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MIDWEST RESIDENTIAL MARKET ASSESSMENT AND DSM POTENTIAL STUDY

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1. EXECUTIVE SUMMARY

This section provides a brief summary of the project goals and methods, findings and conclusions, and recommendations.

1.1 Project Goals

The Midwest Energy Efficiency Alliance's (MEEA) project goals as specified in the original project RFP are to:

- Characterize the Midwest residential market, including estimating saturation rates for existing energy efficiency technologies, products, practices, and behavior.
- Evaluate efficiency opportunities in this market sector.
- Estimate a baseline to assess future residential demand side management (DSM) programs.
- Benchmark other Midwest states to Xcel Energy's Minnesota service area.

1.2 Methodology

In September 2004, MEEA selected Summit Blue Consulting to conduct a regional residential market assessment via a competitive request for proposal process. Summit Blue had partnered with Quantec LLC and Skumatz Economic Research Associates and the team was awarded to contract due to their extensive experience in conducting market potential studies both within the Midwest and nationally. The first major project task was to review and compile information from already completed residential market assessments for Xcel Energy's Minnesota area[1], MEEA's Illinois study[2], as well as similar studies conducted for Iowa[3], and Wisconsin[4]. Project team members had either conducted these studies, or knew of them before the start of this project. The project team did not collect additional primary data for these four states that had already conducted market assessments, but rather used the existing data from these previous studies to characterize these states. The project team used this approach to conserve project resources and to focus the data collection efforts on the five Midwest states for which statistically representative data was not publicly available.

The second major project task was to conduct a thorough search for additional similar studies that had been conducted throughout the Midwest. The project team conducted telephone interviews with 40 Midwest investor-owned utilities, larger municipal utilities and coops, as well as all state energy agencies, and larger city energy agencies. The intent of these interviews was both to get a better understanding of the residential markets in the Midwest, and to identify any organizations that might be interested in teaming with MEEA to conduct additional data collection specific to the organizations' service area.

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[1] Itron, "Xcel Energy Residential DSM Market Assessment Report", (Itron, Vancouver, WA, July 26, 2003).

[2] Midwest Energy Efficiency Alliance, "Illinois Residential Market Analysis", (Midwest Energy Efficiency Alliance, Chicago, IL, May 12, 2003).

[3] Global Energy Partners and Quantec, "Assessment of Energy and Capacity Savings Potential in Iowa, Volume1: Assessment of Energy Efficiency Measures" and Volume III, Technical Potential Estimates (2002).

[4] Energy Center of Wisconsin, "Energy and Housing in Wisconsin", (Energy Center of Wisconsin, Madison, WI, November 2000).

The third major project task was to collect primary data to characterize the five Midwest states (Indiana, Kentucky, Michigan, Missouri, and Ohio) for which publicly accessible in-depth market assessments have not yet been conducted. The general data collection approach was:

- Complete about 480 phone-based residential appliance saturation surveys (RASS) across the sample (96 per state) to obtain dwelling, appliance, fuel, DSM measure, demographic, attitudinal, awareness, and other information.

- Survey 5-10 HVAC equipment distributors and/or residential energy auditors per state. These surveys were done to estimate the saturations of insulation and energy-efficient equipment in the residences in each state.

The fourth major project task was to characterize the DSM measures to be analyzed for this study. Characterization of DSM measures requires: 1) determining the list of DSM measures to evaluate: 2) estimating the baseline energy consumption for each end-use (heating, cooling, cooking, hot water, etc.) or unit energy consumption (UEC); and 3) estimating the incremental savings from each measure - improving from the baseline to the new technology. In addition, the baselines must consider that different classes of homes have different penetrations of technologies, such as existing homes compared to new construction.

The fifth major project task was to estimate the technical and achievable DSM potential for the measures specified in task four. The general approach for derivation of energy efficiency resource potentials consisted of three sequential steps: 1) estimate technical energy efficiency potential; 2) subdivide the technical energy efficiency potential estimates into discrete "bundles" based on cost category, which allows the economic potential to move with the underlying volatility in fuel prices; and 3) estimate market penetration and the resulting achievable potential as a subset of each bundle. All of these estimates were derived using Quantec's Energy ForecastPro model, an end-use forecasting and energy efficiency potentials assessment tool. The conceptual underpinnings and analytic procedures of this model are based on standard practices in the utility industry, and are consistent with the methods used in the Xcel Energy and Iowa studies mentioned above.

The last major project task was conducting an integrated analysis of all the project results. From this assessment of the project findings, the project team developed conclusions and recommendations, which are presented in the next two sections.

1.3 Findings and Conclusions

1.3.1 Conclusions Regarding Midwest DSM Programs and Residential Energy Use

Conclusion #1: The most frequently offered types of DSM programs by the sponsor organizations surveyed in the Midwest are rebate programs, energy audit programs, and other types of energy information programs.

Rebate programs frequently covered multiple technologies, such as efficient heating and cooling equipment, water heaters, lighting, appliances, and new construction measures. Direct load control programs and low income programs are also relatively common in the Midwest. Less common are financing programs and multi-family focused programs.

Conclusion #2: Residential electricity and natural gas use per customer varies over 50% from the lowest use states to the highest use states in the Midwest.

The saturations of electric space heating and water heating have the largest influence on electricity use in the region. Variations in natural gas use are similarly influenced by saturations of natural gas space heating and water heating, as well as climate and average gas space heating efficiencies. Average electric use per customer is lowest in Michigan, Minnesota, Illinois, and Wisconsin, while average natural gas use per customer is lowest in Missouri, Iowa, Wisconsin, and Indiana.

1.3.2 Conclusions Regarding DSM Measure Saturations

Conclusion #3: Generally 5%-15% of customers have either uninsulated ceilings or walls in their homes.

The percentage of customers with uninsulated attics varies from 3% to 11% from state to state, while the percentage of homes with uninsulated walls varies from 5% to 27%. However, more than half of these percentages were self-reported by customers through a telephone survey. Such self-reported responses often over-estimate the actual amount of insulation present in homes.

Conclusion #4: Generally 20%-36% of homes have mostly single-paned windows.

The lowest percentages of single-paned windows are found in Minnesota (20%) and Ohio (22%), while the highest percentages are found in Illinois (36%) and Wisconsin (35%).

Conclusion #5: Less than half of the homes in any Midwest state have one or more compact fluorescent lamps (CFLs).

The percentage of homes with one or more CFLs varies from 13% in Wisconsin to 43% in Kentucky. (However, Wisconsin's data is the oldest of the states analyzed, so the saturation of CFLs there is likely higher currently.) The median percentage of homes with one or more CFLs is 33%.

Conclusion #6: The market shares of efficient gas space heating systems are estimated to be the highest in Iowa, Minnesota, and Wisconsin at 74%, 67%, and 50% respectively.

For Indiana, Kentucky, Michigan, Missouri, and Ohio, energy auditors estimate the shares of more efficient gas furnaces at 23% on average, but slightly higher in Missouri. The higher saturations of efficient gas furnaces in Iowa, Minnesota, and Wisconsin is presumably due to the impact of long standing DSM programs promoting this DSM measure in those states.

Conclusion #7: The highest percentages of more efficient central air conditioners are found in Iowa (74% total) and Minnesota (48% total).

These percentages are much higher than the 24% market share estimated by energy auditors for efficient air conditioners in Indiana, Kentucky, Michigan, Missouri, and Ohio, or the 6% market share found from the on-site audits in Wisconsin. (However, the Wisconsin data is the oldest of that included in this report, so the efficient units' market shares may have increased there since 1999.) The Iowa utilities and Xcel Energy in Minnesota have been promoting energy efficient central air conditioners for a long time, which is presumably mostly responsible for the higher saturations of efficient air conditioners in those states.

Conclusion #8: Midwest electric and gas water heaters are mainly minimum efficiency units.

Midwest electric water heaters are mainly minimum efficiency units, with low efficiency units' market shares ranging from 66% to 87% from state to state. As with electric water heaters, Midwest natural gas

water heaters are mainly minimum efficiency models, which have market shares of 63%-83% from state to state.

Conclusion #9: The saturations of ENERGY STAR® appliances in the Midwest are likely rather low, in the range of 3%-6% depending on the appliance.

The most accurate estimates of ENERGY STAR® appliance saturations should be those provided by the energy auditors in Illinois and Minnesota, who conducted on-site inspections of appliances to determine whether they met ENERGY STAR® standards or not. Customers estimate that far higher percentages of their appliances are ENERGY STAR® units, usually ranging from 16% to 49%, depending upon the appliances and the state of residence. However, most residential customers likely do not know enough about ENERGY STAR® standards to accurately estimate whether their appliances meet these standards or not.

Conclusion #10: The saturations of programmable thermostats vary widely from state to state in the Midwest.

The saturations range from lows of 17% and 19% in Indiana and Kentucky respectively to a high of 47% in Illinois. The mean statewide saturation in the states analyzed is 29%.

1.3.3 Conclusions Regarding Natural Gas DSM Potentials

Conclusion #11: The total DSM potentials for natural gas DSM measures are remarkably consistent from state to state in the Midwest.

The total 20-year technical potential for gas DSM varies only from 44% to 48% of base case consumption between states. The total achievable potential for gas DSM varies between states from about 23% to 27% of base case consumption. In total, the gas technical DSM potential is estimated to be 9.2 billion therms for all nine Midwestern states analyzed, and the maximum achievable gas potential is estimated to be 5.0 billion therms across the Midwest, or about 54% of the gas technical potential.

Conclusion #12: In total, about 43% of the total achievable potential is available from DSM measures whose cost of conserved energy is $1 per therm or less.

About 12% of the total achievable potential is available from measures whose cost of conserved energy is $0.30 per therm or less. On the other hand, about 33% of the total achievable potential is from measures whose costs of conserved energy are more than $1.50 per therm, at or above the currently high commodity cost for natural gas.

Conclusion #13: The most cost-effective natural gas DSM measures are insulating uninsulated attics, ENERGY STAR® programmable thermostats, low flow showerheads, hot water pipe insulation, and faucet aerators.

These measures have costs of conserved energy of $0.30 per therm or less in existing single-family homes. High efficiency furnaces, comprehensive air sealing/infiltration reductions, water heater thermostat setbacks, and multi-family wall insulation are in the second tier of cost-effectiveness, with costs of conserved energy of $0.60 per them or less.

Conclusion #14: Not surprisingly, space heating natural gas DSM measures account for over 80% of total achievable gas DSM potential.

Water heating gas DSM measures account for almost all of the remaining achievable gas DSM potential. Also not surprisingly, single-family homes account for over 80% of total achievable residential gas DSM potential.

1.3.4 Conclusions Regarding Electric DSM Potentials

Conclusion #15: Electric DSM potentials are much smaller shares of base case consumption than gas DSM potentials.

Total electric DSM technical potential equals about 24% of base case consumption which translates to almost 84 billion kWh in savings, compared to about 47% for gas technical potential, which translates to 9.2 billion therms saved. Total electric achievable potential accounts for about 10% of base case consumption, compared to about 25% for gas achievable potential. The differences between the results for the two energy types is due to two primary factors: first, the electric base case consumption estimates include electricity savings from the significant forthcoming federal efficiency standards for central air conditioners and heat pumps that will take effect in 2006. Second, electric space heating, water heating, and lighting account for less than half of total base case electric consumption, but almost all of natural gas base case consumption. The DSM potentials for other electric loads such as appliances are considerably smaller percentages of base case consumption than the DSM potentials for space heating, water heating, and lighting DSM measures.

Conclusion #16: Electric DSM potentials vary much more from state to state than gas DSM potentials.

Electric technical DSM potential varies from about 20% to 30% of base case consumption between states, while electric achievable DSM potential varies from about 8% to 14% between states. Minnesota and Wisconsin have the lowest relative amounts of DSM potential, while Kentucky and Missouri have the largest relative amounts of DSM potential. The amounts of electric DSM potential are proportionate to the saturations of electric space heating and water heating equipment in a state, and inversely proportionate to the magnitudes of historical DSM activity.

Conclusion #17: In total, about 39% of the total electric achievable potential is available from DSM measures whose cost of conserved energy is 6 cents/kWh or less.

On the other hand, 51% of total electric potential comes from DSM measures whose costs of conserved energy are 10 cents/kWh or more, at or above most current Midwest electric rates.

Conclusion #18: The most cost-effective and largest impact electric DSM measures are insulating uninsulated attics, installing ENERGY STAR® heat pumps, installing CFLs, removing or replacing secondary or inefficient refrigerators or freezers, and low flow showerheads.

In total, these measures comprise over 75% of the achievable DSM potential for measures with costs of conserved energy of 6 cents/kWh or less. In fact, most of these measures have costs of conserved energy of 3 cents/kWh or less.

1.4 Natural Gas Recommendations

Four residential natural gas measures account for about 83% of the DSM potential with a cost of conserved energy of $1 per therm or less. The remaining DSM potential at this cost of conserved energy

is accounted for by a variety of measures, each with relatively small impacts. Each of the four major measures are briefly discussed below.

Insulating Un-insulated Attics

The total achievable potential for this measure over the 20 year forecast period is approximately 390 million therms. This represents about two percent of total residential base case natural gas consumption over this period. The total cost of conserved energy for this measure in most Midwest single-family homes is about $0.25 per therm. This cost is based on the total installed cost for the insulation.

ENERGY STAR® Programmable Thermostats

The total achievable potential for this measure over the 20 year forecast period is approximately 210 million therms. This represents about one percent of total residential base case natural gas consumption. The total cost of conserved energy for this measure in most Midwest single-family homes is about $0.17 per therm. This cost is based on the total installed cost for the thermostat. Since the current saturations for programmable thermostats are less than 50% in all Midwest states studied, and vary by over a factor of two from state to state in the Midwest, considerable market potential exists for this measure.

High Efficiency Gas Furnaces

The total achievable potential for this measure over the 20 year forecast period with a cost of conserved energy of $1 per therm or less is approximately 930 million therms. This represents about five percent of total residential base case natural gas consumption. The cost of conserved energy for this measure varies between housing types, and whether a 92% or 96% efficient furnace is analyzed. The 96% efficient furnaces were found to have a lower total cost of conserved energy than the 92% efficient furnaces.

Efficient furnaces have a cost of conserved energy between $1.10 per therm and $1.20 per therm in the more southern states of the Midwest where the annual savings are lower. The total DSM potential from efficient furnaces in those states is about 600 million therms, or about three percent of total residential base case consumption. Whether this conservation is considered cost-effective or not depends on projections for the price of natural gas.

Conduct Comprehensive Shell Air Sealing and Infiltration Reduction

The total achievable potential for this measure over the 20 year forecast period is approximately 280 million therms, or about 1.4% of base case natural gas consumption over this period. This measure is most applicable and cost-effective in existing single family homes. The cost of conserved energy for this measure in most of the Midwest states analyzed is about $0.85 per therm, but in some of the northern states where the annual savings are larger than average, the cost of conserved energy is about $0.57 per therm.

1.5 Electric Recommendations

Six residential electric measures account for about 78% of the DSM potential with a cost of conserved energy of 10¢/kWh or less. The remaining DSM potential at this cost of conserved energy is accounted for by a variety of measures, each with relatively small impacts. Each of the six major measures are briefly discussed below.

Compact Fluorescent Lamps (CFLs)

The total achievable potential for this measure over the 20 year forecast period is approximately 5,800 GWh, or about 1.6% of total residential base case electric consumption over this period. The total cost of conserved energy for this measure varies with how many hours per day the lamps are used. For lamps that are used six hours per day, the cost of conserved energy is about 1.2¢/kWh, while for CFLs that are used 2.5 or 0.5 hours per day, the cost of conserved energy is 2.3¢/kWh or 11¢/kWh, respectively

ENERGY STAR® Heat Pumps

ENERGY STAR® heat pumps have minimum cooling efficiencies of 14 SEER and minimum heating system performance factors of 8.5 starting in 2006. The total achievable potential for this measure over the 20 year forecast period is approximately 3,400 GWh, or about 1.0% of total residential base case electric consumption over this period. The total cost of conserved energy for this measure varies considerably with climate, and ranges from about 1.4¢/kWh to 9.4¢/kWh, and even higher. Almost all of the DSM potential for this measure is in single-family homes.

