The Environmental and Economic Value of DSM: A National Level Assessment

Juanita M. Haydel, Sikander Daryanani, David Kathan and Ira H. Shavel
ICF Resources Incorporated

The environmental consequences of electricity generation are considerable. Emissions of acid rain precursors and "greenhouse gases," generation of solid waste, as well as other environmental impacts are created to varying degrees by the generation of electricity from fossil fuel. Recent debate has focused on assessing the value of alternative resource options in reducing emissions and in complying with environmental policies, such as greenhouse gas emission restriction or tax policies. Demand-side management (DSM) is one such compliance option available to cope with these environmental concerns. This study assesses the value of DSM from an economic and environmental perspective using a national level electric utility planning model.

Background

Demand-side management (DSM) includes efforts by utilities to alter the levels and patterns of electricity use by their customers. The two most common utility objectives in promoting DSM are to increase the efficiency of electricity use with more efficient end-use equipment and appliances (DSM conservation), and to alter the timing of electricity use so that less expensive or more efficient resources are used to meet demand and the need for new capacity additions can be deferred (load shifting). Utilities may have other objectives depending upon their system characteristics; these may include strategic load building, valley filling, or peak clipping.

DSM programs offer utilities the opportunity to reduce the cost of providing energy services to electricity customers. By reducing demand and improving the efficiency of electricity use and production through load shifting, utility-sponsored DSM also has the potential for producing significant reductions in the environmental impacts of generation. In addition, DSM can also be used as a resource option for utility compliance with environmental protection laws, such as the Clean Air Act or future climate change policies.

Others have explored the environmental benefits of DSM. These include research efforts by the Center for Clean Air Policy,[1] the Ohio Office of the Consumers' Counsel[2], and other results recently presented at a conference on *DSM and the Global Environment*,[3] among others. In general, these reports conclude that DSM has the potential for significant reductions in environmental impacts. This paper is unique in that it assesses the potential value of DSM using detailed assessments of DSM potential and a detailed representation of the U.S. electric generating system. Analyses that assess the environmental impacts of DSM by comparing average program impacts to average regional or national utility generation mixes may result in misleading conclusions regarding the environmental benefits and cost savings of DSM. This analysis accounts for regional differences in climate, customer mix, and utility generation mix.

This study measures the value of DSM in a dynamic framework, capturing the impact of DSM on utilities' cost and operation over a 25 year time frame. While impacts may be considerable in the short term, a longer time frame is required to capture full penetration of measures and potential impacts on generation mix and capacity expansion decisions. The study also accounts for the constraints inherent in the operation of a complex electric utility system, including inter-regional transactions and transmission, unit maintenance requirements, and operating restrictions. Finally, this study also recognizes the unique seasonal and daily impacts of DSM programs, interactions among programs, and the peak impact of programs.

The analysis *does not* address the cost-effectiveness of DSM for any particular utility system or for the nation as a whole. It instead answers the question "If certain levels of DSM are implemented, what are the benefits in terms of reduced generation requirements, costs and emissions for the U.S. electric utility system?" Nonetheless, this information on DSM (equivalent to utility system benefits in the "California Tests") could be used as a general benchmark for DSM cost-effectiveness on a national level. This study does not examine the potential benefit of electrification strategies, where more efficient electric technologies displace less efficient fossil technologies. Nor does it examine the potential impact of strategies to shift away from electric technologies to fossil-fueled technologies, when they are more efficient. The focus is on the opportunities for increasing the efficiency of electric end-uses through DSM.

Methodology

This analysis was conducted using ICF Resources' Integrated Planning Model (IPM©™), a detailed electric utility capacity expansion and dispatch planning model. The IPM determines the optimal future mix of generation resources, and the optimal operation of those resources given future demand for electricity, system operating characteristics and constraints, resource costs, and fuel prices and availability. The model is a 13-region model of the U.S. electric generating system and includes a representation of all existing generating resources and resources currently planned to be added before the year 2000.[4] The model also accounts for inter-regional transmission constraints, inter-regional energy flows, and regional renewable resource availability and operating characteristics.

