The Energy Conservation Potential for Retro-Commissioning in Xcel Energy's Minnesota Area

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Introduction and Background

The overall DSM Potential study was conducted to guide Xcel Energy's long-term energy efficiency and load management plans for its service area in the state of Minnesota. Specifically, it was done to provide the basis for the DSM portion of the Company's December 2002 integrated resource plan covering the period 2003-2017. It is the third comprehensive study of its Minnesota energy services potential that the Company has conducted in the past 15 years.

Integrated resource planning identifies the lowest cost mix of resources to serve customers' energy needs over the long-term. It does this by comparing the costs and impacts of various energy supply-side and demand-side scenarios using models developed for this purpose. The Minnesota Public Utilities' Commission requires the state's electric utilities to file resource plans every two years. In addition, Minnesota law requires electric utilities to spend at least 1.5% of their revenues on DSM, while electric utilities with nuclear generating facilities must so spend at least 2% of their revenues, and gas utilities must spend at least 0.5% of their revenues on energy efficiency.

Energy efficiency and load management are important contributors to the Company's long-term approach to meeting its customers' energy needs. The Company has been conducting significant energy services programs for more than 30 years, and has already achieved a significant share of the energy conservation potential in its service area. The Company currently manages over 30 energy services programs in Minnesota, as well as more than 10 programs in Colorado. In 2001, through it's Minnesota energy services programs, the Company achieved energy savings totaling 254 GWh, demand savings of 139 MW, and gas savings of 521 million cubic feet. Program expenses for 2001 totaled $40 million, and long-term avoided costs from these programs totaled $289 million.

Xcel Energy has been conducting a full-scale retro-commissioning energy conservation program in Minnesota since 2000, and previously sponsored several pilot retro-commissioning efforts. Through the program, the Company will reimburse its customers for 50% of the cost of a retro-commissioning study, up to a maximum payment of $15,000. In addition, to assist customers to implement the measures recommended in the studies, the Company will pay its customers a rebate of $200/kW of demand reduced or $2/mcf of gas saved. These rebates are available for retro-commissioning measures with paybacks of one to 15 years, and cannot exceed 50% of the measures' installed costs.

Retro-Commissioning Study Purpose and Approach

Study Purpose

The retro-commissioning phase of the DSM potential study was conducted to refine the Company's previous estimates of retro-commissioning's long-term energy conservation potential. Previously, the Company estimated that the technical potential from retro-commissioning is about 10% of customers' energy use. This estimate was primarily based on the results of national retro-commissioning case studies. However, none of those studies that the Company reviewed were based on retro-commissioning results done for random samples of customers.

Study Approach

For integrated resource planning purposes covering a 15-year time period or more, conservation potential estimates are needed for the average customer who will participate in the Company's program over time. Based on the Company's limited program experience to date, it is difficult to forecast which types of customers are most likely to participate in the company's program over the next 15 years. So we used the average eligible customer to represent the average program participant for conservation potential forecasting purposes. This is consistent with the approach used to estimate conservation potential in the broader study.

To estimate the technical energy conservation potential for retro-commissioning, we selected a sub-sample of 11 commercial and industrial customers from the 525 customers who were part of the initial broader DSM potential study. The customer sample was designed to represent the Company's C&I customer base, and was composed as follows:

Market Segment	Number of Customers in Sample
Office Buildings	Two
Industrial Facilities	Two
Miscellaneous Commercial	Two
Health Care	Two
Retail Stores	One
Schools	One
Colleges	One

Retro-Commissioning Approach

Retro-commissioning is a process of inspecting and analyzing facility energy consuming systems to determine whether:

1. They operate in a manner consistent with the intended use of the facility,
2. They satisfy the occupants' needs for thermal and visual comfort,
3. Any changes or modifications have occurred to the facility which require re-calibration, or other modification to building energy systems, and

4. Energy consumption and costs can be reduced without impacting the services required by the occupants.

The goals of retro-commissioning are improved service from energy consuming devices and lower energy costs through reduced consumption and demand. We employed the following process to conduct these retro-commissioning conservation potential studies. We started by reviewing available material prior to contacting the facility to begin on-site work. This material includes an equipment inventory generated as part of the *DSM Potential Study*, energy billing information from Xcel Energy and mechanical, electrical and plumbing drawings.