Insulating Un-insulated Attics

This measure is also a large electric savings measure, primarily in states with significant electric space heating saturations. The total achievable potential for this measure over the 20 year forecast period is approximately 1,800 GWh, or about 0.5% of total residential base case electric consumption over this period. The total cost of conserved energy for this measure in most Midwest single-family homes is about 1.8¢/kWh.

Removing Secondary Refrigerators

The total achievable potential for this measure over the 20 year forecast period is approximately 1,500 GWh, or about 0.4% of total residential base case electric consumption over this period. The total cost of conserved energy for this measure is about 6.1¢/kWh.

ENERGY STAR® Refrigerators

The total achievable potential for this measure over the 20 year forecast period is approximately 930 GWh, or about 0.3% of total residential base case electric consumption over this period. The total cost of conserved energy for this measure is about 9.3¢/kWh. All the DSM potential for this measure that costs 10¢/kWh or less is from single-family homes.

Efficient Water Heaters

The total achievable potential for high efficiency and heat pump water heaters over the 20 year forecast period is approximately 770 GWh, or about 0.2% of total residential base case electric consumption over this period. The total cost of conserved energy for high efficiency water heaters is about 6.9¢/kWh, while the cost of conserved energy for heat pump water heaters is about 9.9¢/kWh.

2. INTRODUCTION

This section provides the background and context in which this study was conducted, summarizes the project goals and methods, and provides an outline of the entire project report.

2.1 Background

Market assessment studies and DSM potential studies can be valuable sources of information for planning energy efficiency programs. There has been a resurgence of interest in these types of studies in the past five years. A recent ACEEE paper summarized the results of eleven DSM potential studies that have been conducted across the country over this period[5]. Interestingly, however, this ACEEE paper did not cover any such studies from the Midwest, although several studies of this type have been conducted in the Midwest in recent years.

As will be discussed in more detail in the Methodology section, large-scale market assessments or DSM potential studies covering at least residential customers have been conducted in Illinois, Iowa, Minnesota, and Wisconsin in the past five years. These studies were done for somewhat different purposes, including DSM program planning, baseline market characterizations, and utility integrated resource planning (IRPs). Most of these studies included in-depth assessments of DSM potential for those states or utility service areas, and included telephone or on-site surveys of varying degrees of comprehensiveness to provide the input data for their market characterizations and DSM potential estimates.

2.2 Project Goals and Methods

MEEA's project goals as specified in the original project RFP are to:

- Characterize the Midwest residential market, including estimating saturation rates for existing energy efficiency technologies, products, practices, and behavior.
- Evaluate efficiency opportunities in this market sector.
- Estimate a baseline to assess future residential DSM programs.
- Benchmark other Midwest states to Xcel Energy's Minnesota service area.

The approach used for this project was to use data and results from the four recent Midwest residential market assessments to characterize those four states, and provide the input data for conducting DSM potential estimates for those states. In addition, the project team conducted new telephone residential appliance saturation surveys and telephone surveys of energy auditors for the other five Midwest states covered by this study: Indiana, Kentucky, Michigan, Missouri, and Ohio. This data was used to characterize those five states and compare them to the four states where previous studies had been conducted, and to provide the input data for DSM potential estimates for those states.

The project team used Quantec's Energy Forecast Pro model to develop the electric and natural gas DSM potential estimates. Quantec used a previous version of this model for the Iowa DSM potential estimates,

[5] S. Nadel, A. Shipley, and R.N. Elliott, "The Technical, Economic and Achievable Potential for Energy Efficiency in the U.S.—A Meta-Analysis of Recent Studies", Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings.

and it uses a somewhat similar approach to the model used in Minnesota for the DSM potential estimates for that state.

2.3 Organization of Report

This report is divided into the following major sections:

1. Executive Summary
2. Introduction
3. Methodology
4. Market Research Results
5. DSM Potential Results
6. Conclusions and Recommendations

Appendix A: DSM Potential Results by State

Appendix B: DSM Measure Information

Appendix C: Residential Appliance Saturation Survey Instrument and Results

3. METHODOLOGY

This section describes the approach used for this project.

3.1 Characterize the Midwest residential housing markets for states that have already conducted market assessments.

The first major project task was to review and compile information from the already completed residential market assessments for Xcel Energy's Minnesota area[6], MEEA's Illinois study[7], as well as similar studies conducted for Iowa[8], and Wisconsin[9]. Project team members had either conducted these studies, or knew of them before the start of this project. The project team did not collect additional primary data for these four states where recent market assessments were conducted, but rather used the existing data from these previous studies to characterize these states. The project team used this approach to conserve project resources and to focus the data collection efforts on the five Midwest states for which statistically representative data were not publicly available.

The project team also conducted a thorough search for additional, similar studies that had been conducted throughout the Midwest, and collected additional data from the organizations interviewed to support several of the ultimate project recommendations requested by MEEA. This was accomplished by conducting telephone interviews with 40 Midwest investor-owned utilities, larger municipal utilities and coops, as well as all state energy agencies and larger city energy agencies. The intent of these interviews was both to get a better understanding of the residential markets in the Midwest, and to identify any organizations that might be interested in teaming with MEEA to conduct additional data collection specific to the organizations' service area.

The four previously conducted studies had somewhat different objectives, and often used somewhat different approaches to accomplish their objectives. The objectives and methodology for each of the four studies is summarized briefly below.

3.1.1 MEEA Illinois Residential Market Analysis

This study was published in May 2003, and the primary data collection was conducted in June through October of 2002. The study had four primary objectives:

1. Evaluate opportunities for efficiency in the residential sector of Illinois.

2. Determine saturation rates of existing technologies, products, and practices/behavior in Illinois.

3. Understand consumer energy decision-making and consumer energy usage.

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[6] Itron: 2003, *op.cit*.

[7] Midwest Energy Efficiency Alliance (MEEA): 2003, *op.cit*.

[8] Global Energy Partners and Quantec: 2002, *op.cit*. We also relied on information relating to economic and achievable potential estimates contained in the individual Iowa utility Energy Efficiency Plans filed in 2002-03 by Alliant Energy, Aquila Networks, Atmos Energy, and MidAmerican Energy.

[9] Energy Center of Wisconsin: 2000, *op.cit*.

4. Provide a baseline to help determine future programs that will most effectively impact consumers in Illinois[10].

The data collection approach included:

- Initial telephone interviews to gather basic household information.

- On-site surveys to record appliances, household envelope features, and heating/cooling equipment. These 309 surveys were conducted in Cook County (including Chicago), the collar counties surrounding Chicago, northwest Illinois, central Illinois, and southern Illinois. Only single-family homes were surveyed, and the sample was not designed to gather representative information on newly constructed homes separately from older homes. Four to six homes per day were surveyed by each auditor.

- Completion of a survey by the homeowner. The survey covered the residents' awareness and understanding of the ENERGY STAR® label, and general energy issues[11].

Engineering estimates or DOE-2 analysis were used to estimate energy impacts for each DSM measure evaluated. One prototype home was developed using the survey results, and energy impacts were calculated separately for northern Illinois using Chicago weather data, and for southern Illinois using St. Louis weather data[12].

Annual savings estimates were calculated for 34 DSM measures. These measures included HVAC system renovation or replacement measures, adding various types of insulation, replacing appliances with ENERGY STAR® models, and water heating efficiency measures such as adding low flow showerheads. Of these 34 measures, 19 were selected as priority measures for which DSM potential estimates were developed[13].

Technical DSM potential was estimated by multiplying the number of homes in Illinois times the percentages of homes for which a given measure is applicable times the average impacts per DSM measure. The technical potential estimates just considered the then-current population of single family homes in Illinois. Population growth was not factored into the estimates. Technical potential was expressed in the report as a percentage of all homes for which a measure is applicable[14].

"Raw economic potential" applied an "economic feasibility percentage" to technical potential to estimate the percentage of technical conservation potential that is cost-effective. Economically feasible meant that "the homeowner has some reason (such as age or condition) to consider the idea of purchasing or replacing a technically potential measure, without regard for first cost or existing market barriers"[15].

Market potential was calculated based on DSM measures' installed cost, payback to the customer, and a "market barrier factor". The key factor used to estimate market potential was an "annual market capture percent", which represents the probability that a DSM measure will be adopted based on it's installed

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[10] MEEA: 2003, *op cit., p. 9.*

[11] MEEA: 2003, *op cit., p. 9-12.*

[12] MEEA: 2003, *op cit., p. 13.*

[13] MEEA: 2003, *op cit., p. 27.*

[14] MEEA: 2003, *op cit., p. 45-46.*

[15] Personal communication with Glenn Haynes, RLW Analytics, 8-15-05.

cost, payback, and the market barrier factor. First cost was assigned an importance equal to three times the payback period. The market barrier factor captures the effects of known non-economic barriers by using a discreet value of 1-3, where one indicates no known barriers exist, two indicates average barriers, and three indicates formidable barriers. The final market potential estimates, the "yearly realizable potential" are the product of the raw economic potential and the annual market capture percent. No formal forecasting models were used to estimate market potentials.

3.1.2 Xcel Energy Residential DSM Market Assessment Report

This project was part of the third phase of a three phase project to update the Company's DSM potential estimates for its Minnesota service area. The project report summarizing the study was published in July 2003, and the primary data was collected from November 2002 through April 2003. The primary objective of the overall project was to support developing the DSM part of the Company's integrated resource plans. This was the third large-scale assessment of DSM potential in its Minnesota territory that the Company has conducted in the past 15 years.

Key data collection elements of this study included:

- Conducting 400 on-site surveys for a representative sample of the Company's residential customers. Customer building types covered included single-family dwellings, apartments, and mobile homes. Separate sub-samples for newly constructed buildings were developed for each type of residential housing. The data collected included complete energy equipment inventories and building envelope specifications, as well as a substantial customer energy conservation attitude and awareness survey.

- Updating DSM measure costs and lifetime estimates based on recent Company information and other secondary sources such as the California Energy Commission's Database of Energy Efficiency Resources.

DSM potential estimates were developed using Itron's Assessment of Energy Technologies (ASSET) model, and covered the period 2003-2017. Xcel Energy had used this ASSET model for its last major DSM potential study in the mid-1990s, and in subsequent updates since that time[16]. The ASSET modeling for the residential sector focused on the Company's two main electric energy conservation program areas: a rebate program for efficient central and room air conditioners, and residential lighting conservation programs[17]. Detailed processing of the on-site survey results was only conducted to the extent needed to develop DSM potential estimates for air conditioners and lighting in order to minimize project costs.

Technical potential estimates were made assuming that the most efficient equipment option, thermal shell configuration, or control device is selected at each decision point. For retrofit actions, only changes that are technically feasible without major structural changes are included, while for new construction, a broader set of actions is considered. All measures are assumed to be installed regardless of measure cost or acceptability to the customer[18].

Economic potential estimates were based on implementing all technically feasible measures that meet a stated economic criterion. The economic criterion used for this study is a modified total resource cost test

[16] Itron: 2003, *op cit., p. 1-1*.

[17] Itron: 2003, *op cit., p. 2-4*.

[18] Itron: 2003, *op cit., p 1-2*

that does not include program administrative costs. The intent of the economic screening is just to compare DSM measure costs to DSM measure benefits[19].

Market or achievable potential is the most difficult to estimate of the three types of DSM potential. Achievable potential estimates incorporate the following factors:

- Customers' awareness and attitudes towards DSM measures.
- Market barriers such as information costs.
- Decision models that are based on customer decision-making processes rather than on simpler cost-effectiveness calculations.
- Calibration factors based on previous customer actions relating to DSM program participation[20].

For this study three estimates of market potential were reported: first, DSM potential based on Xcel Energy's current customer rebates. Second, DSM potential based on setting rebates equal to zero, and third, DSM potential based on doubling the amount of the Company's current rebates. In all cases market potential estimates are estimated relative to the minimum efficiency technology that is legally available[21].

3.1.3 Energy Center of Wisconsin's Energy and Housing in Wisconsin

This study was published in November 2000, and the primary data collection was conducted in 1999. This study only covered single family, owner occupied housing. The primary objectives of the study were:

1. Characterize key residential housing and household behavioral factors in Wisconsin:
    a. Housing structural, mechanical system, and major appliance characteristics.
    b. People's use of mechanical systems and appliances.
    c. People's knowledge and attitudes about energy efficiency, conservation, and energy costs.
2. Combine people's attitudes towards energy efficiency with data on where opportunities exist in order to develop more realistic estimates of market potential for structural improvements or social marketing campaigns to change behavior[22].

Although the second project objective mentions market potential, traditional DSM potential estimates that show the total potential energy savings for the state for a number of DSM measures were not developed as part of the study. The study does present average annual dollar savings per customer for each measure, and the total annual dollar savings from all the measures evaluated[23]. However, the DSM potential for the

[19] Itron: 2003, *op cit., p 1-2*.

[20] Itron: 2003, *op cit, p 1-3*.

[21] Itron: 2003, *op cit., p 1-3-1-4*.

[22] ECW: 2000, *op cit., p. 1*.

[23] ECW: 2000, *op cit., p. 16-18*.

measures are not presented in energy terms, nor are traditional technical, economic, and market potential estimates presented.

A sample of 299 Wisconsin homeowners was the source of data for this study. Low-income households and newly constructed homes were over-sampled to ensure that representative data was collected for those two market segments. For each participating household, three types of data were collected:

1. Trained home energy raters conducted an on-site audit to collect data on the structure and appliances. These audits were designed to collect sufficient information to complete a HERS rating, and typically lasted two to three hours. The auditors also collected data beyond that needed to complete a HERS rating, such as a lighting inventory and measuring showerhead flow rates.

2. Homeowners completed a 32 page survey on their energy practices, energy attitudes, and demographics.

3. Natural gas and electric monthly billing histories were collected from almost all the participants' utilities.

The HERS rating software provided an energy rating for each home on a 1-100 scale, and also estimated the annual energy use for heating, air conditioning, and water heating[24].

3.1.4 State of Iowa DSM Potential Studies

State of Iowa DSM potential estimates were conducted in a series of studies between 2001 and 2003. The initial phase was a joint research effort sponsored by the Iowa Utility Association (IUA), whose members included Alliant Energy, Aquila Networks, Atmos Energy, and MidAmerican Energy. The study addressed electric and gas savings across the residential, commercial, industrial, and agricultural sectors. Three research activities were conducted:

1. Data collection.

2. Development of a base case forecast consistent with each utility's long-run customer and sales forecasts.

3. Estimates of energy and capacity technical potential estimates for each utility using Quantec's Quant.sim end-use forecasting and DSM potential model.[25]

The data collection effort assimilated data from a variety of sources including: historical and forecasted loads and customer data from the utilities; customer counts and sales by sector and market segment from the utilities' customer information systems; historical DSM impacts reported to the Iowa Utilities Board (IUB); the Energy Information Administration's 1997 Residential Energy Consumption Survey (RECS), and 1999 Commercial Building Energy Consumption Survey (CBECS); a survey of equipment distributors serving Iowa; and DSM measure data from dozens of vendors and industry reports.

The residential sector base case began with initial estimates of energy consumption by end-use and dwelling type using an engineering thermal load model known as BEST. Typical building parameters

[24] ECW: 2000, *op cit., p. 1-3*.

[25] Energy ForecastPro, the tool used in this study for MEEA, is the successor tool to Quant.sim.

(such as square footage, base equipment types and efficiencies, and shell levels) were specified, providing initial estimates of base case energy usage by fuel and end-use. The values from BEST were then input into Quant.sim, along with other data such as customer counts, fuel shares, and efficiency shares, and adjusted as necessary to calibrate total energy sales to each utility's econometric forecasts.

The assessment of potential began with a thorough assessment of DSM measures commercially available and applicable to the state of Iowa. Several hundred measures were analyzed, including nearly 100 in the residential sector alone. The analytics provided the information necessary to conduct the potential assessment: energy savings, costs, lifetime, and other key measure characteristics. All HVAC measure savings estimates were derived in subsequent runs with BEST. Overall technical potential estimates—relative to each utility's load forecast—were then derived in Quant.sim, providing distinct estimates by dwelling type, end-use, and vintage (existing, new construction).