In this analysis, the model was first used to determine an optimal generation expansion plan and system dispatch assuming no future reductions in demand from new DSM programs. Next, the model was used to determine an optimal expansion plan and dispatch assuming DSM programs of utilities were available to reduce electricity demand levels. No costs were assigned to these programs; therefore, they were all "selected" by the model, generally in the first year of analysis. However, the full impacts of programs were not available for several years, following typical penetration patterns. The differences between these two model runs--in terms of generation, cost, and emissions--indicates the value of DSM. In order to develop a range of estimates of potential value, these analyses were conducted for each two alternative scenarios, described below, representing alternative views of the electric utility planning environment in the future.

Other assumptions are important in assessing the value of DSM. New generating units that are planned to come on line before 2000 were assumed to be fixed in this analysis. The model, however, is allowed to add generating units (e.g., conventional and advanced fossil technologies, nuclear power, and renewables)[5] as required to meet load and reserve requirements in a least-cost manner.

The price and availability of coal and natural gas will affect the future generating mix and thus, the value of DSM. Using supply curves, the model represents coal and natural gas markets in detail. Coal supply curves are used to represent various types of coal (sulfur content, Btu) in supply areas across the country.[6] Each of these coal supply curves is linked to the various utility regions in the model via a coal transportation network. Similarly, gas supply is also represented by national gas supply curves which account for the impact of previous development rates on current production costs.[7] Because the different regions compete among themselves for available supplies, the prices, production levels, and distribution patterns of coal and natural gas are all determined within the context of an equilibrium solution.

The IPM has the capability to represent demand-side resources on a level-playing field with supply-side resources within an optimization framework. It has detailed representation of individual DSM programs, including information on the load shape impacts of individual programs, as well as the market penetration rates. Table 1 illustrates the DSM programs included in this analysis. Estimated impacts (kilowatthour savings relative to standard equipment) and market potential was

Table 1. Demand Side Management Options Evaluated

Residential
- Efficient Heat Pumps
- Efficient Water Heaters, Heat Pump Water Heaters and Water Heater Cycling
- Efficient Central Air Conditioners, Heat Pumps, Room Air Conditioners, and A/C Cycling
- Efficient Refrigerators and Freezers
- Compact Fluorescent
- Energy Audits, Weatherization and Thermal Performance Improvements

Commercial
- Heat Pumps
- High Efficiency Cooling and Thermal Storage
- Efficient Water Heaters and Heat Pump Water Heaters
- High Efficiency Refrigeration
- High Efficiency Lighting
- High Efficiency Motors and Adjustable Speed Drives
- Energy Audits

Industrial
- High Efficiency Motors and Adjustable Speed Drives
- Waste Heat Recovery Systems
- High Efficiency Lighting
- Energy Audits
- High Efficiency HVAC

based on a recent study conducted for the Electric Power Research Institute and the Edison Electric Institute, and were broken down by region with Energy Information Administration and Census market size information.[8] Load shapes were based on publicly available data or developed in-house by ICF Resources.[9,10]

Reference Scenarios, Data and Assumptions

The potential future environmental and economic impact from DSM is dependent on many uncertain factors: the mix of generation and fuel resources over the longer term (i.e., coal, gas, or nuclear), the rate of electricity demand growth, the cost and performance characteristics of generating technologies, fuel prices, the life of future units (and thus the rate at which older less efficient units are replaced with newer, more efficient technologies), and the level of economic renewable resource potential.

The effect of these uncertainties are addressed through the use of *reference scenarios*. Table 2 summarizes the assumptions underlying the two scenarios. The first reference scenario assumes relatively little change from current policies and trends, and as such depends heavily upon coal and gas for meeting future electricity needs. For this scenario, electricity demand is assumed to grow at a rate of 2.5 percent per year, before considering the effects of DSM programs. This projection is based the high economic growth scenario of the Energy Information Agency of the U.S. Department of Energy. Under this scenario, generating unit technologies remain relatively unchanged from today and fossil units are assumed to have operating lives of 60 years. These assumptions are combined with lower levels of DSM to define the *High Growth/Low DSM* scenario.