Initially, over the course of one-half day, our engineers meet with the facility operating engineers to learn about the facility, its history, use by the occupants, and relevant energy systems and their operation. SBC personnel tour the facility with the operating engineer to learn the location and details of particular equipment.

With the information from the operating engineer, we speculate on the energy use by each system type and its overall contribution to energy use at the facility. This apportionment of energy use is used to focus the time intensive steps of on-site measurement and monitoring on the most relevant equipment.

Finally, SBC staff spend two or three days on site inspecting the equipment and its operation. The inspection process includes some or all of the following:

- Recording and verifying equipment and motor nameplate data.
- Inspecting equipment condition and physical operating attributes: Belt tension, fan wheel rotation, damper operation, filter condition etc.
- Spot measurements of temperature, pressures and power consumption.
- Installation of temporary data logging equipment to measure the same variables over a short period of time (typically 1 week).
- Inspection of operation logs.
- After-hours inspection of equipment to verify off-schedules and lighting shutdown implementation.

We then analyze this information with respect to the needs of the occupants and the activities that take place in the facility.

Summary of Technical Potential Results for Minnesota

Summaries of three of the retro-commissioning studies are summarized below as case studies that represent the range of savings found for customers in this study. All of these case studies are for customers in the Twin Cities area.

Downtown University Campus—High Savings Case Study

The University campus is a combination of renovated existing buildings and relatively new construction. The gross floor area of the campus is approximately 189,000 ft^2 and additional facilities are currently under construction. The new construction will be served with steam and chilled water from the existing physical plant. The re-commissioning study considered the impacts of the campus expansion.

This facility uses about 4.1 million kWh per year, has a peak demand of about 770 kW, and used about 173,000 therms of natural gas for calendar year 2002. Electricity use is 23% above benchmarks and natural gas use is more than 250% of comparable facilities[1]. Energy costs total $1.61 per square foot, or 16% more than the average for downtown St. Paul office buildings[2] (the most comparable building type). The energy consumption and high costs are even more remarkable considering the facility has many state-of-the-art energy efficient technologies and extensive automation capabilities.

Lighting Systems are mostly T-8 lamps and electronic ballasts and compact fluorescent downlights. The building mechanical systems are mostly variable volume air handlers with variable frequency drives to modulate air flow. Cooling is provided with one of two identical water-cooled centrifugal chillers; and zone heating is provided by steam boilers with hot water converters for water end-uses.

The site has two automation systems: a Siebe system controls the older buildings and the physical plant and an Automated Logic system is installed with newer construction. The monitoring and control capabilities of the two systems are extensive. The facility staff has not deployed the full utility of the controls.

We collected data for this facility in April and May of 2003, and completed the project report in July 2003. The building was in cooling mode while we were on site, so we were able to make good estimates for air conditioning re-commissioning savings.

The identified recommissioning savings opportunities are summarized below. Currently, the campus operates 24x7 and the steam plant is active twelve months each year.

Table 1 Summary of Downtown University Re-commissioning Savings Estimates

System	# of Recs.	Electricity kW	Electricity kWh	Nat. Gas therms	Savings $	Implement. Costs ($)
Interior Lighting	2	8.5	77,900	0	$3,200	$600
Air Handling	8	4.1	986,300	35,200	$59,200	$7,000
Chilled Water & Cooling	5	76.7	210,000	0	$7,700	$9,300
Boilers & Space Heating	2	0	0	37,200	$20,500	$10,175
Total	**17**	**88.3**	**1,276,200**	**72,400**	**$90,600**	**$27,075**

[1] US Department of Energy, Energy Information Agency, *Commercial Building Energy Consumption Survey 1999.*
[2] Building Owners and Managers Association, 2001 *BOMA Experience Exchange Report*.