Following the completion of the Phase I technical potential estimates, each utility completed economic and achievable potential estimates as part of the development of the Energy Efficiency Plans required by the IUB. The basic methodology for developing these estimates was very similar to the Xcel Energy study approach:

- Each measure was first screened for economic viability using the total resource cost test. Passing measures were then considered in Quant.sim, resulting in a second set of estimates reflecting the economic potential.

- Market barriers, awareness, acceptance and other factors affecting customer choice were considered through a review of the penetration rates associated with other programs in the United States. The penetration rates associated with best program practices were deemed "achievable", and applied to the economic potential estimates.

3.2 Characterize the five Midwest states for which residential market assessments have not yet been completed.

The focus for primary data collection for this project is the five Midwest states (Indiana, Kentucky, Michigan, Missouri, and Ohio) for which publicly accessible in-depth market assessments have not yet been conducted. The general data collection approach was:

- For the base case approach, complete about 480 phone-based residential appliance saturation surveys (RASS) across the sample (96 per state) to obtain dwelling, appliance, fuel, DSM measure, demographic, attitudinal, awareness, and other information.

- Survey 5-10 HVAC equipment distributors and/or residential energy auditors per state. These surveys were done to estimate the saturations of insulation and energy-efficient equipment in the residences in each state.

3.2.1 Design and Conduct of the RASS

The RASS survey instrument used for this project is presented in Appendix C. The survey instrument was designed to collect information such as household characteristics; energy payments; familiarity with conservation activities; conservation measures already in practice; a resident's heating/cooling system usage; a resident's water heating system usage; and type of fuel or energy source used for major appliances or household equipment. The information was needed to identify the saturations of existing

equipment and fuel uses in the Midwest energy market to support estimation of the technical, economic, and market demand side management potential.

The survey was administered by telephone to residents of Indiana, Kentucky, Michigan, Missouri, and Ohio. Responses were obtained from 96 households per state, with a total of 480 respondents across the five state region.[26] The study was designed to achieve the following accuracy levels for a question with a proportional response of 50%:

- For each state: +/- 10% at 95% confidence.
- Overall accuracy: +/-5% at 95% confidence.

The accuracy levels that may be used to examine significant differences vary by the reported percentages response to the question. Table 1-1 provides these estimated accuracy levels at the 95% confidence levels. Because there are different numbers of responses for "all" / electric customers than there are for gas customers, the relevant accuracy levels are provided in separate columns.

Table 3-1. Estimated Accuracy Levels for Proportional Responses for MEEA RASS – "All" / Electric Customers vs. Those with Natural Gas Service

Proportional Response	All / Electric respondents Accuracy at 95% confidence level		Gas respondents Accuracy at 95% confidence level				
	All States +/-	Overall +/-	IN +/-	KY +/-	MI +/-	MO/OH +/-	Overall +/-
50%	10%	5%	12%	15%	12%	13%	6%
40% or 60%	10%	4%	12%	15%	11%	12%	5%
30% or 70%	9%	4%	11%	13%	11%	12%	5%
20% or 80%	8%	4%	10%	12%	9%	10%	4%
10% or 90%	6%	3%	7%	9%	7%	9%	3%
Number of respondents	96	480	67	46	72	60/62	317

Skumatz Economic Research Associates (SERA) conducted this work as a subcontractor to Summit Blue Consulting. The telephone survey work was conducted by Population Research Systems (PRS).

RASS studies are not detailed analytical reports per se. Rather, the major purpose of the study is to provide a comprehensive set of tables (and database) that can be used to look up information on the characteristics and saturations of the Midwest residential market as needed for a wide variety of program planning, market segmentation, and other purposes. In addition, detailed information from this RASS was needed to support estimation of the technical, economic, and market demand side management potential.

[26] The sample was selected randomly in the states. Five calls were made to respondents before the observation was replaced.

3.2.2 Trade Ally Surveys

The 2005 MEEA trade ally interviews were conducted to provide data to augment the information collected in the 2004 MEEA Residential Appliance Saturation Survey (RASS). The trade ally interviews were designed to provide feedback on analytical factors that residents would generally not know: stock and trends in equipment as well as measure efficiencies for HVAC equipment, water heaters, appliances, and insulation.

To gather this information, SERA conducted a phone survey of home builders and energy auditors for MEEA. The survey asked detailed questions about the saturation rates of a variety of efficiency levels for appliances and energy saving measures present in single and multifamily homes in Indiana, Kentucky, Michigan, Missouri, and Ohio.

The full data collection instrument, which is quite detailed and demanding for respondents, is provided in Appendix C. In summary, the measures and appliances and efficiency levels[27] addressed in the interview included:

HVAC: For each type, respondents were asked for information separately regarding single vs. multifamily and for new vs. existing homes

- *Electric heat pump:* SEER[28] 10; SEER 12 & SEER 13; SEER 14; and SEER 15+
- *Electric central AC:* SEER 10; SEER 12 & SEER 13; SEER 14; and SEER 15+
- *Electric room AC:* EER[29] 9.3; EER 9.7; ENERGY STAR® or EER 10.7 and above
- *Gas space heat:* Base furnace 80 AFUE[30]; condensing furnace 92 AFUE; and condensing furnace 96 AFUE

Water Heating: For each type, respondents were asked for information separately regarding single vs. multifamily and for new vs. existing homes.

- *Electric water heat:* EF[31] 0.88; EF 0.917; and EF 0.95.
- *Gas water heat:* Base 40 gal EF 0.59; EF 0.63; and EF 0.70.

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[27] Respondents were asked about the specific technical efficiency levels (e.g. SEER 10). For purposes of the potential modeling work, these efficiency levels were then labeled, in order, "Minimum efficiency level", "High efficiency", and "Higher efficiency". For several measures, an additional level was asked about, and it was labeled "Premium efficiency."

[28] Seasonal Energy Efficiency Rating (SEER). a measure of central air conditioning systems. The higher the rating, the higher the efficiency of the model.

[29] Energy Efficiency Rating (EER), a measure of efficiency of room air conditioning systems. The higher the rating, the greater the efficiency of the model.

[30] Annual Fuel Utilization Efficiency rating (AFUE) measures the seasonal or annual efficiency. The higher the rating, the greater the efficiency.

[31] Energy Factor (EF) rates the overall efficiency of a heater. The higher the rating, the greater the efficiency.

Appliances: For each type, respondents were asked for information separately regarding single vs. multifamily and for new vs. existing homes.

- *Refrigerators:* Base vs. ENERGY STAR®
- *Freezers:* Base vs. ENERGY STAR®
- *Electric cooking oven:* conventional vs. convection
- *Gas cooking oven:* conventional vs. convection
- *Electric clothes dryer:* base dryer vs. high efficiency with moisture sensor
- *Gas clothes dryer:* base dryer vs. high efficiency with moisture sensor

Insulation: For each type, respondents were asked for information separately regarding new vs. existing construction, as well as information on the percent that could be "feasibly upgraded."[32]

- *Ceiling insulation:* none; medium to R-19; optimal from R-19 to R-38
- *Floor insulation:* none; medium to R-11; optimal R-11 to R-19.
- *Wall insulation:* none; medium to R-13 blow in; optimal R-13 to R-19 batt.
- *Duct insulation:* none; medium from R-3 to R-8; optimal above R-8.

Windows: For each type, respondents were asked for information separately regarding new vs. existing homes, as well as information on the percent that could be "feasibly upgraded."

- *Windows:* low efficiency means NOT low-E[33] and less efficient than U=0.35[34]; medium efficiency requires either not low-E or U less efficient than 0.35; optimal efficiency defined as low-E and U=0.35 or better.

Respondents were asked for percentages or ranges where possible, as well as for qualitative data and feedback on trends and factors affecting the results. The small sample size, and the difficulty of answering these technical questions about efficiency saturations led to an emphasis on qualitative and quasi-quantitative results. However, this level of detail was sufficient to allow Quantec to adjust the default data in its ForecastPro model to represent the MEEA states – the purpose of the data collection work.

The data collection work was conducted in April through June 2005. SERA staff encountered several problems throughout the process of constructing sample population lists and conducting the survey itself.

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[32] R-values signify the measure of resistance to heat flow. The higher the R-value, the better the insulation.

[33] The term "Low-E" refers to coatings placed on glass that reflect specific wavelengths of energy. Low-E glass reflects heat energy while admitting visible light, keeping heat out. In winter, however, the low-angle visible light passes into the house and is absorbed by the interior.

[34] The U-factor (U) reflects the numerical value of heat transfer. It combines the four ways in which glass transfers heat (conduction, convection, radiation, and air leakage). Since it is the inverse of R-values, the lower the U-value, the greater the insulation.

Specifically, there were difficulties constructing a viable population list of equipment "specifiers" and homebuilders as well as finding qualified and knowledgeable energy professionals willing to participate in the survey. Despite these complications, enough data were obtained to draw useful and reasonably reliable conclusions about the state of heating, ventilation and air conditioning (HVAC) equipment as well as household appliances in homes in the Midwest.

3.2.3 Issues Related to Developing Population and Sample

The first step in conducting the survey involved obtaining a sample of potential respondents. Our initial approach was to try to contact distributors and other professionals that work in either household appliances or HVAC specification. SERA staff used an online index (yp.yahoo.com) to construct a population list. For the major cities in each state, SERA recorded contacts from the following categories and made calls.

SERA made over 60 calls, but could not find anyone willing to participate, and attribute the 100% non-participation rate to two main factors. First, contact names were not available for this sample, and many may have thought we were telemarketers and terminated the interview. Second, SERA mostly contacted retailers busy with customers, so they neither had the time nor desire to participate.

After the unsuccessful round of initial calls, the team considered other approaches. Summit Blue staff investigated other sample sources, and located two additional sources. The first was a list of Missouri energy auditors, provided by Ameren, and the second was a website for Energy-efficient Homes Midwest (eehmidwest.org), which provided a directory of auditors in the other states. Although the initial target audience was a broad survey of energy professionals in the Midwest, including auditors, SERA found that only calls to auditors were productive in yielding completed surveys—subsequently, all responses obtained are from energy raters or auditors. This selection may have introduced some bias into these results – although the auditors with whom we spoke worked in a wide variety of single family and multifamily homes, both new and old, there is the potential that the specific areas in which energy auditors are likely to be knowledgeable differs systematically from those of other energy professionals. As such, results from this survey should be regarded as primarily energy auditor perspectives on energy conservation potential.[35]

After making several calls to the auditors on the lists provided by Summit Blue, SERA searched the web for additional lists of energy auditors in Kentucky, Ohio, Missouri, Michigan and Indiana, and found several additional sources, including:

- The Energy and Environmental Ratings Alliance (ratingsalliance.org)
- The National Energy Raters Association (energyraters.org)
- The Indoor Environmental Standards Organization (iestandards.org)
- The National Conservation Guild (www.nationalguild.com/Contacts/inaud.html)

These new contact sources were not as productive as those previously provided by Summit Blue. They contained many wrong or outdated phone numbers as well as contacts that were not knowledgeable about household energy efficiency. One particular problem with sources from these lists was that a given contact's primary profession was not always conducive to producing accurate estimates of what percentage of homes have equipment at specific efficiency levels. For example, one contact remodeled houses for a living and, as a result, had little experience with direct observation of heating equipment and

[35] In practice, this bias is not unique to our adapted sampling strategy. The initial sample plan was simply to contact energy professionals to avert the costs associated with a detailed household survey.

appliances. In discussions with interviewees, it became apparent that energy auditing was not a primary profession for many certified energy auditors but an ancillary qualification.

In summary, the first group of 60 provided no responses. A total of 150 sample points were then gathered from the follow-up approaches, and 28 surveys were completed, or a 19% response rate The survey team made at least 5 calls to each sample point.

3.3 Characterize DSM Measures

Characterization of DSM measures requires 1) determining the list of DSM measures to evaluate, 2) estimating the baseline energy consumption for each end-use (heating, cooling, cooking, hot water, *etc*.) or unit energy consumption (UEC) and 3) estimating the incremental savings from each measure - improving from the baseline to the new technology(ies). In addition, the baselines must consider that different classes of homes have different penetrations of technologies, such as existing homes compared to new construction.

The project team first drew up a list of prospective measures from past experience and added to and subtracted from that list as necessary for the project. Additions included new technologies or improvements to existing technologies, subtractions included measures that were made obsolete by shifting baselines. The goal was a comprehensive list of DSM measures applied in different segments of the residential market: new versus existing construction and single-family versus multi-family housing.

Once identified, the project team determined which measures would have a significant climate-dependent savings component. Those measures that were determined to be climate-*independent* (lighting, appliances, and domestic hot water) were characterized using engineering calculations and assumptions for energy savings. Climate-dependent measures (HVAC equipment, insulation, air-sealing etc) were simulated with a computer model to determine savings.

3.3.1 Climate-Independent End-Uses

Climate-independent end-uses are described in many resources, including: the US Department of Energy, EnergyStar Program[36], the California Database of Energy-efficient Resources[37], various utility on-line audit services and manufacturer data. These resources were particularly useful for appliances. Other end-uses were analyzed using engineering principles such as steady-state heat loss, rated power and hours of operation.

A combination of resources was used to produce consensus unit energy consumption (UECs) for the end-uses for both 1) the stock equipment, e.g. that equipment currently employed in the housing stock and 2) the standard equipment, e.g. that equipment that is the current off-the-shelf replacement. Existing homes are more likely to have stock equipment and new homes would use standard equipment.

3.3.2 Climate-Dependent End-Uses

Climate-*dependent* DSM end-uses were modeled using Energy-10 software, an hourly simulation tool designed specifically for small commercial and residential structures. The project team made 18 baseline models reflecting typical constructions of three building types: new single-family homes, existing single family homes, and multi-family construction; three climate zones: temperate (Louisville, KY), cold

[36] http://www.energystar.gov/

[37] http://www.energy.ca.gov/deer/

(Chicago, IL) and very cold (Minneapolis, MN), as well as two heating sources: natural gas heat and electric heat.

Model input parameters, such as building size, installed equipment type and age and insulation levels, were based on survey results and building code (new construction) information. The models were then calibrated to produce energy consumption that corresponded to published consumption for the respective states and/or climate zones.

The results of the baseline simulations were used to populate unit energy consumption (UEC) for source of heat (electric furnace, heat pump, electric room heat and gas heat) and air-conditioning (central or room). The UECs described both the *stock* consumption, e.g. the consumption of the average installed end-use, and the *standard* consumption of the same end-use if it were installed today, e.g. reflecting current efficiency standards.

3.3.3 Climate-Independent Measures

Using the same techniques and sources as for the climate-independent end-uses, the project team estimated savings for the list of conservation measures (generated in step 1). The absolute savings (kWh, Therms) were transformed to a percentage of the total UEC for the affected end-use.

For climate-independent measures, multiple measures were often ascribed to each end-use, e.g. low-flow showerheads, faucet aerators, and new water heaters could be applied to the domestic hot water end-use. Uniform savings estimates were used across all climate zones though they might vary according to construction type, e.g., single- family versus multi-family or new homes versus existing construction.

3.3.4 Climate-Dependent Measures

Similarly, the project team estimated the savings from climate-dependent measures using the same calibrated simulation models used to estimate the UECs for climate-dependent end-uses. Savings for climate dependent measures were estimated for each of the three climate zones considered. Again, absolute savings for each measure was transformed to a percentage of the total end-use UEC.

For climate-dependent measures, multiple measures were often ascribed to each end-use, e.g. furnaces of varying efficiency or type could be applied to the heating end-use. Some measures could impact multiple end-uses, such as high-efficiency windows affect heating and cooling end-uses. Separate savings estimates were simulated for each of the three climate zones and each construction type.

3.3.5 Measure Costs and Lifetimes

The project team has determined that there is general uniformity of measure cost and lifetimes across the geography considered in this study. Variations in costs exist for certain higher cost measures such as HVAC equipment and insulation where labor costs factor in more heavily. Measure cost estimates for these measures were weighted by factors contained in industry sources such as the RS Means Mechanical Cost Data.