The *Low Growth/High DSM* reference scenario reflects a greater availability of highly efficient, low environmental impact options, including renewable resources, higher efficiency gas technologies, and greater DSM market potential. Moreover, the Low Growth/High DSM scenario has lower growth in demand for electricity services, averaging about 2.1 percent growth per year. Coupled with higher levels of DSM this scenario offers the potential for larger reductions in total electricity generation requirements.[11]

The price and availability of natural gas will also affect future resource decisions and therefore the value of DSM. If gas prices make gas an attractive alternative source of future generation, then the emissions and economic value of DSM may also be reduced. The two reference scenarios have alternative views of natural gas markets. In the Low Growth/High DSM scenario, the natural resource base is larger and technological improvements in drilling occur more rapidly; thus, prices are lower.

ICF relied primarily upon a study prepared by Barakat & Chamberlin Incorporated (BCI) for the Electric Power Research Institute (EPRI) and the Edison Electric Institute (EEI) to develop alternative scenarios of potential reductions in demand from DSM. This study provides alternative estimates of the impacts of utility DSM programs on U.S. electricity demand through the year 2010. In the BCI study, estimates of per unit energy impacts and penetration were developed for load control,

Table 2. Major Assumptions for Reference Scenarios

	High Growth/Low DSM	Low Growth/High DSM
Electricity Demand (Annual Growth)	2.5%	2.1%
Demand-Side Management Market Potential	6% potential reduction in demand by 2015	16% potential reduction in demand by 2015
Fossil Steam Powerplant Lifetimes	60 year life	50 year life
New Conventional Generating Sources	Moderate technological advances	Greater technological advances
Renewable Resources	Total resource potential of 100 GW	Total resource potential of 300 GW, lower costs
Natural Gas Resource Base	Base estimate of natural gas resource base	Higher natural gas resource base

load shifting, efficient buildings, equipment and processes, electrification, innovative rates, and self-generation programs.

The present analysis focuses on the benefits of load control and efficient buildings and equipment. Because there is considerable uncertainty surrounding the impacts of DSM programs (due to uncertainty in electricity prices, economic growth, unit program impacts, market penetration rates, and the level of utility participation), the BCI study presented a range of possible outcomes based on a range of estimates of unit energy and load impacts and market penetration rates. This range of estimates was used in this study.

More detailed estimates of market penetration by year under the alternative scenarios were developed from the BCI estimates. These detailed estimates were developed by coupling the BCI data with detailed regional estimates of market size (e.g., number of households, commercial floorspace, and the number of industrial establishments) consistent with each scenario's forecast of future electricity requirements in order to derive estimates of total market potential for each region.[12] The resulting total market potential for DSM is estimated to be about 6 percent of total load in 2015 in the High Growth/Low DSM scenario, reducing load growth to 2.3 percent per year. Under the Low Growth/High DSM scenario, DSM potential is estimated to total 16 percent of load growth in 2015, resulting in a 1.6 percent average annual growth in electricity generation requirements.[13] Table 3 summarizes the resulting DSM potential and generation requirements under the alternative scenarios with and without DSM. The DSM scenarios used in this analysis are not intended to bound the range of potential reductions in demand from DSM. Others have estimated much higher levels of potential reduction in electricity demand from energy efficiency improvements. These scenarios are chosen to represent a reasonable range of potential DSM impacts.