If implemented, re-commissioning recommendations can reduce electric consumption and costs by about 31% and 25%, respectively, and electric demand about 11%. Natural gas consumption and costs would be reduced about 42%. Identified re-commissioning savings represent almost 49 cents per square foot or 30% of total energy costs. None of the recommendations reduce services to the occupants. In fact, several recommendations, if implemented, will enhance comfort for building occupants.

Metal Fabrication Facility—Average Savings Case Study

This industrial facility is about 75,000 square feet in size. The company primarily performs metal stamping to produce medical device housings for products such as pacemakers. The majority of the structure was built in 1968, but significant additional renovation and expansion work was done in stages over the years, with the last major addition completed in 1998. About 200 employees work in the facility.

The company has been bought and sold twice in recent years, most recently about a year ago. The newest owners have required facilities staff to focus on several building projects unrelated to energy matters. In addition, the newest owners have several misconceptions about energy, such as believing that higher light levels are usually better, that will likely make energy conservation projects problematic to receive approval to conduct.

This facility used about 3.9 million kWh per year, had a peak demand of about 1,000 kW, but only used about 30,000 therms of natural gas for calendar year 2002. Electricity consumption is about 32% above benchmarks[3], gas consumption about 79% below benchmarks, and total energy costs are about 8% below comparable buildings.

Almost half of the facility's electricity is used by the dozens of punch presses present at the facility. These machines are not amenable to re-commissioning, as they use almost no energy except when their motors are on. Other significant electric end uses at the plant are indoor lighting, which uses about 20% of their electric energy, air compressors, which use about 10% of their electric energy, and air conditioning, which uses about 8% of their electric energy.

The facility's heating and air conditioning is done by about thirty-eight rooftop heating and cooling units, many of which are rather old. These units are controlled by individual old-fashioned thermostats. No energy management systems are used at the facility.

We collected data for this facility in March 2003, and completed the project report in June 2003. None of the air conditioning systems were running while we were on site, as the building was in heating mode. Insufficient information was available from the facility engineer to make re-commissioning recommendations for air conditioning.

[3] 1998 Energy Information Agency, US Department of Energy, *Manufacturing Energy Consumption Survey*.

The re-commissioning recommendations, developed through this study, focus primarily on lighting, HVAC, and process equipment. The largest savings were found from HVAC measures.

Table 2 Summary of Metal Fabrication Re-Commissioning Savings Estimates

	# of	Electricity			Natural Gas		Total Savings	Impl. Cost
System	**Recs.**	**KW**	**KWh**	**$**	**therms**	**$**	**$**	**$**
Interior Lighting	1	0	33,500	1,200	0	0	$1,200	$0
HVAC	3	0	180,400	$6,300	1,300	$560	$6,860	$4,750
Process	1	0	26,000	$900	0	0	$900	$150
Total	5	0	239,900	$8,400	1,300	$560	$8,960	$4,900

If all of the recommendations are implemented as described, total annual energy cost savings are estimated at about $9,000, or about $0.12/ft^2. This is about a 4% savings over current costs. Potential electric energy savings are estimated at about 240,000 kWh, or about 6% of total electricity use. Annual gas savings from implementing all measures is estimated at 1,300 therms, or about 5% of gas usage.

This facility also has significant energy conservation potential from redesigning their lighting systems, and reducing air compressor energy use. However, these are not re-commissioning conservation measures, so their conservation impacts are not included in this study, although they were included in the report presented to the customer.

Nursing Home Facility—Low Savings Case Study

The facility studied is a full service nursing home serving approximately 150 residents with varying health and living needs. The facility is staffed with medical professionals twenty-four hours per day, serves three meals per day for the residents and provides a range of community activities.

The facility was converted from a junior high school in 1986 and has had some additional expansion for administrative offices since that time. The gross occupied area is about 100,000 square feet. The site is well maintained and operated. The Building Automation System, BAS, is fairly thorough in its capabilities and, in general, it is well utilized.

This facility used about 1.5 million kWh per year, had a peak demand of about 450 kW, and used about 120,000 therms of natural gas for the period of October 2001 to September 2002. Electricity consumption is more than 30% below CBECS benchmarks[4], while natural gas use is about 25% higher than comparable buildings. The higher natural

[4] 1999 Energy Information Agency, US Department of Energy, *Commercial Buildings Energy Consumption Survey*.

gas use could be due to the more northern location of the facility compared to the CBECS region, on-site laundry, and preparing three meals per day.