The project team estimated measure lifetimes from a combination of resources including: manufacturer data, typical economic depreciation assumptions, the California DEER database, various studies reviewed for this report and survey responses from residential customers interviewed for this assessment.

3.4 Estimate technical, economic, and market DSM potential.

The general approach for derivation of energy efficiency resource potentials consisted of three sequential steps: (1) estimate technical energy efficiency potential, (2) subdivide the technical energy efficiency potential estimates into discrete "bundles" based on cost category, which allows the economic potential to move with the underlying volatility in fuel prices, and (3) estimate market penetration and the resulting achievable potential as a subset of each bundle.

All of these estimates were derived using Quantec's Energy ForecastPro model, an end-use forecasting and energy efficiency potentials assessment tool. The conceptual underpinnings and analytic procedures of this model are based on standard practices in the utility industry, and are consistent with the methods used in the Xcel energy and Iowa studies referenced above.

Each set of potential estimates (technical, economic, and achievable) is derived as follows:

1. Produce base case end use energy forecasts of loads over a 20-year planning horizon for each state building type and vintage, calibrating total residential electric and gas usage by climate zone to actual residential energy sales as estimated by the Energy Information Administration.[38]

2. Develop a second forecast incorporating the current saturations, DSM measures' applicability and expected penetration, and energy saving impacts of all commercially available energy efficiency measures, and

3. Determine the potential estimates by subtracting the second forecast from the base case forecast.

3.4.1 Technical energy efficiency potential

The technical potential scenario assumes 100% market penetration of energy efficiency measures over the forecast horizon. For each end-use, such as air conditioners, heat pumps, and furnaces, the technical potential scenario modifies the base case efficiency shares by assigning a 100% market share to the most efficient equipment level.

Energy ForecastPro then modifies equipment energy usage given the upgrade in the efficiency of the end-use equipment. Classic examples of this are insulation, windows, duct sealing, showerheads, and lighting retrofits. The accurate assessment of retrofit savings also requires the characterization of physical applicability factors, and the percentage of applicable shares where the measure has yet to be installed. The basic retrofit equation is

$$SAVE_{ijcfm} = EUI_{ijcf} \times PCTSAV_{ijcfm} \times APPFACTOR_{ijcfm} \times INCFACTOR_{ijcfm},$$

where

[38] The base case provides an estimate of future energy consumption in the absence of new energy efficiency programs. It establishes a benchmark against which the impacts of technical and achievable energy efficiency potentials can be assessed. The effects of equipment standards and naturally occurring efficiency improvements, which emanate from the reduction of usage as low-efficiency equipment is retired, are also taken into account in the base case forecast.

$SAVE_{ijcfm}$ = annual energy savings for measure m for end-use j in climate zone c for dwelling type i using fuel f.

EUI_{ijcf} = calibrated annual end-use energy consumption for the equipment configuration ijcf.

$PCTSAV_{ijcfm}$ = is the percentage savings of measure m relative to the base usage for the equipment configuration ijcf, taking into account measure interactions such as lighting and HVAC.

$APPFACTORi_{jcfm}$ = is the fraction of households that is applicable to install measure m. For "non-competing" measures, which are primarily non-lighting, this estimate is generally close to 100%, with lesser amounts due to engineering limitations (for example, the share of buildings with enough room in the wall cavities to install additional insulation). For competing measures within an end use, such as various types of lighting retrofits, this factor is used to represent the share of the end use associated with the measure.

$INCFACTOR_{ijcfm}$ = fraction of the applicable end-use / households that has not yet been converted to measure m.

3.4.2 Measure Stacking and Interaction Effects

Measure stacking effects occur as a result of sequential ordering of complementary retrofit measures such as when wall, ceiling, and floor insulation are applied to a single end use. Since measure savings are always calculated in terms of reductions in end use consumption, clearly installation of one measure will reduce the savings potentials of subsequent measures. To incorporate stacking effects it is therefore necessary to establish a rolling, reduced baseline as each new measure is added. This is shown in the equations below, where measures 1, 2, and 3 are applied to end use if:

$$SAVE_{ijcf1} = EUI_{ijcf} \times PCTSAV_{ijcf1} \times APPFACTOR_{ijcf1} \times INCFACTOR_{ijcf1}$$

$$SAVE_{ijcf2} = (EUI_{ijcf} - SAVE_{ijcf1}) \times PCTSAV_{ijcf2} \times APPFACTOR_{ijcf2} \times INCFACTOR_{ijcf2}$$

$$SAVE_{ijcf3} = (EUI_{ijcf} - SAVE_{ijcf1} - SAVE_{ijcf2}) \times PCTSAV_{ijcf3} \times APPFACTOR_{ijcf3} \times INCFACTOR_{ijcf3}$$

A similar interaction effect occurs when equipment replacement measures and retrofit measures apply to the same end use. If retrofit opportunities are captured first, replacement of existing equipment with high-efficiency equipment can be expected to have a smaller impact on EUI than it would have had the replacement taken place first. Clearly, the ordering of retrofit measures and retrofit versus replacement decisions depend on practical considerations concerning energy efficiency program design and implementation. For the purposes of this study, it was assumed that measures with the highest savings opportunities would be implemented first and retrofits will always precede equipment replacement.

3.4.3 Economic Energy Efficiency Potential

The economic potential studies referenced previously in this chapter reflect total resource cost (TRC) based economic criteria. In the TRC approach, measure benefits are obtained by multiplying savings by the avoided costs of generation, transmission and distribution, discounted back to the present, and the result is compared to the installed measure's cost. TRC-based economic screening process – where measures are eliminated if the benefit-cost ratio is less than 1.0 – is dependent on utility-specific avoided costs.

This screening approach does not work as well when avoided costs are uncertain, or vary widely over a region as is the case with MEEA. An alternative method of capturing measure economics, and ultimately

economic potential, is to use the levelized cost of each measure. Levelized costs are traditionally used by regionally planning organizations to provide a broad comparison of energy efficiency resources to supply resources.[39] It is important to recognize that levelized costs themselves do not represent cost-effectiveness criteria, and are not the same as total resource costs. They represent the cost of energy efficiency in terms of a level payment, similar to a mortgage payment. They do not include generation, transmission or distribution costs, or quantifiable non-energy benefits such as operation and maintenance savings attributable to energy efficiency measures. When combined with the size of the resource (kWh or therms saved), the levelized costs effectively represented the "supply curve" of energy efficiency resources.[40]

The first step in this process is to calculate each measure's levelized cost, which reflects the cost per kWh saved over its lifetime, subject to a discount rate (usually a utility's cost of capital). The formula is as follows:

$$LevelizedCost = InstalledCost / \sum_{l=1}^{L} SAVE/(1+DiscountRate)**l$$

where the denominator is the total savings of the measure over its lifetime (l), discounted back to the present. Suppose for example, a measure costs $50, and will save 100 kWh per year over a 10 year life. If the discount rate is 7.5%, the net present amount of the lifetime savings is 686 kWh. We then divide the installed cost of $50 by 686 to yield the levelized cost of $0.073. Each kWh saved over the lifetime of the measure costs 7.3 cents.

The next step is to aggregate measure savings potential into logical groups or bundles, and associated cost points. This grouping exercise is important in fully integrated resource planning because individual measure savings are generally not large enough to weigh against supply-side alternatives. The idea is to give the measures enough critical mass so that they can be selected by the resource planning model.[41]

For MEEA, the categories (bundles) in the table below are illustrative of the types of thresholds that can be employed using levelized costs. As one move up the ladder from cost group A to E, it is less likely that the measures contained therein would be cost-effective in a utility resource plan.

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[39] See, for example, The Fifth Northwest Electric Power and Conservation Plan, Northwest Power and Conservation Council (NWPCC), May 2005, http://www.nwcouncil.org/energy/powerplan/default.htm.

[40] Some utilities are also using the supply curve (cost category) approach in integrated resource planning. In this approach, the economic potential is a subset of the achievable potential, with the economically viable amount of DSM resources selected as part of the integrated planning process. Put differently, the avoided costs are an *output* rather than input in the process. This approach also follows utility industry risk management approaches, allowing multi-attribute selection criteria to be employed. A resource with less cost volatility may be selected over a more cost volatile resource even when their expected costs are identical. For an example of the use of this fully integrated demand and supply-side resource selection approach, see Puget Sound Energy's 2005 Least Cost Plan, http://www.pse.com/about/supply/LCP/20050503.

[41] For example, in the previously referenced Puget Sound Energy plan, the DSM measures were grouped by sector, building type, end-use, and vintage – across retrofit and replacement categories – to give the planning model a sense of possible DSM program activity should the resource block be selected.

Table 3-2. Electric and Gas Measure Categories and Levelized Cost Thresholds

Category or Bundle	Electric Measure Levelized Cost Thresholds	Gas Measure Levelized Cost Thresholds
Cost Level A	≤ $0.03/kWh	≤ $0.30/Therm
Cost Level B	$0.03 to $0.06/kWh	$0.30 to $0.60/Therm
Cost Level C	$0.06 to $0.10/kWh	$0.60 to $1.00/Therm
Cost Level D	$0.10 to $0.15/kWh	$1.00 to $1.50/Therm
Cost Level E	> $0.15/kWh	> $1.50/Therm

In this breakout, measures in category A are cost-effective with any fuel price forecast, even one with natural gas prices returning to $3/MMbtu. Conversely, measures in Categories D and E are unlikely to be cost-effective, unless the recent energy industry price shocks continue unabated and natural gas rises to$20/MMbtu or more. The great uncertainty, therefore, is associated with categories B and C.[42]

3.4.4 Achievable Potential

The next step is to apply market penetration rates to the technical potential estimates within each cost category to obtain to obtain achievable potential. A variety of factors affect market penetration of energy efficiency measures, including inherent market barriers resulting from customers' tendency to avoid administrative and financial burdens, program marketing strategies, and delivery mechanisms. This is why some energy efficiency programs, even with full incremental cost incentives, can have a wide range of penetration rates, seldom achieving full market saturation. The available information suggests that, although incentive levels do play a significant role in determining program success, other, non-financial factors may play an equal, if not more important, role.

In estimating market potential, we apply what some industry analysts call the "experiential approach", where the maximum achievable penetration rate is based on the penetration rates achieved from similar utility energy efficiency programs.[43] The following penetration rates were applied to the technical potential estimates in each state to obtain maximum achievable potential:[44]

- Gas new construction: 50%

[42] The key to developing categories in an actual resource planning application is to discern categories that would also always be selected, such as A, and categories that would never be selected, such as E, and then iteratively focus on the middle categories within the resource planning model to discern the appropriate assessment threshold(s).

[43] There was a great deal of research conducted on DSM market penetration rates in the mid-1990s. Interestingly, with the new era of post-2000 utility programs, there has yet to be a comprehensive assessment of market penetration rates that looks beyond simple payback relationships. That is, we are not aware of any recent studies that look at all program design elements, including incentives. Most of the maximum achievable penetration rates applied here are derived from a 1995 multi-client study conducted by Barakat and Chamberlin, Inc., Market Penetration of DSM Programs: The Effects of Price and Nonprice Program Features. We note that the incentives in the "best" programs (in terms of market penetration) approached 100% of incremental measure cost, a level that is far higher than has historically been applied in Iowa, Minnesota, and most other mid-western states.

[44] For comparison purposes, see Chapter 3 of The Fifth Northwest Electric Power and Conservation Plan. The NWPPC has always assumed that 85% of the cost-effective conservation potential can be accomplished over the course of 20 years, where the cost-effective threshold is variable and follows the levelized cost approach described above.

- Electric new construction: 50% except for lighting measures, which are set equal to 25%
- Gas and electric equipment replacement, existing construction: 60%
- Existing construction retrofit: 50%, except lighting, which is set equal to 30%

4. MARKET RESEARCH RESULTS

This chapter discusses the results of the market research that was conducted for this project, as well as the results of previous market assessments or DSM potential studies from four Midwestern states. Three original market research studies were conducted for this project:

1. Surveys of 40 utilities, state and municipal energy offices across all nine Midwestern states.

2. Residential appliance saturation surveys with 480 residential customers in the five Midwestern States that had not previously conducted market assessments or DSM potential studies that are publicly available.

3. Surveys of energy auditors in the same five Midwestern states.

4.1 Results from Interviews with Midwest Energy Organizations

4.1.1 Introduction

The project team surveyed forty Midwest energy organizations by telephone regarding their residential EE programs and any previous residential market assessments studies they might have conducted. The organizations interviewed included representatives from electric and gas investor-owned utilities, larger municipal and cooperative utilities, cooperative and municipal utility associations, and state or municipal energy and regulatory agencies.

The purpose of these interviews was to determine:

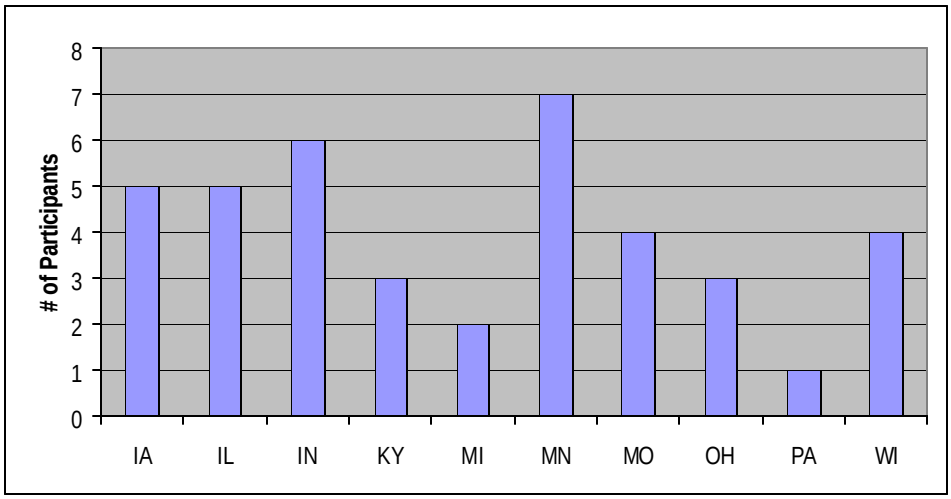
- The existence of already completed residential market assessment studies, or primary data on residential customers that they have collected that they would be willing to share for this study, such as utility residential appliance saturation surveys (RASS) or billing data for customers who are part of the primary data collection effort.

- Their willingness to fund either primary on-site data collection or RASS research for samples of about 100 to 300 of their customers.

- Their current DSM programs and details on such, especially ENERGY STAR® programs.

The respondent distribution by state is shown in Figure 4-1.

Figure 4-1. Survey Respondents



4.1.2 Current Residential Energy Efficiency Programs

Twenty-seven of the 40 organizations are currently conducting residential EE programs in the Midwest and half of respondents have more than one type of program currently in place. Table 4-1 documents the number of energy organizations with common program types.

Table 4-1. Residential Program Offerings

Residential EE Program Type	Number of Organizations with Programs
Rebate programs	13
RCS style energy audits	11
Direct load control	9
Other information programs	7
Web-based energy audits	7
Low-income	8
Financing programs	4
Other	3
Additional Load Management	0
Multi-family	2

Rebate programs were the most common type of residential energy efficiency program, with most of the programs covering multiple technologies including:

- Space heating equipment – furnaces and heat pumps (including geothermal systems)
- Cooling equipment
- Water heating equipment
- Lighting – both bulbs and fixtures

- Appliances (e.g., ENERGY STAR® clothes washers)
- Comprehensive new construction

4.1.3 Previous Residential Market Assessment Research

Nineteen of the organizations surveyed have previously conducted market assessment research on residential customers of various types. Table 4-2 lists the types of research reported and the number of organizations that have conducted them. Four of the 15 organizations surveyed have conducted multiple types of research projects.

Table 4-2. Market Research Efforts

Research Type	Number of Organizations Conducting Research
Broad Based Market Assessment	1
DSM Potential Studies	6
Appliance Saturation Survey	9
Other Market Assessment Research	3

Although many market studies have been completed, only seven of the 19 organizations that responded thought their study results were publicly available. All others were unsure (4) or knew the reports were confidential (8). The status of information availability is listed in Table 4-3.