Table 3. Base Generation Requirements and DSM Potential (GWH)

	1995	2005	2015	Annual Growth Rate
High Growth and Low DSM Scenario				
Total Demand	3,261	4,160	5,347	2.5
DSM	69	147	278	
Net Energy	3,192	4,013	5,069	2.3
Low Growth/High DSM Scenario				
Total Demand	3,196	3,911	4,814	2.1
DSM	211	428	749	
Net Energy	2,985	3,483	4,065	1.6

Results

Base Case (No DSM) Generation Mix

Alternative scenarios of future utility generation mixes have important implications for determining the value of DSM in reducing emissions and costs. Under either scenario, the U.S. generation mix continues to be dominated by coal-fired generation. In the absence of reductions in demand from DSM, and under a High Growth/Low DSM scenario, coal-fired generation makes up 54 percent of the generation mix in 1995. By 2005, gas prices are relatively moderate, and increased utilization of gas-fired generation make up declining contributions from nuclear and hydropower facilities. However, by 2015 gas prices rise and coal's total contribution to the mix increases to 72 percent of total generation requirements.

In the short-term, the generation mix under the Low Growth/High DSM scenario does not differ greatly from the High Growth/Low DSM Scenario. However, in the longer term, gas is more plentiful and less costly and plays a larger role in meeting future demand. In 2015, gas provides 20 percent of total requirements. Table 4 summarizes these results.

Table 4. Projected Generation Mix Without DSM (% of Total Generation Requirements)

	1995	2005	2015
High Impact Scenario			
Nuclear	21	16	9
Coal	54	52	72
Gas/Oil	14	23	11
Other	11	9	8
Low Impact Scenario			
Nuclear	21	17	11
Coal	53	46	60
Gas/Oil	14	27	20
Other	12	10	9

Impacts on Generation Mix

Table 5 illustrates the incremental effects of DSM on generation and capacity requirements of DSM under the two Reference Scenarios. These results are derived from a comparison of the model runs with and without DSM. Under the High Growth/Low DSM Scenario, DSM provides only a small reduction in load by 1995 (2 percent). Accordingly, displaced generation in the short-term is predominantly gas-fired combined cycle units. A small amount of coal-fired generation is also displaced in 1995. Future changes in load shape, captured by the dynamic aspect of the model, changes the optimal timing of coal-fired resource additions. While impacts at the time of peak are considerable (and are proportionately greater relative to load), the impact on installed generation is smaller, because, as noted earlier, units currently in the planning stage and expected online before 2000 are not allowed to be deferred.

In the intermediate term (2005), gas-fired combined cycle is the predominant generation type displaced. Considerable amounts of coal-fired generation are also displaced. By 2015, DSM programs implemented in the mid 1990s displace the need for significant amounts of coal and gas-fired generation. In this year, 80 percent of displaced generation is coal-fired. In total, over 90 GW of capacity (coal, gas turbine, and combined cycle) is displaced. Accordingly, the emissions benefits of DSM grow, and significant cost savings due to displaced capital requirements are gained.

Under the High Growth/Low DSM scenario, the effect on the overall generation mix is slight. Table 6 summarizes the mix of resources (including DSM) which is used to meet electricity service requirements under the two scenarios. The contribution of coal drops slightly (72 to 68 percent) under this scenario.

Under the Low Growth/High DSM scenario, a larger proportion of displaced generation in the short-term is from existing coal units, because with lower load growth, fewer additions of new gas-fired generation are required. By 2015, reductions in energy requirements of nearly 16 percent significantly reduces generation from coal and natural gas units. Under this scenario the mix of resources used to meet load changes considerably by 2015. Coal meets only 48 percent of total load (as compared to 60 percent without DSM).

Projected impacts on capacity requirements are also significant. By 2015, nearly 200 GW of new capacity is displaced. Baseload, intermediate, and peaking capacity are displaced in nearly equal measure. Tables 5 and 6 summarize the generation mix impacts of DSM under the Low Growth/High DSM scenario. It is important to note that in neither case is nuclear or hydropower generation on the margin. Decreases in demand (or increases for that matter) would not alter the dispatch of these base-load facilities.

Impact on Carbon and Sulfur Emissions

Utility carbon emissions are projected to grow considerably over the next 25 years, consistent with future demand projections and future generation mix. Recent debate has focused on alternative control strategies for reductions of utility carbon emissions. Under both scenarios emissions grow slightly faster than demand growth, because of increasing reliance on coal-fired power, and carbon emissions are projected to nearly double by 2015 from 1990 levels.