We collected data for this study in September and October of 2002, and completed the project report in December 2002. The chilled water system was not running when we were on site, but we were able to collect enough information from the facility engineer to make several re-commissioning recommendations for this system.

The re-commissioning recommendations developed through this study focus on the ventilation and chilled water systems. In most cases the changes involve special maintenance effort or minor set-point changes with the BAS. In other cases more extensive control programming is required. These changes can be cost-effective if implemented as a group to minimize service calls from the controls vendor.

Table 3 Summary of Nursing Home Re-Commissioning Savings Estimates

System	# of Recs.	Electricity		Nat. Gas	Savings	Implement.
		KW	kWh	Therms	$	$
Interior Lighting	2	0.1	4,900	0	$175	$200
Ventilation	6	1.2	30,300	0	$1,325	$750
Space Cooling	4	11.3	17,000	0	$1,000	$375
Boilers & Space Heating	0	0	0	0	0	0
Miscellaneous	1	0	0	0	0	$1,200
Total	13	12.5	52,200	0	$2,500	$2,525

If all of the recommendations are implemented as described, electricity use will be reduced by about 3.5%, electric demand will be reduced by about 3%, and overall energy costs will be reduced by $0.033/ft^2$. The relatively low savings can be attributed to several factors:

1. A well-utilized BAS,
2. Requirements for continuous operation of most equipment,
3. Air-to-air heat exchangers already operating on the major ventilation units,
4. Good preventative maintenance practices, and
5. Multiple small pieces of equipment with low consumption per machine.

In addition to the re-commissioning savings, we identified an opportunity for the customer to reduce their energy costs by correcting their power factor.

Technical Potential Conclusions

The findings from the re-commissioning studies conducted for this project found a wide range of energy and demand savings for the eleven customers studied. Summary statistics include:

- Electric re-commissioning energy savings ranged from 2% to 31% of customers' base electricity consumption. The mean reduction in electric energy consumption found from these studies was 6% of base use, while the median savings was 6.2% of base use.

- Electric demand savings also varied considerably, from zero demand savings up to 12.5% of customers' peak demands. The mean and median demand savings were 2.8% of customers' base demand.
- Natural gas savings had the widest range of variation for any of the energy or demand savings evaluated, ranging from zero savings to almost 80% of customers' base gas use. The mean savings was 13%, while the median savings was 4.6%.

High energy-using customers show slightly higher than average re-commissioning savings. The five highest electricity users compared to average similar facilities could save a mean of 7.7% of their baseline electric use, about 25% higher than the overall mean electricity re-commissioning savings. However, the correlation between high electricity use and high re-commissioning energy savings is somewhat weak. Two of these five customers' re-commissioning electric savings was less than the median, and a third equaled the median.

Similar findings were found for high natural gas users. The five highest gas users compared to average similar facilities could save 17.9% of their baseline natural gas use, about 38% higher than the overall mean gas re-commissioning savings. However, the correlation between high natural gas use and high gas re-commissioning savings is also somewhat weak. Two of these five customers' gas savings were less than the mean, and the largest re-commissioning gas savings customers' baseline gas use was lower than average among similar facilities.

The re-commissioning measures that we identified through this project are very cost effective for customers. About 80% of the measures specified in these reports had customer paybacks of less than one year. All the remaining re-commissioning recommendations had paybacks of less than five years.

Almost half of the study customers' air conditioning systems were shut down during the times of our site visits, so we were not able to directly estimate re-commissioning potential savings for these systems, as is discussed in the previous sections for each site. To provide a rough estimate for the savings potential for these sites, we assumed that these customers' re-commissioning air conditioning savings would have matched the median air conditioning savings from the customers that we did estimate savings for. The median air conditioning re-commissioning savings from the six customers that we estimated savings for were about 14% of their air conditioning energy use and 5% of their air conditioning demand.