Table 4-3. Information Availability

Research Availability	Number of Utilities Responding
Publicly Available	7
Unsure	4
Not Publicly Available	5
Confidential	3
Total	**19**

The only four studies that were comprehensive enough and allowed sufficient analysis of the underlying data for the purposes of this study were those discussed in the Methodology section. These studies covered Illinois, Iowa, Minnesota and Wisconsin.

4.1.4 Interest in Study

All the energy organizations were either unsure or knew that their company would not be willing to release a representative sample of 100-200 residential customer billing histories for this project, as shown in Table 4-4. Significant follow-up with the initially unsure organizations did not locate any willing to release such data for this project, so that aspect of the project plan could not be implemented.

Table 4-4. Willingness to Share Customer Data

Willing to release customer data for study?	Number of Utilities Responding
Yes	0
Unsure	31
No	9
Total	**40**

Similarly, only one respondent was willing to fund increased surveys of residential customers to oversample in their service area, as shown in Table 4-5. The rest were either unsure or unwilling. Significant follow up and proposal developments with the initially unsure organizations did not locate any organizations willing to fund such work as part of this project. The one organization that expressed interest in doing so is conducting an independent study.

Table 4-5. Interest in Oversampling

Interested in funding surveys?	Number of Respondents
Yes	1
Unsure	25
No	14
Total	**40**

Interest in participating in future market assessment research for commercial and industrial customers received a similarly uncertain or negative response, as shown in Table 4-6. Only two organizations were definitely interested, 33 were unsure, and the rest were not interested.

Table 4-6. Interest in Future Commercial and Industrial Market Assessment

Interested in future C&I?	Number of Respondents
Yes	2
Unsure	33
No	5
Total	**40**

4.2 Data Sources

As discussed in the Methodology section, residential market assessments have been conducted in the last few years for four Midwest states – Illinois, Wisconsin, Minnesota, and Iowa. Four different organizations produced four different reports for somewhat different purposes, which resulted in somewhat different data being gathered, computed, and reported for each state. Fortunately, comparable data were compiled on many key statistics, which allows for some insightful comparisons between states. Much of these data are presented and discussed in this chapter.

Also, as discussed in the Methodology section, the project team conducted primary research on residential customers in five additional Midwest states – Indiana, Kentucky, Michigan, Missouri, and Ohio – where previous publicly available broad based market assessments had not recently been conducted. The project team conducted detailed telephone residential appliance saturation surveys (RASS), and separate telephone surveys of energy auditors familiar with residential construction and equipment use. While these surveys collected similar but somewhat different data than the four residential market assessments mentioned above, their results allow for comparisons of certain key efficiency indicators across the entire nine-state region.

The type(s) of residential customers surveyed or audited, and the basis for the study's market assessments are summarized here for each state:

- Illinois – on-site surveys conducted for single-family homes, detached only.
- Wisconsin – on-site surveys of owner-occupied single-family homes, attached and detached.
- Minnesota – on-site surveys of single-family homes, individual apartment units, and mobile homes.
- Iowa – distributor surveys of equipment efficiencies. The entire residential segment was assessed.
- Indiana, Kentucky, Michigan, Missouri, and Ohio – the two surveys characterized a cross-section of the entire residential market, including new and existing homes, single-family and multi-family dwellings, and both all-electric and natural gas customers.

4.3 Comparative Customer Demographic and Energy Use Statistics

In this and the next three sections, we present data compiled from the four residential market assessment studies, and the surveys covering the five additional states, as introduced above. The accompanying tables organize data for comparisons between states. For many of the statistics discussed below, there is some variability between what each study reports. Also there are several statistics that lack data entirely in one or more studies. As a result, meaningful comparisons are difficult to draw for some statistics.

4.3.1 Electricity and Natural Gas Use

The market assessment studies for Illinois and Wisconsin (broken down by home type) contained data on residential customer energy use from the on-site audits, and similar data were available from a supplementary database for Minnesota. No energy consumption data were included as part of the Iowa study, however, nor as part of the surveys of Indiana, Kentucky, Michigan, Missouri, and Ohio. Hence, only EIA data[45] are presented in Table 4-7, showing a simple average of residential electricity and natural gas consumption for customers in each state. The electric data in Table 4-7 was calculated, from utility-by-utility EIA data, from the largest utilities in each state, while the gas data was calculated from state-by-state production and consumption data.

[45] Energy Information Administration, *Electric Sales and Revenue 2003 Spreadsheets*, www.eia.doe.gov/cneaf/electricity/esr/esr_tabs.html; and Energy Information Administration, *Summary Statistics for (individual state)*, www.eia.doe.gov/oil_gas/natural_gas/data_publications/natural_gas_annual/nga.html.

Overall average annual electrical use appears to correlate most strongly with electric space heating and water heating saturations, as will be shown later in this chapter. The four states with the lowest overall annual electric use, Michigan, Minnesota, Illinois, and Wisconsin, also have the lowest electric space heating saturations, as well as the lowest electric water heating saturations. Conversely, the three states with the highest average annual electrical use, Missouri, Indiana, and Kentucky, have the highest penetrations of electric space heating and water heating systems. Since space heating and water heating systems are usually the largest energy using systems in residences, these results are not surprising.

Overall average annual natural gas use appears to be a bit more complicated to explain, varying with the saturations of gas space heating and water heating systems, as well as climate and gas space heating efficiencies. Illinois residents use the most natural gas of any state in the region, and the saturations of gas space heating and water heating systems in Illinois are also the highest in the region. Missouri residents use the least amount of natural gas of any state in the region, which appears to be a function of its second lowest saturations of gas space heating and water heating systems, as well as having the most southern climate in the region.

Table 4-7. Average Annual Residential Energy Use

	Electricity (kWh)	Natural Gas (therms)
Michigan	7,907	1,266
Minnesota	8,169	1,087
Illinois	8,336	1,318
Wisconsin	8,593	950
Iowa	9,243	917
Ohio	11,112	1,096
Missouri	11,930	879
Indiana	12,120	986
Kentucky	12,893	1,124

4.3.2 Customer Income

The Illinois and Minnesota studies report stratified customer income information, and similar information was as part of the RASS surveys of customers in Indiana, Kentucky, Michigan, Missouri, and Ohio. The customer income data is presented in Table 4-8. In general, the household incomes in the five states surveyed by telephone were significantly lower than in Illinois and Minnesota. Half or more of the customers surveyed in Indiana, Kentucky, Michigan, Missouri, and Ohio reported incomes less than $40,000, while only about one-third of the customers audited in Illinois and Minnesota did so. This discrepancy could simply be due to sampling differences between customers who agreed to be audited in Illinois and Minnesota compared to the simpler telephone interviews in the other five states.

Table 4-8. Total Household Income

	Illinois	Minnesota	Indiana	Kentucky	Michigan	Missouri	Ohio
Under $20,000	6%	13%	22%	22%	24%	10%	22%
$20,000 - $40,000	22%	23%	29%	34%	26%	40%	32%
$40,000 - $60,000	24%	21%	22%	13%	24%	20%	25%
$60,000 - $80,000	17%	18%	9%	9%	9%	17%	11%
$80,000 - $120,000	22%	16%	15%	18%	10%	8%	8%
Over $120,000	9%	9%	3%	4%	7%	5%	2%

4.4 Housing Characteristics

4.4.1 Housing Unit Types and Sizes

Almost all of the studies report information on housing type and size. These data are presented in Tables 4-9 and 4-10. As seen in Table 4-9, all of the samples consisted predominantly of one- and two-story single-family detached homes. Some states' data includes a sizeable proportion of multi-family and/or mobile homes, as well – most notably Minnesota, Michigan, Ohio, and Kentucky.

Table 4-9. Housing Type and Number of Floors and Bedrooms

	Illinois	Wisconsin	Minnesota	Indiana	Kentucky	Michigan	Missouri	Ohio
Housing Type								
Detached, single-family	100%	100%	64%	84%	78%	75%	81%	74%
Attached, single-family	0%		12%	5%	6%	3%	3%	6%
Multi-family	0%	0%	22%	8%	4%	16%	11%	16%
Attached townhouse	0%	0%	- - -	- - -	- - -	- - -	- - -	- - -
Manufactured/mobile home	0%	3%	2%	3%	12%	6%	5%	4%
Number of Floors								
One	47%	46%	44%					
Two	51%	- - -	48%					
Three	2%	- - -	6%					
Four or more	- - -	- - -	2%					
Multi-story	- - -	45%	- - -					
Bi/Tri-level	- - -	5%	- - -					
Number of Bedrooms								
One			11%	3%	4%	6%	3%	3%
Two			28%	23%	19%	23%	23%	23%
Three			39%	54%	49%	48%	54%	54%
Four			15%	17%	21%	21%	17%	17%
Five or more			7%	3%	7%	2%	3%	3%

In Table 4-10, we see that the Minnesota study surveyed a larger proportion (50%) of homes less than 1,400 sq.ft. in size, than did the other studies – probably due to the inclusion of more townhouses and multi-family homes than were part of the samples for the other states. The Michigan sample contained the second largest proportion (43%) of smaller homes. The Kentucky sample contained the largest proportion (28%) of homes that are 2,500 sq.ft. or larger.

Table 4-10. Housing Size (Total Conditioned Square Footage)

	Illinois	Wisconsin	Minnesota	Indiana	Kentucky	Michigan	Missouri	Ohio
less than 1,400	35%	39%	50%	18%	23%	43%	21%	28%
1,400 to 2,499	48%	51%	36%	61%	49%	49%	56%	53%
2,500 to 3,499	12%	8%	11%	15%	21%	5%	15%	14%
more than 3,500	5%	2%	3%	6%	7%	3%	8%	5%
Mean (ft^2)	1,800	1,632	1,605	2,047	2,094	1,674	2,065	1,935
Median (ft^2)	1,660	1,502	1,392					

4.4.2 Insulation Levels

The Illinois, Wisconsin, and Minnesota studies report information on the insulation found in the homes audited for these studies. Data on the percentage of homes found with insulation in their walls and roof are presented in Table 4-11, along with similar data collected in the telephone surveys of customers in Indiana, Kentucky, Michigan, Missouri, and Ohio.

It should be understood that the data presented in Table 4-11 for Indiana, Kentucky, Michigan, Missouri, and Ohio, is based on homeowners' responses to telephone questions. In each of the five states, at least 85-90% of these homeowners believe that their homes have insulation in the walls and roof. However, when experienced residential energy auditors were interviewed in each state, they estimated a significantly higher percentage of uninsulated walls and roofs – approximately 30% for the five-state region. It is likely that the auditors are more correct, since their opinions are based on many on-site observations of residential insulation in their areas. Homeowners are sometimes unaware that their walls or roofs are uninsulated. Therefore the data for Indiana, Kentucky, Michigan, Missouri, and Ohio in Table 4-11 are maybe overestimated.

From Table 4-11, it appears that Indiana, Ohio, and especially Illinois, have higher percentages of homes without wall insulation than the other Midwest states. All nine states are remarkably comparable regarding roof insulation however, with approximately 90 to 95 percent of homes having at least some roof insulation.

Table 4-11. Wall and Roof Insulation

	% of homes with insulated walls	% of homes with insulated roof
Illinois	73%	91%
Wisconsin	89%	>95%
Minnesota	90%	89%
Indiana	86%	93%
Kentucky	92%	89%
Michigan	90%	94%
Missouri	95%	97%
Ohio	86%	90%

As a note, in the course of their on-site home visits, the energy auditors for the Minnesota study indicated that only 14% of the insulated areas they observed was feasibly accessible for retrofits.

4.4.3 Windows

Information collected by on-site audits and by telephone surveys on the type and efficiency of residential windows is presented in Table 4-12. Homes in Minnesota and Ohio have the highest percentages of double or triple-paned windows, at 80% and 78% respectively. The Illinois residential population may have the least efficient windows of these eight states, as they have the largest percentage of single-pane windows and the smallest percentage of storm windows of the states assessed. Ohio also has relatively few storm windows, but this may in part be due to having more triple-pane windows than every other state except Kentucky.

It should be understood that the window efficiencies listed at the bottom of Table 4-12 were estimated by energy auditors in Indiana, Kentucky, Michigan, Missouri, and Ohio, but were interpreted from on-site audit data for Wisconsin and Minnesota. These differences in data sources may explain the significant disparities in efficiency estimates between the two groups of states.

Table 4-12. Type and Efficiency of Windows

	Illinois	Wisconsin	Minnesota	Indiana	Kentucky	Michigan	Missouri	Ohio
Homes with DSM measures								
% of windows with storm windows	36%	54%		48%	42%	43%	54%	38%
Window Glass (% of windows)								
Single Pane	36%	35%	20%	26%	25%	24%	26%	22%
Double Pane	63%	64%	78%	66%	60%	68%	63%	63%
Triple Pane	1%	1%	2%	8%	15%	8%	12%	15%
Window Efficiency								
Low		85%	97%	39%	39%	39%	39%	39%
Medium				39%	39%	39%	39%	39%
Optimal		15%	3%	22%	22%	22%	22%	22%
Qualitative Assessment of Relative Efficiency				Average	Higher than Average	Average	Lower than Average	Average

4.5 Lighting, HVAC, and Appliance DSM Measure Saturations

All of the studies reported information on the penetration of energy-efficient appliances, compact fluorescent lamps, and other DSM measures. As with other statistics, there is variability in the exact data that was reported. The Illinois, Wisconsin, and Minnesota information was gathered during their on-site audits, while the information from Iowa came from their survey of equipment distributors, and the Indiana, Kentucky, Michigan, Missouri, and Ohio information was either self-reported by residential customers, or estimated by local energy auditors, in telephone surveys.

4.5.1 Lighting

As seen in Table 4-13, compact fluorescent lamps are still somewhat uncommon in residential light fixtures. Only in Kentucky and Missouri are CFL's found in more than one-third of homes. Illinois and Wisconsin appear to have the lowest percentage of homes with compact fluorescents. For Wisconsin, this is likely due to the older vintage of that study, for which the on-site data was collected in 1999.

Tubular fluorescent lamps are quite common in residences in the Midwest, however, with 42% to 78% of homes having at least one such fixture. The saturations of tubular fluorescent lamps is highest in Illinois and Minnesota, with 78% and 60% of homes respectively having at least one tubular fluorescent fixture.

Table 4-13. Penetration of Energy-Efficient Lighting

	Illinois	Wisconsin	Minnesota	Indiana	Kentucky	Michigan	Missouri	Ohio
Homes with at least one CFL	23%	13%	33%	33%	43%	32%	39%	34%
Homes with fluorescent tubes	78%		60%	50%	53%	42%	43%	50%
No. CFLs in household (if any)								
1 – 2		98%	54%	30%	32%	42%	18%	27%
3 – 6		2%	24%	39%	41%	36%	36%	36%
More than six		0%	22%	31%	27%	22%	46%	37%

4.5.2 HVAC

Data from all four previously conducted studies and the five-state RASS surveys on HVAC equipment are presented in Tables 4-14 and 4-15. The saturations of different types of HVAC equipment vary considerably by state, and some of this variation is explained by the varying compositions of customer types surveyed or audited in each state.

As shown in Table 4-14, the saturations of natural gas space heating systems vary considerably across the Midwest, from a low of 46% in Kentucky to 92% and 97% in Wisconsin and Illinois respectively. In Kentucky, only 48% of the customers surveyed report that they have natural gas service to their homes, compared to an average of 66% of customers across the five states covered by the RASS surveys.

The market shares of efficient gas space heating systems are the highest in Iowa, Minnesota and Wisconsin at 74%, 67% and 50% respectively. The high percentages of efficient furnaces in these states is presumably due to the effects of long-standing DSM programs promoting this technology in these states. For Indiana, Kentucky, Michigan, Missouri, and Ohio, energy auditors estimate the shares of more efficient gas furnaces at 23% on average, but slightly higher in Missouri.

The saturations of heat pumps throughout the Midwest are quite low, ranging from 1% in Illinois, Michigan and Wisconsin up to a high of 8% in Kentucky. The saturations of efficient heat pumps is estimated to be the highest in Iowa at 74%, compared to an average of 25% for the five state group of Indiana, Kentucky, Michigan, Missouri and Ohio, but slightly higher in Missouri.

