2007 and 2008 there appears to have been a positive effect of introduction of DSM programs, but the overall amount of peak load reduction is very small and there is substantial regional variability. The empirical results support the hypothesis that there are spatial variations in peak load reduction ratio by user type and between regions. They do not, however, address issues of regional variation in peak load seasonality and the associated need for DSM tailoring, an important area for follow-up research.

Public policies have also played a significant role both by promoting energy-efficient technologies in the residential and commercial sectors via DSM that has led utilities to employ programs that reduce operating costs, promote public energy conservation, and shift peak load demands. Government's involvement to promote demand response began with the EPACT1992, which required utilities to increase clean energy use and improve overall energy efficiency, and continued with EPACT 2005, which set new directions to attain clean energy use across all the sectors while also managing peak loads.

As evident from the empirical results, since 2005 DSM has been focusing on expanding traditional load management and interruptible programs. Just as power supplies vary by region and peak load demand vary regionally by user and by seasons, so must DSM if it is to produce additional load smoothing. It is the intersection of region, user, and season that must be the focus of the next round of research, to enhance DSM via strategic targeting.

Footnotes

[1] U.S. Energy Information Administration Glossary, http://www.eia.doe.gov (Accessed December 5, 2011)

[2] U.S. Energy Information Administration, Form EIA-861, "Annual Electric Power Industry Report," Electric Power Annual (January 2010), Tables 9.1, 9.6 and 9.7.

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