Applying the median air conditioning savings to these five customers increased the overall mean re-commissioning electric energy savings to 6.8% from 6.0%, and increased the corresponding median overall savings estimate to 7.3% from 6.2%. Similarly, the overall re-commissioning mean demand savings increased to 3.6% from 2.8% using this adjustment, but the corresponding median demand savings stayed the same at 2.8%.

These adjusted savings estimates provide the best measure of the likely average re-commissioning energy conservation potential in the Company's service area. They show that the long-term average re-commissioning electricity savings is likely to be below the Company's previous savings estimate of 10% of customers' gross electric consumption. However, the annual savings that the Company is able to garner from its re-commissioning program in the short-term will depend more on the number of studies conducted, and the effectiveness of converting the savings potential identified in such studies into actual realized savings.

Other more qualitative conclusions from this study include:

- Many rooftop air conditioners' economizers are not operating as designed to minimize energy use. This finding is consistent with other studies conducted across the country.
- Many building engineers do not believe that they are responsible for minimizing their facilities' energy use. They generally see their jobs as serving the building occupants and responding to their requests.
- The building engineers at the nursing home and downtown office building study participants, by contrast, did clearly see that a significant part of their jobs was to minimize their facilities' energy use. These two facilities had the lowest percentage savings from the re-commissioning measures of all the 11 facilities that we studied for this project.
- Building automation systems (BAS) are often not used to their full potential as energy conservation tools. Sometimes the building engineers only know how to perform very basic functions using the BAS, and they rarely know how to use the BAS' most advanced features, such as performing chilled water setback control, or capturing trend data over a period of time for analysis.
- Customers valued the diagnostic aspects of the re-commissioning studies that told them how well their systems were performing.
- Customer awareness of re-commissioning and Xcel Energy's re-commissioning program is still somewhat low. Most of the customers that we contacted to participate in this part of the study were initially not very familiar with re-commissioning or the Company's program.

ASSET Model Summary

Technical conservation potential estimates are only the starting point for forecasting the expected impacts from the Company's conservation programs. The latter type of conservation potential is usually called achievable potential or market potential. This type of conservation potential is forecasted through a modeling approach, which is described below.

This section describes the approach used for estimating DSM potentials. These estimates are developed using the ASSET model, developed by Itron (formerly Regional Economic Research or RER). ASSET is a PC-based program specifically designed to estimate technology adoption rates and market potential. The framework has the following key features and capabilities.

- Customer segmentation provides the foundation for modeling technology decisions based on customer characteristics and attitudes.
- Equipment inventory data provide a starting point for defining market size and the applicability of technology options.
- Physical barriers to adoption (technology applicability and feasibility), and market barriers to adoption (customer awareness, customer willingness, and supply-side availability) are modeled to impose realistic limits on market potential estimates.
- A variety of adoption models are available to estimate market adoption rates based on technology and customer characteristics. Specific modeling frameworks are provided for four different types of decisions: new construction, replacement at time of burnout, equipment conversions, and retrofit actions.
- Model runs with and without program incentives are executed and the results are compared to derive incentive impacts. Also, technical potential and economic potential runs provide estimates of impacts in the absence of market barriers to adoption.