The saturations of regular electric space heating systems vary considerably across the Midwest, from lows of 2% in Illinois, 4% in Minnesota, 5% in Wisconsin, and 7% in Michigan to highs of 20% to 22% in Kentucky and Missouri.

The highest saturations for central air conditioners are shown to be in Illinois (90%), Missouri (85%), and Kentucky (76%). Missouri and Kentucky are the most southern states included in this study, so one would expect their air conditioning saturations to be among the highest of the states studied. The high saturation for Illinois is partly explained by the fact that only single-family homes were studied in that state, and such homes usually have higher central air conditioning saturations than apartments do. For example, in Minnesota the saturation of central air conditioners in single family homes is 65%, compared to 18% in multi-family dwellings.

The highest percentages of more efficient central air conditioners are found in Iowa (74% total) and Minnesota (48% total). The high penetrations of efficient central air conditioners in these areas are presumably due to the effects of Iowa and Minnesota utilities promotion of this measure through their DSM programs. Xcel Energy in Minnesota has covered efficient central air conditioners in their DSM programs for 25 years.

These percentages are much higher than the 24% market share estimated by energy auditors for efficient air conditioners in Indiana, Kentucky, Michigan, Missouri, and Ohio, or the 6% market share found from the on-site audits in Wisconsin. However, the Wisconsin data is the oldest of that included in this report, so the efficient units' market shares may have increased there since 1999. The RASS survey results shown for the five state region (Indiana through Ohio) at the top of Table 4-15 show that residential customers estimate the percentages of their central air conditioners that are ENERGY STAR® units as far higher than the corresponding efficient units' market shares estimated by the energy auditors. The energy auditors' estimates are likely more accurate, as they have more knowledge about central air conditioners efficiency than most residential customers do.

The highest saturation of room air conditioners is found in Minnesota at 28% for all residential customers, considerably higher than the next highest saturations found in Wisconsin at 20% saturation, and Indiana at 19% saturation. Minnesota's relatively high saturation is likely due to the large share of multi-family homes in its customer sample. The penetration of efficient room air conditioners is estimated to be relatively low across the Midwest at 16%-25% market shares.

Table 4-14. Space Heating Efficiency

	Illinois	Wisconsin	Minnesota	Iowa	Indiana	Kentucky	Michigan	Missouri	Ohio
Homes with DSM measures									
Programmable Thermostat	47%	35%	27%		17%	19%	29%	31%	26%
Heating Duct Insulation		4%	8%		63%	72%	54%	70%	63%
Gas-Fired Space Heat Efficiency									
Overall Saturation	97%	92%	83%		65%	46%	73%	62%	64%
Minimum		50%	33%	27%	77%	77%	77%	77%	77%
High		47%	27%	64%	21%	21%	21%	21%	21%
Higher		3%	40%	10%	2%	2%	2%	2%	2%
Qual. Assessment of Relative Eff.					Average	Average	Average	Higher than Average	Average
Heat Pumps Efficiency									
Overall Saturation	1%	1%	3%		5%	8%	1%	4%	2%
Minimum				27%	74%	74%	74%	74%	74%
High				64%	23%	23%	23%	23%	23%
Higher					2%	2%	2%	2%	2%
Premium				10%	<1%	<1%	<1%	<1%	<1%
Qual. Assessment of Relative Eff.					Average	Average	Average	Higher than Average	Average
Other Electric Heating									
Central Systems Saturation	2%	1%	1%		5%	18%	4%	19%	7%
Other Primary Heating Systems Saturation	0%	2%	3%		11%	2%	3%	3%	6%

Table 4-15. Space Cooling Efficiency

	Illinois	Wisconsin	Minnesota	Iowa	Indiana	Kentucky	Michigan	Missouri	Ohio
Homes with DSM measures									
ENERGY STAR® Central AC			10%		29%	46%	19%	35%	38%
ENERGY STAR® Room AC			2%		40%	67%	36%	38%	30%
Central Air Conditioning Efficiency									
Overall Saturation	90%	51%	54%		66%	76%	60%	85%	62%
Minimum (10 SEER)		94%	52%	27%	75%	75%	75%	75%	75%
High (12 SEER)		6%	32%	64%	21%	21%	21%	21%	21%
Higher (About 13 SEER)		0%	13%		3%	3%	3%	3%	3%
Premium (About 14 SEER)		0%	3%	10%	<1%	<1%	<1%	<1%	<1%
Qual. Assessment of Relative Eff.					Average	Average	Lower than Average	Higher than Average	Average
Room Air Conditioning Efficiency									
Overall Saturation	5%	20%	28%		19%	15%	11%	8%	15%
Minimum		84%		83%	63%	63%	63%	63%	63%
High		16%		17%	25%	25%	25%	25%	25%
Other (lower than minimum)					13%	13%	13%	13%	13%
Qual. Assessment of Relative Eff.					Average	Average	Lower than Average	Higher than Average	Average

4.5.3 Water Heating

As seen in Table 4-16, Kentucky is the only Midwestern state with a majority of electric water heaters, as 61% of its units are heated with electricity. This is likely due to the 48% availability of natural gas service in Kentucky, as discussed in the previous section. Illinois and Minnesota have the lowest saturations of electric water heaters in the Midwest, at 4% and 13% respectively.

Midwest electric water heaters are mainly minimum efficiency units, with low efficiency units' market shares ranging from 66% to 87%. The percentage of more efficient electric units is estimated to be highest in the five states of Indiana, Kentucky, Michigan, Missouri, and Ohio, at an average of 30%, and slightly higher than the 30% average in Indiana and Kentucky.

Illinois and Minnesota have the largest market shares of natural gas water heaters at 96% and 83% saturations respectively. Kentucky and Missouri have the smallest market shares of gas water heaters at 36% and 52% respectively.

As with electric water heaters, Midwestern natural gas water heaters are mainly minimum efficiency models, which have market shares of 63%-83%. The percentage of more efficient gas units is estimated to be highest in the five state Indiana to Ohio region at an average of 38%, and slightly higher than 38% in Kentucky.

As with air conditioning equipment, residents of the five states of Indiana, Kentucky, Michigan, Missouri, and Ohio estimate the percentages of their water heaters that are ENERGY STAR® units as higher than similar estimates by energy auditors in those states. In contrast, though efficiency estimates were not made for Minnesota, only 1% of the water heaters were found to be ENERGY STAR® during the onsite audits conducted by trained energy auditors. Given the source for this estimate, it is likely the most accurate of these estimates for the penetration of efficient water heaters throughout the Midwest, and the other estimates for the penetrations for efficient water heaters are likely overstated.

Michigan and Indiana residents report having installed the most low-cost water heater efficiency measures – pipe insulation, tanks wraps, low-flow showerheads, and faucet aerators – while Illinois and Minnesota residents appear to have installed the fewest of these types of DSM measures.

Table 4-16. Water Heating Efficiency

	Illinois	Wisconsin	Minnesota	Iowa	Indiana	Kentucky	Michigan	Missouri	Ohio
Electric Water Heaters									
Overall Saturation	4%	28%	13%		39%	61%	27%	41%	28%
Minimum Efficiency Units		87%		83%	66%	66%	66%	66%	66%
High Efficiency Units		7%		13%	26%	26%	26%	26%	26%
Highest Efficiency Units		6%		5%	4%	4%	4%	4%	4%
Other (lower than minimum)					5%	5%	5%	5%	5%
Qual. Assessment of Relative Eff.					Higher than Average	Higher than Average	Lower than Average	Lower than Average	Average
Natural Gas Water Heat									
Overall Saturation	96%	62%	83%		55%	36%	68%	52%	64%
Minimum Efficiency Units		82%		83%	63%	63%	63%	63%	63%
High Efficiency Units		15%		13%	28%	28%	28%	28%	28%
Highest Efficiency Units		3%		5%	10%	10%	10%	10%	10%
Qual. Assessment of Relative Eff.					Lower than Average	Higher than Average	Average	Average	Average
Homes with DSM measures									
Pipe Insulation	10%		12%		19%	15%	31%	19%	12%
Hot Water Tank Wrap	7%	11%	6%		26%	15%	17%	10%	12%
Water Heater Timer					3%	6%	6%	7%	5%
Low Flow Showerhead	29%	51%			66%	60%	68%	61%	60%
ENERGY STAR® Water Heater			1%		44%	57%	40%	50%	40%

4.5.4 Appliances

Refrigerator and freezer data are presented in Table 4-17. Residents of Indiana, Michigan and Ohio have the highest percentages of just one refrigerator in their homes at 82%-85% of all homes surveyed respectively. Kentucky and Missouri have the highest percentages of homes with two or three refrigerators, at 34% and 27% respectively. The saturations of stand alone freezers vary from 40%-43% in Ohio and Minnesota respectively to 60% in Wisconsin.

The energy auditors surveyed in Indiana, Kentucky, Michigan, Missouri, and Ohio report saturations of efficient refrigerators in the region at 31% and efficient freezers at 18%. These estimates are quite close to the percentages of these appliances that residents of these states report as being ENERGY STAR® units: they report that 26% of their refrigerators are ENERGY STAR® units, and 18% of their freezers are ENERGY STAR® units. However, these estimates may all be too high, as the energy auditors that conducted the on-site surveys in Illinois and Minnesota found only 5% and 3% ENERGY STAR® refrigerators, respectively.

Data on kitchen stoves, ovens, dishwashers, and microwave ovens is presented in Table 4-18. The majority of Midwestern stoves use electricity as the heating fuel. Electric stoves have market shares ranging from a low of 48% in Michigan to 83% in Kentucky. Natural gas stoves have market shares ranging from a low of 15% in Kentucky to 44% in Michigan. Midwestern ovens have similar market shares to those of stoves. Electric ovens have market shares ranging from a low of 49% in Michigan to 85% in Kentucky. Natural gas ovens have market shares ranging from a low of 11% in Kentucky to a high of 40% in Michigan.

The energy auditors surveyed in Indiana, Kentucky, Michigan, Missouri, and Ohio report average saturations of efficient electric ovens in the region at 19% and efficient gas ovens at 22%. These estimates are quite similar to these states' residents estimates that 25% of their ovens are ENERGY STAR® units.

The saturations of dishwashers throughout the Midwest varies from lows of 54%-57% in Ohio and Kentucky respectively to highs of 71%-77% in Missouri, Minnesota, and Illinois. Estimates of the percentages of ENERGY STAR® dishwashers made by residents vary from lows of 31% in Indiana and Ohio to highs of 46%-47% in Missouri and Kentucky respectively. However, these estimates may be considerably overstated, as the energy auditors who conducted the Illinois and Minnesota on-site surveys estimated that only 4% of dishwashers in those states were ENERGY STAR® units. Since no known Midwest organizations are conducting DSM programs promoting ENERGY STAR® dishwashers, it is unlikely that the market shares of ENERGY STAR® units could vary by a factor of ten from state to state in the Midwest.

The saturations of microwave ovens are quite high for the five state region from Indiana to Ohio, varying only from a low of 92% in Ohio to 100% in Indiana. Residents of those states estimated the saturations of ENERGY STAR® units as varying from lows of 16% to 18% in Michigan and Ohio to a high of 30% in Kentucky.

Data on clothes washers and dryers are presented in Table 4-19. The saturations of clothes washers where such data was collected varies from 80% in Minnesota to 98% in Illinois and Wisconsin. The saturation of ENERGY STAR® clothes washers as estimated by the energy auditors during the on-site surveys in Illinois and Minnesota was 5%-6% respectively.

Most Midwestern clothes dryers use electricity as the heating fuel, except in Minnesota and Michigan. The market share of electric clothes dryers varies from lows of 34%-43 in those two states respectively to

highs of 79%-89% in Indiana and Kentucky respectively. The market shares of natural gas fired clothes dryers varies from lows of 6% in Kentucky to highs of 43%-44% in Minnesota and Michigan respectively.

Energy auditors estimate that the average share of efficient electric clothes dryers is 8% in Indiana, Kentucky, Michigan, Missouri, and Ohio, while their estimate of the share of efficient natural gas clothes dryers is considerably larger at 26%. Residents estimate that the percentage of dryers that are ENERGY STAR® units in these states is considerably larger than the auditors, varying from 32% in Ohio to 49% in Missouri.

Table 4-17. Refrigerators and Freezers

	Illinois	Wisconsin	Minnesota	Indiana	Kentucky	Michigan	Missouri	Ohio
Number of refrigerators								
One	75%	78%	76%	82%	66%	82%	73%	85%
Two	25%	22%	20%	18%	30%	18%	23%	13%
Three or More	0%	0%	3%	0%	4%	0%	4%	2%
Overall Saturation								
Stand-alone Freezers		60%	43%	51%	52%	45%	46%	40%
% ENERGY STAR®								
Refrigerator	5%		3%	25%	37%	16%	27%	23%
Stand-alone Freezer			0%	7%	24%	18%	22%	19%
Refrigerator Efficiency								
Minimum				69%	69%	69%	69%	69%
High				31%	31%	31%	31%	31%
Qual. Assessment of Relative Eff.				Average	Average	Average	Lower than Average	Higher than Average
Freezer Efficiency								
Minimum				82%	82%	82%	82%	82%
High				18%	18%	18%	18%	18%
Qual. Assessment of Relative Eff.				Average	Average	Lower than Average	Average	Higher than Average

Table 4-18. Kitchen Appliances

	Illinois	Wisconsin	Minnesota	Indiana	Kentucky	Michigan	Missouri	Ohio
Overall Saturation								
Electric Stove		61%	61%	63%	83%	48%	62%	66%
Natural Gas Stove		27%	37%	35%	15%	44%	32%	31%
Electric Oven		67%	66%	66%	85%	49%	72%	67%
Natural Gas Oven		27%	35%	32%	11%	40%	24%	27%
Dishwasher	77%	64%	72%	60%	57%	62%	71%	54%
Microwave Oven				100%	96%	98%	96%	92%
% ENERGY STAR®								
Stove				33%	33%	23%	34%	31%
Oven				26%	24%	22%	27%	26%
Dishwasher	4%		4%	31%	47%	37%	46%	31%
Microwave Oven				22%	30%	16%	22%	18%
Electric Oven Efficiency								
Minimum				81%	81%	81%	81%	81%
High				19%	19%	19%	19%	19%
Qual. Assessment of Relative Eff.				Lower than Average	Average	Average	Average	Higher than Average
Natural Gas Oven Efficiency								
Minimum				78%	78%	78%	78%	78%
High				22%	22%	22%	22%	22%
Qual. Assessment of Relative Eff.				Lower than Average	Average	Higher than Average	Lower than Average	Average

Table 4-19. Clothes Washers & Dryers

	Illinois	Wisconsin	Minnesota	Indiana	Kentucky	Michigan	Missouri	Ohio
Overall Saturation								
Clothes Washer	98%	98%	80%					
Electric Clothes Dryer	98%	73%	34%	79%	89%	43%	73%	68%
Natural Gas Clothes Dryer		23%	43%	13%	6%	44%	16%	21%
% ENERGY STAR®								
Clothes Washer	5%		6%					
Clothes Dryer	0%		3%	38%	36%	39%	49%	32%
Electric Dryer Efficiency								
Minimum				94%	94%	94%	94%	94%
High				8%	8%	8%	8%	8%
Qual. Assessment of Relative Eff.				Average	Average	Average	Average	Average
Gas-Fired Dryer Efficiency								
Minimum				74%	74%	74%	74%	74%
High				26%	26%	26%	26%	26%
Qual. Assessment of Relative Eff.				Lower than Average	Average	Average	Average	Average

4.6 Customer Awareness of Energy Efficiency

The RASS survey of residential homeowners in Indiana, Kentucky, Michigan, Missouri, and Ohio assessed customer awareness of the ENERGY STAR® label. Similarly, homeowners receiving the energy audits in Illinois and Minnesota were asked a few questions about the ENERGY STAR® label, as well. All of this data is presented in Table 4-20. Only the Minnesota study gathered any data on familiarity (including current usage) with efficient equipment in general, however.

Over half of the residential customers, in every state surveyed, reported being entirely unfamiliar with the ENERGY STAR® label. The percentages of customers who are somewhat or very familiar with the ENERGY STAR® label vary from lows of 31%-37% in Minnesota and Illinois to a high of 47%-48% of customers in Kentucky and Indiana.