Table 5. Incremental Impacts of DSM on Generation and Capacity Requirements

	High Growth/Low DSM						Low Growth/High DSM					
	1995		2005		2015		1995		2005		2015	
	GW	BkWh	GW	BkWh	GW	BkWh	GW	BkWh	GW	BkWh	GW	BkWh
Coal	1	(11)	(6)	(51)	(34)	(222)	0	(90)	0	(32)	(78)	(573)
Oil/Gas Steam	0	(6)	0	(26)	0	7	0	(13)	0	17	0	0
GTs	(5)	(3)	(2)	(1)	(30)	2	(13)	(7)	(9)	(5)	(67)	(9)
CCycl	(7)	(41)	(24)	(117)	(26)	(62)	(12)	(82)	(67)	(369)	(57)	(186)
Other	(1)	(8)	(1)	(5)	(1)	(3)	(3)	(19)	(6)	(38)	5	18
Total	(12)	(68)	(31)	(147)	(91)	(278)	(28)	(210)	(82)	(427)	(197)	(750)

Table 6. Projected Generation Mix with DSM (% of Total Generation Requirements)

	1995	2005	2015
High Growth/Low DSM Scenario			
Nuclear	21	16	9
Coal	53	50	68
Gas/Oil	12	21	10
Other	12	9	8
DSM	2	4	5
Low Growth/High DSM Scenario			
Nuclear	21	17	11
Coal	50	45	48
Gas/Oil	10	17	15
Other	12	10	10
DSM	7	11	16

DSM could reduce these emissions considerably. Table 7 summarizes the carbon emissions impacts of DSM under the alternative scenarios. Under the High Growth/Low DSM scenario, carbon emissions reductions are estimated to be 11 million tons of carbon or nearly 2 percent of base level emissions. By 2015, these reductions rise to 62 million tons or nearly 6 percent of base level emissions. Under the Low Growth/High DSM scenario, reductions in carbon total 40 million tons in 1995, or 7 percent of base levels. By 2015, demand reductions could achieve over 170 million tons of carbon or a 20 percent reduction off of base case (year 2015) levels. Under this scenario, reductions in carbon per kWh-saved are greater than in earlier years or under the High Growth/Low DSM Scenario, because of the proportionately greater level of coal displaced.

Table 7. Projected Emissions of Carbon by the U.S. Electric Utility Sector (Millions of Tons of Carbon)

	1995	2005	2015
High Growth/Low DSM Scenario			
Total Emissions Without DSM	584	752	1,136
Reductions from DSM	11	24	62
% Reduction from Base Levels	1.8	3.1	5.5
Low Growth/High DSM Scenario			
Total Emissions Without DSM	564	655	913
Reductions in Emissions from DSM	40	51	173
% Reduction from Base Levels	7.1	7.8	19.0

Total emissions of SO_2 are unchanged as a result of the demand reductions attributable to DSM. This is because total utility emissions are capped under the CAAA. Thus, when demand reductions are achieved through DSM, the SO_2 reduction requirements (from an unconstrained case) are decreased and utilities may alter their SO_2 compliance strategy to reduce total cost.

There is, however, an economic benefit associated with lower SO_2 reduction requirements. The total amount of this benefit is a function of both the level of reductions, or the marginal *source* of SO_2 reductions (i.e., what is the last SO_2-removal option taken to reduce emissions) and the marginal *cost* of reduction (e.g., the cost of fuel switching or scrubbing an existing plant). We have estimated a range of economic benefits based on a range of SO_2 savings (based on a range of SO_2 rates of 0.3 to 1.0 lbs. per MMBtu) and on a range of market values for SO_2 allowances. Under the High Growth/Low DSM Scenario, this economic benefit is estimated to range from \$18 million to \$97 million in 2005 (on a levelized, annual basis in 1990 dollars) assuming a range of allowance values of \$250 to \$400 per ton of SO_2.[14] By 2015, this value rises to about \$80 million to \$420 million. Under the Low Growth/High DSM Scenario, the economic value of SO_2 emissions reductions are lower in 2005 (\$11 to \$61 million) because of the greater reliance on gas-fired generation. However, by 2015, the economic value is much higher (\$204 million to \$1.1 billion) because of the greater reductions achieved. Table 8 summarizes these results of this analysis for 2005.