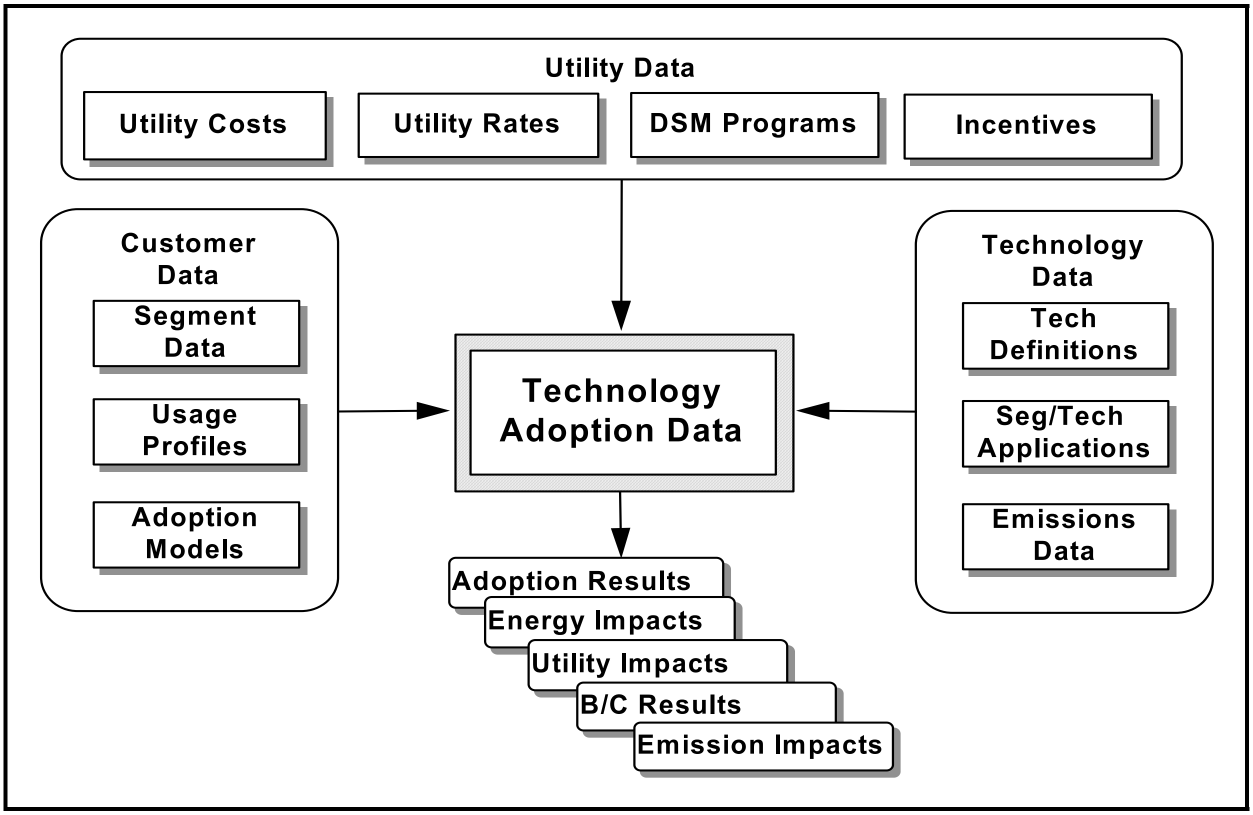
The framework is based on a series of database tables and input files that describe customer characteristics, technology trends, program characteristics, and adoption behavior. These databases can be modified and refined, providing the Company with the capability to reassess potentials as knowledge about the market and the impact of utility programs increases over time.

The remainder of this section provides an overview of the ASSET model structure, data requirements, and impact accounting conventions that are used.

Overview of ASSET

ASSET (Assessment of Energy Technologies) is a modeling framework that focuses on technology adoption modeling. The framework is specifically designed for modeling market potential, modeling technology penetration rates, and estimating market potentials. The following provides a brief summary of the modeling framework and data requirements, as illustrated in Figure 1.

Figure 1: ASSET Modeling Framework



As shown in the figure, ASSET inputs appear in four input groups, containing Utility Data, Customer Data, Technology Data, and Technology Adoption inputs. Each input group contains definitions that serve as handles for linking data in that group with data in other groups. For example, in Customer Data, customer segments are defined, and these segment identifiers are referenced in the Technology Data section. Similarly, in the Utility Data section, a variety of rates are defined, and the rate identifiers are referenced in the Technology Data section.

Utility Data. Inputs in the Utility Data section are broken into four parts. These parts contain information about Utility Costs, Energy Rates, and DSM Programs and Incentive Rules.

- ***Utility Cost File.*** These inputs include data for converting changes in electric retail sales into utility cost impacts. T&D loss factors are entered to convert end-use energy into generation-level requirements. Avoided costs convert system energy impacts into dollar values. Avoided costs are entered by season and time-of-use period. This input file also contains information used in cost/benefit analysis, including discount rates that are used in financial calculations and to compute the present value of cost and benefit streams.