Table 4-20. Customer Awareness of Energy Efficiency Measures

Awareness of ENERGY STAR® label	Illinois	Minnesota	Indiana	Kentucky	Michigan	Missouri	Ohio
Very Familiar	6%	19%	16%	20%	12%	13%	18%
Somewhat Familiar	31%	12%	32%	27%	28%	29%	23%
Not at all Familiar	63%	69%	52%	53%	60%	58%	59%

5. DSM POTENTIAL RESULTS

This section contains the results of the technical, economic, and achievable residential energy efficiency potentials in the nine-state area addressed by MEEA in this study.

As noted in the Methodology section, it is important to recognize that the estimates of achievable potential represent an upper limit or maximum as to what the programs could achieve if there were no restrictions on the incentive budgets up to full incremental cost rebates. However, most energy efficiency programs pay less than full incremental cost rebates to mitigate rate impacts of programs, and to ensure that the customer contribution is a fair one.

The results below provide both total and state specific results. Results are presented first for natural gas, followed by electric savings. The results are first summarized by cost category for both technical and achievable potential for the region in terms of aggregate savings in year twenty after 20 years of resource acquisition (participation).

Individual measure savings are then reported in aggregate by building type (single- and multi-family) and vintage (existing and new construction) for the nine-state region based on the tables in Appendix A, which detail measures ordered by the magnitude of savings within a cost category.[46] Note that some measures in the tables have savings that vary by climate zone / state, which means the regional total tables may contain a measure multiple times. Finally, a series of pie charts describe the aggregate breakouts by end-use, state, market, and dwelling type. The formula used to calculate levelized cost is as follows:

$$LevelizedCost = InstalledCost / \sum_{l=1}^{L} SAVE/(1+DiscountRate)**l$$

where the denominator is the total savings of the measure over its lifetime (l), discounted back to the present. Suppose for example, a measure costs $50, and will save 100 kWh per year over a 10 year life. If the discount rate is 7.5%, the net present amount of the lifetime savings is 686 kWh. We then divide the installed cost of $50 by 686 to yield the levelized cost of $0.073. Each kWh saved over the lifetime of the measure costs 7.3 cents.

5.1 Natural Gas Potentials

Natural gas energy-efficiency technical potential in the residential sector is estimated at 9.2 billion therms across all states in the 20th year of a planning horizon (Table 5.1). This represents nearly 47% savings relative to the base case. Maximum achievable potential is estimated at approximately 5.0 billion therms, or approximately 54% of the technical potential. Approximately 12% (595 million therms) of the achievable potential can be achieved at an average cost of 30 cents per therm or less.

Maximum technical and achievable gas energy-efficiency potential in the 20th year of the planning horizon, broken out by cost category for the individual states can be found in Tables 5.2 – 5.10. The maximum achievable potential in the 20th year ranged from a minimum of 172 million therms in Kentucky to a maximum of 1.2 billion therms in Illinois. Not surprisingly, larger states like Illinois, Michigan and Ohio tend to have higher energy-efficiency potentials than smaller states like Kentucky and Missouri.

[46] Measure tables are contained in Appendix A.

Table 5-1. Distributions of Residential Sector Gas Energy Efficiency Potentials by Cost Category, All States

Cost Category ($ / therm)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	Therms	%	Therms	%
A: Less than $0.30 / therm	1,098,662,901	12%	595,481,781	12%
B: $0.30 to $0.60 / therm	355,167,822	4%	193,137,365	4%
C: $0.60 to $1.00 /therm	2,517,450,160	27%	1,370,449,435	27%
D: $1.00 to $1.50 / therm	2,220,705,808	24%	1,215,313,942	24%
E: Greater than $1.50 / therm	3,045,050,380	33%	1,627,708,218	33%
Total Savings in Year 20	9,237,037,070		5,002,090,742	
Base Case Consumption Year 20	19,818,558,874		19,818,558,874	
Percent of Base Case	46.6%		25.2%	

Table 5-2. Distributions of Residential Sector Gas Energy Efficiency Potentials by Cost Category, Illinois

Cost Category ($ / therm)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	Therms	%	Therms	%
A: Less than $0.30 / therm	272,045,533	12%	146,925,059	12%
B: $0.30 to $0.60 / therm	33,009,916	1%	17,937,179	1%
C: $0.60 to $1.00 /therm	739,129,830	32%	400,829,110	32%
D: $1.00 to $1.50 / therm	433,778,332	19%	237,593,785	19%
E: Greater than $1.50 / therm	821,964,425	36%	435,797,177	35%
Total Savings in Year 20	2,299,928,036		1,239,082,310	
Base Case Consumption Year 20	4,898,691,622		4,898,691,622	
Percent of Base Case	46.9%		25.3%	

Table 5-3. Distributions of Residential Sector Gas Energy Efficiency Potentials by Cost Category, Indiana

Cost Category ($ / therm)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	Therms	%	Therms	%
A: Less than $0.30 / therm	98,937,042	12%	53,827,967	12%
B: $0.30 to $0.60 / therm	75,469,319	9%	41,112,951	9%
C: $0.60 to $1.00 /therm	304,982,158	37%	167,195,691	38%
D: $1.00 to $1.50 / therm	159,130,439	20%	88,071,510	20%
E: Greater than $1.50 / therm	176,102,154	22%	93,781,670	21%
Total Savings in Year 20	814,621,113		443,989,790	
Base Case Consumption Year 20	1,696,998,544		1,696,998,544	
Percent of Base Case	48.0%		26.2%	

Table 5-4. Distributions of Residential Sector Gas Energy Efficiency Potentials by Cost Category, Iowa

Cost Category ($ / therm)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	Therms	%	Therms	%
A: Less than $0.30 / therm	46,549,681	12%	25,252,356	12%
B: $0.30 to $0.60 / therm	30,052,745	8%	16,251,015	8%
C: $0.60 to $1.00 /therm	143,529,328	38%	78,622,346	38%
D: $1.00 to $1.50 / therm	72,520,029	19%	40,024,585	19%
E: Greater than $1.50 / therm	89,453,943	23%	47,369,021	23%
Total Savings in Year 20	382,105,726		207,519,324	
Base Case Consumption Year 20	801,829,001		801,829,001	
Percent of Base Case	47.7%		25.9%	

Table 5-5. Distributions of Residential Sector Gas Energy Efficiency Potentials by Cost Category, Kentucky

Cost Category ($ / therm)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	Therms	%	Therms	%
A: Less than $0.30 / therm	33,945,808	11%	18,410,967	11%
B: $0.30 to $0.60 / therm	9,928,106	3%	5,496,859	3%
C: $0.60 to $1.00 /therm	122,940,070	39%	66,900,775	39%
D: $1.00 to $1.50 / therm	49,807,260	16%	27,092,006	16%
E: Greater than $1.50 / therm	101,292,309	32%	54,478,754	32%
Total Savings in Year 20	317,913,553		172,379,361	
Base Case Consumption Year 20	664,629,648		664,629,648	
Percent of Base Case	47.8%		25.9%	

Table 5-6. Distributions of Residential Sector Gas Energy Efficiency Potentials by Cost Category, Michigan

Cost Category ($ / therm)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	Therms	%	Therms	%
A: Less than $0.30 / therm	236,788,069	13%	129,114,488	13%
B: $0.30 to $0.60 / therm	54,320,743	3%	29,019,887	3%
C: $0.60 to $1.00 /therm	246,771,422	14%	134,980,842	14%
D: $1.00 to $1.50 / therm	610,261,569	34%	332,556,529	34%
E: Greater than $1.50 / therm	656,599,759	36%	354,922,049	36%
Total Savings in Year 20	1,804,741,562		980,593,795	
Base Case Consumption Year 20	3,984,404,136		3,984,404,136	
Percent of Base Case	45.3%		24.6%	

Table 5-7. Distributions of Residential Sector Gas Energy Efficiency Potentials by Cost Category, Minnesota

Cost Category ($ / therm)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	Therms	%	Therms	%
A: Less than $0.30 / therm	87,038,050	14%	46,807,982	14%
B: $0.30 to $0.60 / therm	19,782,826	3%	10,524,011	3%
C: $0.60 to $1.00 /therm	79,452,697	13%	42,919,653	13%
D: $1.00 to $1.50 / therm	187,009,799	30%	100,240,954	30%
E: Greater than $1.50 / therm	251,150,474	40%	133,100,741	40%
Total Savings in Year 20	624,433,846		333,593,341	
Base Case Consumption Year 20	1,420,350,670		1,420,350,670	
Percent of Base Case	44.0%		23.5%	

Table 5-8. Distributions of Residential Sector Gas Energy Efficiency Potentials by Cost Category, Missouri

Cost Category ($ / therm)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	Therms	%	Therms	%
A: Less than $0.30 / therm	30,490,536	5%	16,609,660	5%
B: $0.30 to $0.60 / therm	55,364,983	9%	30,339,312	9%
C: $0.60 to $1.00 /therm	63,719,462	10%	34,571,062	10%
D: $1.00 to $1.50 / therm	242,544,040	38%	133,063,463	39%
E: Greater than $1.50 / therm	240,652,083	38%	130,299,571	38%
Total Savings in Year 20	632,771,103		344,883,068	
Base Case Consumption Year 20	1,314,639,694		1,314,639,694	
Percent of Base Case	48.1%		26.2%	

Table 5-9. Distributions of Residential Sector Gas Energy Efficiency Potentials by Cost Category, Ohio

Cost Category ($ / therm)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	Therms	%	Therms	%
A: Less than $0.30 / therm	212,058,885	12%	114,564,251	12%
B: $0.30 to $0.60 / therm	38,412,539	2%	21,355,201	2%
C: $0.60 to $1.00 /therm	730,266,919	42%	397,275,419	43%
D: $1.00 to $1.50 / therm	275,076,283	16%	152,959,890	16%
E: Greater than $1.50 / therm	468,230,122	27%	248,588,743	27%
Total Savings in Year 20	1,724,044,747		934,743,504	
Base Case Consumption Year 20	3,616,664,889		3,616,664,889	
Percent of Base Case	47.7%		25.8%	

Table 5-10. Distributions of Residential Sector Gas Energy Efficiency Potentials by Cost Category, Wisconsin

Cost Category ($ / therm)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	Therms	%	Therms	%
A: Less than $0.30 / therm	80,809,296	13%	43,969,049	13%
B: $0.30 to $0.60 / therm	38,826,644	6%	21,100,950	6%
C: $0.60 to $1.00 /therm	86,658,275	14%	47,154,538	14%
D: $1.00 to $1.50 / therm	190,578,057	30%	103,711,220	30%
E: Greater than $1.50 / therm	239,605,111	38%	129,370,492	37%
Total Savings in Year 20	636,477,383		345,306,250	
Base Case Consumption Year 20	1,420,350,670		1,420,350,670	
Percent of Base Case	44.8%		24.3%	

Tables A-1 through A-5, in Appendix A, show the gas achievable potential breakouts and levelized costs by cost category and measure for single family existing construction, single family new construction, multifamily existing construction, and multifamily new construction across the 9-state region. Notice that the totals across these tables necessarily sum to the achievable potential column in Table 5-1.

As expected, retrofit space and water heating measures are dominant in natural gas cost categories A and B. For example, if a home has no attic insulation or poor thermostat control, it is not surprising that these measures provide the greatest savings within category A. Similarly, tried and true measures like low-flow showerheads, aerators, and pipe insulation – the heart of water heater retrofit programs nationwide – are in category A.

Interestingly, condensing furnaces with an efficiency factor (EF) of 96% or greater are incrementally more cost-effective than their 92% counterparts. This is due to the relatively low incremental cost per EF of furnaces between 92% and 96% (less than $150) vs. the incremental cost between 80% and 92% (approximately $1,100). A similar effect holds for high-efficiency water heaters, and suggests that programs with bonus or tiered incentives for higher efficiency levels make sense given the current incremental cost structure. All cooking and drying measures fall into cost categories D and E. Again, note that some measures in the tables appear more than once due to differences in levelized cost categorization across climate zones or states.

It is also important to recognize that the value of other resource savings – such as electricity (cooling) savings for building envelope measures, and electric dryer and water savings for clothes washers – are not considered in the levelized cost calculations for natural gas DSM measures. If a utility applies a TRC test that must consider benefits over all fuels (water), then a more comprehensive analysis is required.

As shown in Figure 5.1, expected savings in space heating is the largest component of the achievable gas energy efficiency potential in the residential sector, and accounts for 82% of the gas achievable potential. Retrofit measures to existing construction accounts for the largest share (48%) of achievable gas energy-efficiency potentials in the residential sector, with the installation of replacement measures in existing construction accounting for 24% of the potential. New construction accounts for the remaining 28% (Figure 5.2).

State-specific breakouts of achievable potential follow population patterns, with Illinois, Ohio, and Michigan constituting approximately 63% of the estimated savings, approximately consistent with those states' shares of the total Midwest population (Figure 5.3). Within all of the states, the achievable potential gas savings represent approximately 25% of the baseline usage, with little fluctuation from state to state (Figure 5.5).

Single-family dwellings account for the largest share (83%) of achievable gas energy-efficiency potentials in the residential sector. Multi-family dwellings account for 17% of the gas energy-efficiency potential in the residential sector (Figure 5.4).

Figure 5-1. Distribution of Residential Sector Achievable Gas Energy Efficiency Potential by End-Use

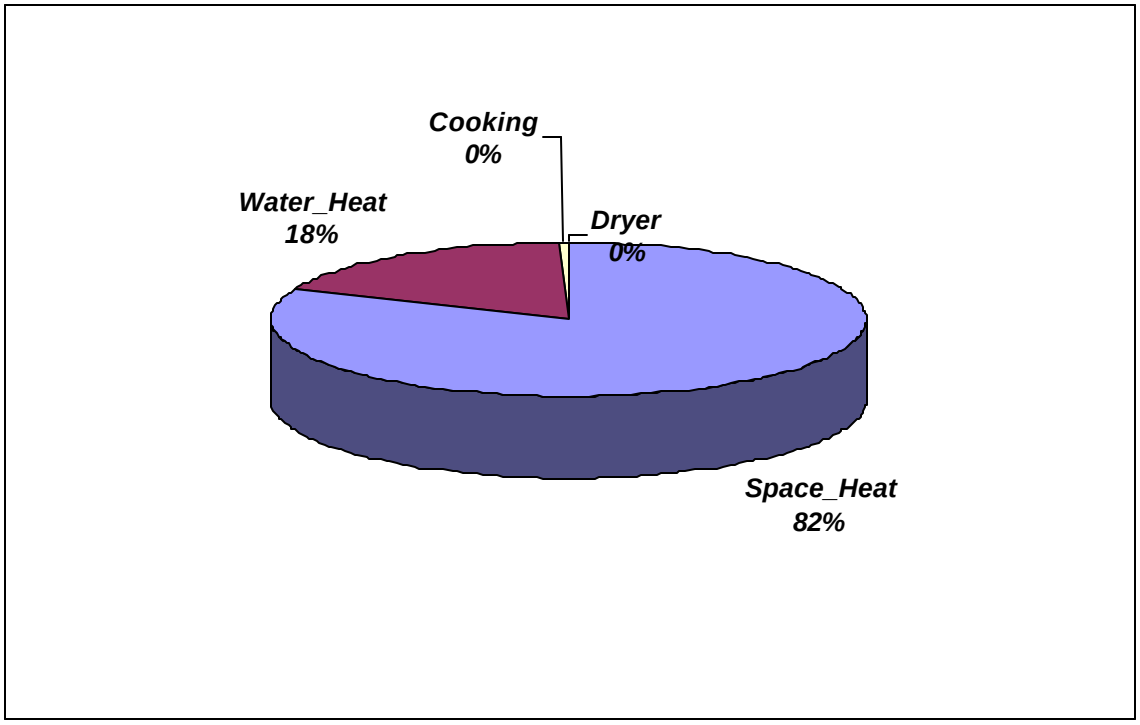


Figure 5-2. Distribution of Achievable Gas Energy Efficiency Potential by Market Type