Cost Savings

Reductions in total cost represent the savings in fuel, variable and fixed operation and maintenance expenses, and capital expenses which accompany reductions in generation requirements and capacity additions. Because the reductions in demand from DSM were made available without cost, the savings presented here represent national level, total utility system cost savings, and represent a monetary value of DSM.

Table 8. Value of SO_2 Reductions from DSM in 2005

Scenario (Market Value of Allowances and Removal Rate)	High Growth/Low DSM		Low Growth/High DSM	
	Tons (TTons)	Mil. of 1990 $	Tons (TTons)	Mil. of 1990 $
$250/Ton and 0.3 lbs/MMbtu	73	18	46	204
$400/Ton and 1.0 lbs/MMbtu	243	97	153	1,100

In 2005, under the High Growth/Low DSM Scenario, the total cost savings--or the value of DSM--is $6.2 billion (on an annual levelized basis in 1990 dollars). This is equivalent to $0.034 per kWh-saved. By 2015, this figure rises to nearly $16 billion, or $0.057 cents per kWh. In the last year of analysis, over two-thirds of the value of DSM results from savings in capital costs. Table 9 summarizes the costs savings from the alternative levels of DSM under the two scenarios.

Under the Low Growth/High DSM Scenario, total dollars savings increase, but not in proportion to the increase in the level of reductions in demand from DSM. By 2015, total DSM potential in the Low Growth/High DSM Case is three times the level in the High Growth/Low DSM Case (on a percentage basis). However, total costs savings are only about twice the level of the High Growth/Low DSM scenario. This is true for two reasons. First, the costs of generation and fuel are slightly lower in this scenario. Second, the increased level of reductions, coupled with a slightly lower demand forecast, results in decreasing marginal costs with each kWh saved. Specifically, under the Low Growth/High DSM Scenario, reductions in load are sufficient to begin to displace base load coal-fired generation. This relatively less expensive energy reduces the average savings per kWh. Under the Low Growth/High DSM Scenario, total cost savings are nearly $35 million in 2015, or $0.047 per kWh. This demonstrates the importance of assessing the impact of aggregate DSM programs on marginal costs in a dynamic framework.

Table 9. Cost Savings from DSM (billions of 1990 $ and $/kWh)

	1995	2005	2015
High Growth/Low DSM Scenario			
Total Dollars Saved	2.5	6.2	15.8
$/kWh	0.037	0.042	0.057
Low Growth/High DSM Scenario			
Total Dollars	5.5	14.5	35.6
$/kWh	0.026	0.034	0.047

Conclusions

This study has demonstrated the potential cost savings attributable to alternative levels of DSM using an analysis of the marginal impacts on utility planning and dispatch under alternative scenarios of future load growth and DSM potential, among other factors. The resulting emissions impacts and cost savings are indicators of the value of DSM in meeting future national demand for electricity services. As this study indicates, DSM can have a discernable impact on generation levels, the generation mix, and future capacity requirements.

In both scenarios, value does not increase significantly, until the opportunity for displacing considerable amounts of capacity are available. Moreover, the savings estimates presented here are levelized annual estimates. They do not represent traditional ratemaking, where capital costs (savings in this case) are higher in the initial years of an investment (a deferred investment), and lower in later years. Impacts on marginal average rates could vary depending on the rate treatment which would have been afforded generation investments.

These estimated cost savings can be used as a yardstick for assessing the value of DSM on a national level--or a measure of benefits in a national DSM cost-effectiveness analysis. These results *cannot* be used to assess the value of DSM on a regional or utility basis. Load growth, generation dispatch, costs, and capacity requirements vary considerable across the country. Savings and emissions benefits would also vary. A similar analysis on a regional basis, however, would indicate where the greatest opportunities lie for reducing cost and emissions with DSM programs.