- ***Energy Rate Files.*** This input section contains utility rate schedules. Each file describes a single rate. In the Technology Data section, rate schedules are referenced by name and assigned as part of the application of technology options in specific segments.
- ***DSM Programs Table.*** This table contains information about utility incentive programs. Programs are usually defined broadly, and may cover a variety of measures and multiple segments. Data about fixed program costs are also entered here.
- ***Incentive Rules Table.*** Incentive rules are entered into this table. Formulas for program incentives may be based on measure costs or on energy savings. Also, variable program costs are entered with the incentives. This approach allows different incentive rules to be assigned to different measures covered by a single program.

Customer Data. Inputs in the Customer Data section are broken into three parts. The Usage Profiles section provides data about energy usage profiles by season and time-of-use period. The Segment Data section contains data about customer characteristics. The Adoption Models section provides a list of models that can be used to estimate technology adoption rates.

- ***Usage Profiles Table.*** This table provides data about energy usage profiles by season and time of use period. Inputs include energy-use fractions, peak factors, and system coincidence factors for each period.
- ***Segment Data Table.*** This table contains segment definitions and provides data and forecasts of segment size and segment growth. Typically, segments are defined by housing type for the residential sector, building type for the commercial sector, and industry group for the industrial sector.
- ***Adoption Model Files.*** Each adoption model is stored in a separate file. These models define the structure of technology competition and provide equations for modeling adoption rates and program participation rates.

Technology Data. Inputs in the Technology Data section are broken into three parts. The purpose of these data is to define technology options and to enter data on technology costs and performance in each market segment.

- ***Technology Definitions Table.*** This table contains one row for each technology. Inputs include technology identification and data for efficiency values, market availability, and other factors.
- ***Segment/Technology Data Table.*** This table contains one row for each technology and segment combination. Data elements include equipment costs, minimum and maximum life values, base-year shares, and energy intensities for electricity and natural gas usage.

Technology Adoption Inputs. This final input area pulls all of the other inputs together to define measure competition groups. Separate inputs are entered for each type of decision, and data are assigned to the adoption modeling problem based on the following key linkages: (a) measure costs and energy impacts come from the Technology Data section, (b) usage profiles and measures of segment size come from the Customer Data section, (c) rates, programs, and incentive rules come from the Utility Data section, and finally (d) adoption models are assigned from the Customer Data section.

The ASSET model will be used to estimate the potentials for energy conservation in the Company's entire Minnesota service area once all of the scheduled 11 retro-commissioning studies are completed. This model was used for this purpose in the previous phases of this project, and in a previous conservation potential study that the Company conducted in the mid-1990s.

ASSET Modeling Results Based on Re-Commissioning Technical Potential Studies

Itron/RER re-ran the ASSET model to estimate long-term re-commissioning DSM potential based on the latest technical potential results. The latest ASSET analysis scaled the technical potential results for each customer studied up to represent all similar customers in the population. The achievable potential results are estimated by calibrating the ASSET model to match the Company's 2003 program goals.

The latest ASSET modeling forecast results are that achievable re-commissioning DSM potential for 2003-2017 is 15 MW and 152 GWh. This is about 60% less than the 37 MW and 10% less than the 168 GWh of achievable previously estimated for planning purposes. Differences between these estimates and the previous estimates are the result of the individual building analyses performed in this study. Previously the estimated impacts from re-commissioning were based on a generic 10% savings of total energy consumption with a generic load shape applied. The new findings show different levels of savings potential by end use, which result in the new estimates.

For energy savings by end use, ventilation has the largest share of achievable re-commissioning potential at 51%. The other end use shares are air conditioning at 22%, lighting at 16%, heating at 5%, and miscellaneous measures at 6%. For demand savings by end use, ventilation also has the largest share of achievable re-commissioning potential, but a lower 31% of the total demand reduction. This is followed closely by cooling at 28%. The other end use demand shares are 20% for lighting, 19% for heating, and 2% for miscellaneous measures. These end use shares are based on the current incentive scenario results and re-commissioning's measure load shape.