Similarly, each utility's system characteristics and circumstances vary. Moreover, different combinations of programs could be expected to result in different estimates of cost savings and emissions impacts. Because of interaction between programs, and changes in marginal costs as programs are added and subtracted, these estimated costs savings cannot be compared to any one individual program to assess its cost-effectiveness.

Finally, it is important to note that this analysis examined the value of DSM *absent* any policies on greenhouse gases. Our research indicates that carbon emission or tax policies could significantly increase the value of DSM, as it becomes available to displace more expensive carbon reduction options.

Endnotes

1. Center for Clean Air Policy, *An Efficient Approach to Reducing Acid Rain: The Environmental Benefits of Energy Conservation*, May 1989.

2. Ohio Office of the Consumers' Counsel, *Clearing the Air: Using Energy Conservation to Reduce Acid Rain Compliance Costs in Ohio*, July 1988.

3. Although the entire volume examines the potential environmental benefits of DSM, several papers examine national level impacts of DSM: Ahmad Faruqui and Erik Haites, "Impact of Efficient Electricity Use and DSM Programs on United States Electricity Demand and the Environment;" Eric Hirst, "Utility DSM Programs Could Cut Electricity Use 20% During the Next Two Decades;" and Robert Ciliano, et al., "Impact of Appliance Efficiency Standards and Building Codes on Global Climate Change," *DSM and the Global Environment*, prepared by Synergic Resources Corporation, April 22-23, 1991.

4. These capacity additions are based on projections by utilities as reported to NERC. *Annual Data Summary: 1990 Electricity Supply & Demand for 1990-1999*. North American Electric Reliability Council. November 1990.

5. This analysis relies on the Electric Power Research Institute's *Technical Assessment Guide (EPRI TAG)* for data on the cost and performance of generating sources.

6. The coal supply curves and coal transportation network used in this analysis were derived from the databases and methodology represented in ICF Resources' Coal and Electric Utilities Model (CEUM).

7. The representation of natural gas supply in the model was derived from ICF Resources' North America Gas Market Model (NAGM).

8. Barakat & Chamberlin, Incorporated, *Impact of Demand-side Management on Future Customer Electricity Demand: An Update*. Prepared for the Electric Power Research Institute and Edison Electric Institute. CU-6953. September 1990.

9. The model requires detailed 24 hour load shape impacts for 3 representative day types (weekday, weekend, and peak day) for three season-types (summer, winter, and spring/fall).

10. Load shapes developed by EPRI, BPA, for the Michigan Electricity Options Study, and load shapes developed at ICF in support of specific client analyses using the DOE-2 building simulation model were used.

11. There are a number of other assumptions underlying the alternative reference scenarios. These include the availability and cost of nuclear power and renewable resources. While these options are critically important in determining the ease and cost of compliance with greenhouse gas policies, they are less important under base case conditions.

12. Electrification, and rate programs are not included. In the modeling structure, cogeneration is included as a supply option and its benefits are not discussed here. ICF Resources developed estimates of potential cogeneration capacity based on prior work done for the U.S. Environmental Protection Agency.

13. Several issues are worth noting. First, because electrification was excluded as a demand-side option, total potential reductions in demand from conservation programs are higher than BCI's "most likely" and high estimates, percent, because electrification was not included. Second, BCI's estimates of potential impact were performed for 2000 and 2010. This analysis examines the impacts

for 2005 and 2015. Moreover, ICF Resources applied the basic assumptions underlying the BCI study (i.e., per unit impacts, and penetration rates) to an electricity demand forecast which differs from the forecast and underlying market assumption used by BCI in its estimate. Thus, total reductions from DSM as a percent of total load may vary from those reported by BCI.

14. These allowance values are based on recent transactions reported in the industry. "First allowance deals may embolden other utilities to jump into market," *Electric Utility Weekly*, May 18. 1992.

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