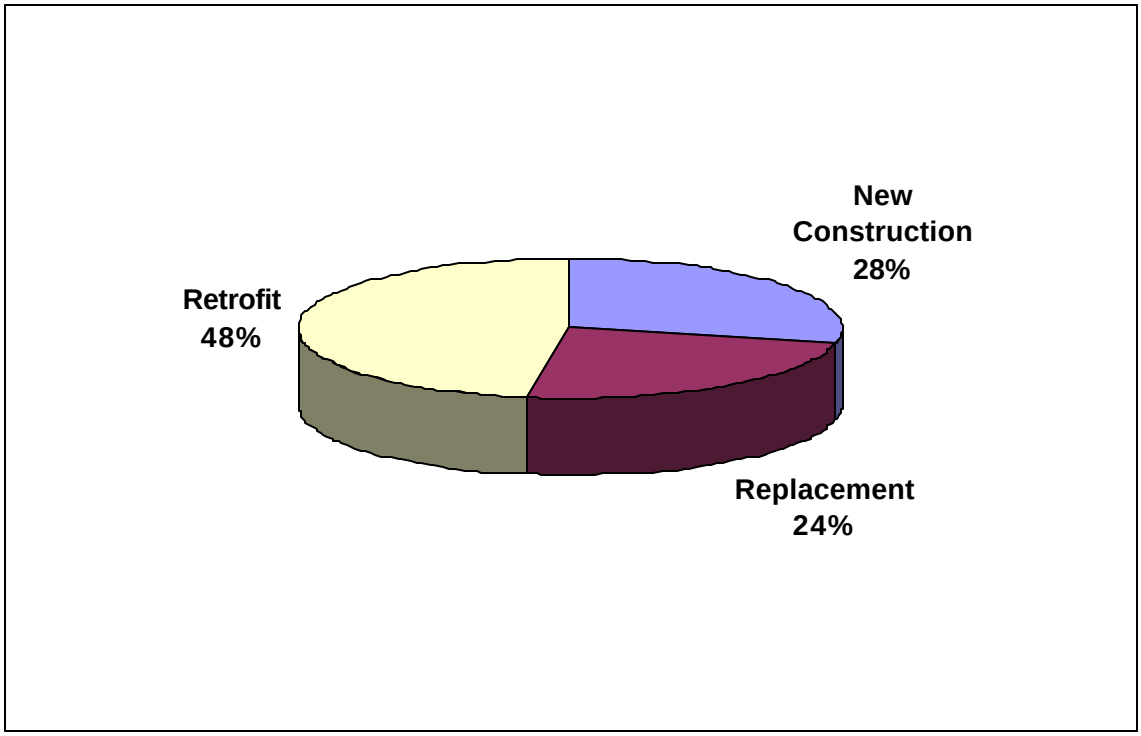


Figure 5-3. Distribution of Achievable Gas Energy Efficiency Potential by State

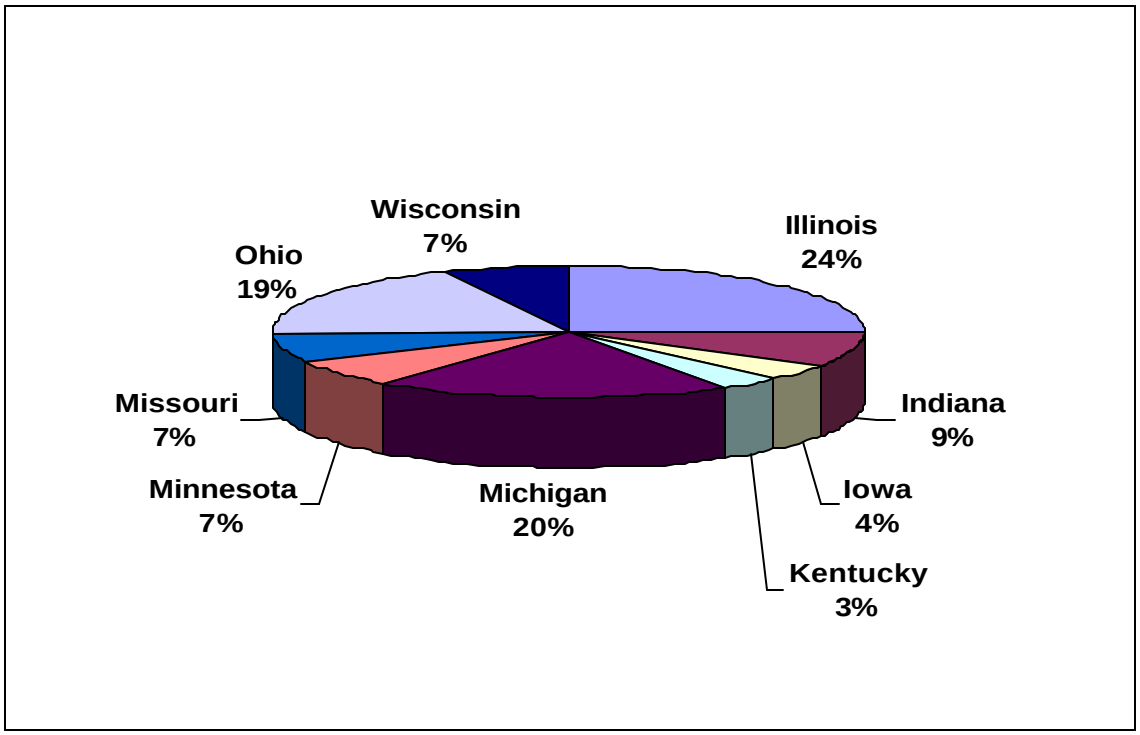


Figure 5-4. Distribution of Achievable Gas Energy Efficiency Potential by Dwelling Type

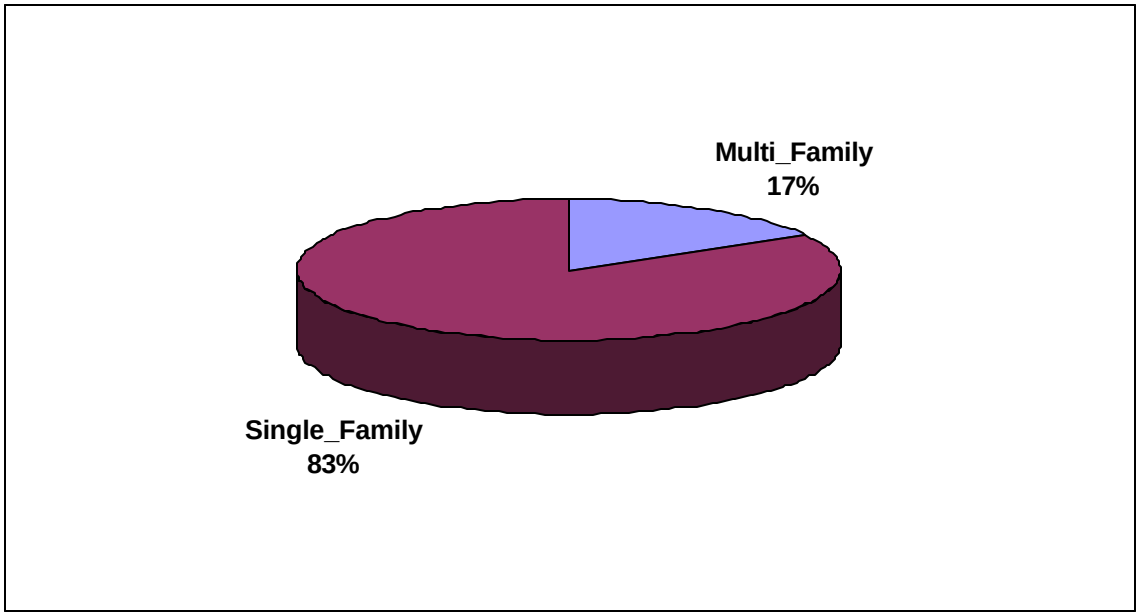
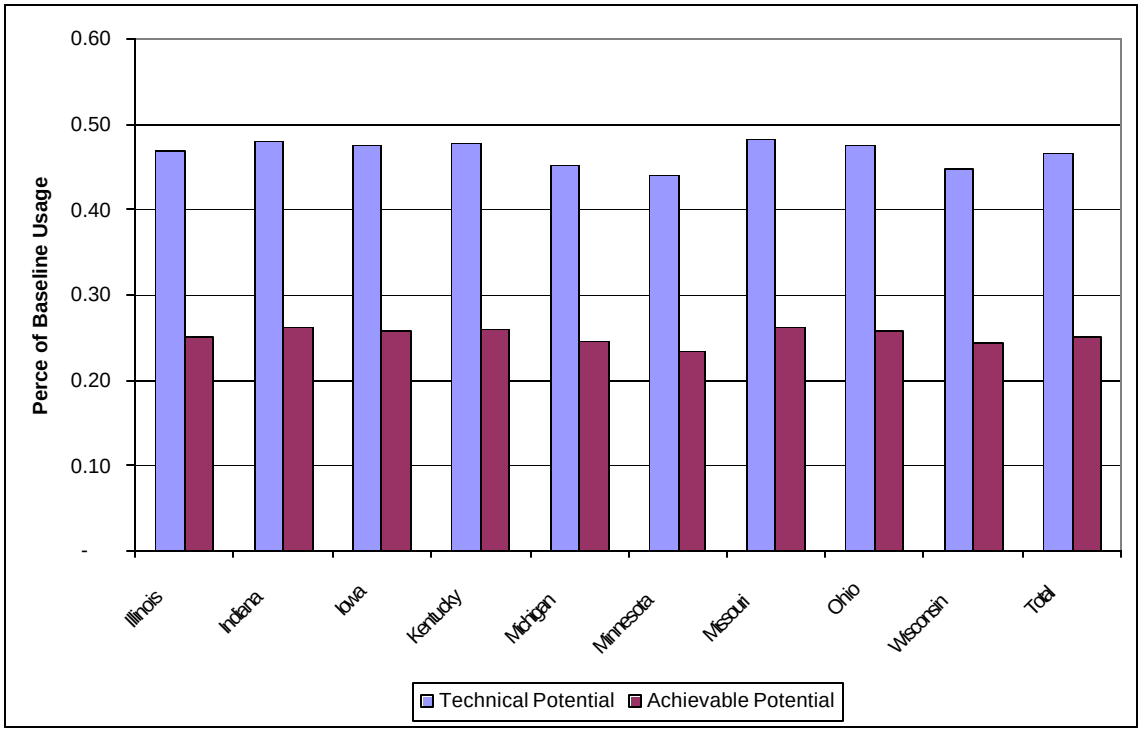


Figure 5-5: Technical and Achievable Gas Potential By State and Total as a Percent of the Baseline Usage



5.2 Electric Potentials

Electric energy-efficiency technical potential in the residential sector is estimated at 84 billion kWh across all states in the 20th year of a planning horizon (Table 5.11). This represents nearly 24% savings relative to the base case.

There are two primary reasons for the difference between the electric and gas potential estimates. First, there are new Heat Pump and Central AC standards effective as of 2006, which are captured in the baseline. Second, the majority of electric technical potential savings are in HVAC, Water Heating and Lighting (approximately 87% of savings), while the majority of gas technical potential savings are in Space Heating and Water Heating (99%). The electric savings represent 44% of the baseline consumption for these end uses, and the gas savings represent 47% of the baseline consumption for these end uses. So, the real difference is how much of average household energy usage is represented by these end uses. Space and Water Heating represent 98% of gas usage, while HVAC, Water Heating and Lighting only represent 48% of total electric usage.

Maximum achievable potential is estimated at approximately 37 billion kWh, or approximately 44% of the technical potential. Approximately 27% (9.8 billion kWh) of the achievable potential can be achieved at an average cost of 3 cents per kWh or less.

Maximum technical and achievable electric energy-efficiency potential in the 20th year of the planning horizon, broken out by cost category for the individual states can be found in Tables 5.12 – 5.20. The maximum achievable potential in the 20th year ranged from a minimum of 1.8 billion kWh in Iowa to a maximum of 6.6 billion kWh in Ohio.

Table 5-11.5-6. Distributions of Residential Sector Electric Energy Efficiency Potentials by Cost Category, All States

Cost Category ($ / kWh)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	kWh	%	kWh	%
A: Less than $0.03 / kWh	29,313,327,430	35%	9,820,443,518	27%
B: $0.03 to $0.06 / kWh	9,461,835,166	11%	4,223,090,826	12%
C: $0.06 to $0.10 /kWh	8,896,810,659	11%	4,508,486,582	12%
D: $0.10 to $0.15 / kWh	12,074,199,197	14%	5,719,974,229	16%
E: Greater than $0.15 / kWh	24,428,481,500	29%	12,445,357,065	34%
Total Savings in Year 20	84,174,653,951		36,717,352,221	
Base Case Consumption Year 20	357,228,735,736		357,228,735,736	
Percent of Base Case	23.6%		10.3%	

Table 5-12. Distributions of Residential Sector Electric Energy Efficiency Potentials by Cost Category, Illinois

Cost Category ($ / kWh)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	kWh	%	kWh	%
A: Less than $0.03 / kWh	5,139,493,249	41%	1,653,410,182	32%
B: $0.03 to $0.06 / kWh	1,181,046,524	10%	491,091,350	10%
C: $0.06 to $0.10 /kWh	789,152,082	6%	391,264,325	8%
D: $0.10 to $0.15 / kWh	1,335,075,056	11%	596,826,345	12%
E: Greater than $0.15 / kWh	3,985,783,621	32%	2,013,765,823	39%
Total Savings in Year 20	12,430,550,533		5,146,358,025	
Base Case Consumption Year 20	58,131,856,214		58,131,856,214	
Percent of Base Case	21.4%		8.9%	

Table 5-13. Distributions of Residential Sector Electric Energy Efficiency Potentials by Cost Category, Indiana

Cost Category ($ / kWh)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	kWh	%	kWh	%
A: Less than $0.03 / kWh	3,349,254,462	33%	1,144,342,637	26%
B: $0.03 to $0.06 / kWh	972,281,553	10%	429,385,094	10%
C: $0.06 to $0.10 /kWh	855,537,302	8%	437,564,369	10%
D: $0.10 to $0.15 / kWh	2,113,122,727	21%	1,024,035,531	23%
E: Greater than $0.15 / kWh	2,874,270,539	28%	1,431,319,457	32%
Total Savings in Year 20	10,164,466,583		4,466,647,087	
Base Case Consumption Year 20	40,895,246,529		40,895,246,529	
Percent of Base Case	24.9%		10.9%	

Table 5-14. Distributions of Residential Sector Electric Energy Efficiency Potentials by Cost Category, Iowa

Cost Category ($ / kWh)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	kWh	%	kWh	%
A: Less than $0.03 / kWh	1,547,167,966	37%	523,981,269	30%
B: $0.03 to $0.06 / kWh	402,432,826	10%	175,292,089	10%
C: $0.06 to $0.10 /kWh	385,247,500	9%	182,154,870	10%
D: $0.10 to $0.15 / kWh	704,086,274	17%	332,239,727	19%
E: Greater than $0.15 / kWh	1,125,151,973	27%	560,567,139	32%
Total Savings in Year 20	4,164,086,538		1,774,235,094	
Base Case Consumption Year 20	17,278,311,161		17,278,311,161	
Percent of Base Case	24.1%		10.3%	

Table 5-15. Distributions of Residential Sector Electric Energy Efficiency Potentials by Cost Category, Kentucky

Cost Category ($ / kWh)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	kWh	%	kWh	%
A: Less than $0.03 / kWh	2,397,270,570	24%	880,278,862	19%
B: $0.03 to $0.06 / kWh	1,224,533,284	12%	587,423,666	13%
C: $0.06 to $0.10 /kWh	2,321,333,291	23%	1,172,543,622	25%
D: $0.10 to $0.15 / kWh	1,079,011,574	11%	518,991,025	11%
E: Greater than $0.15 / kWh	2,947,374,864	30%	1,502,781,453	32%
Total Savings in Year 20	9,969,523,582		4,662,018,628	
Base Case Consumption Year 20	32,941,385,188		32,941,385,188	
Percent of Base Case	30.3%		14.2%	

Table 5-16. Distributions of Residential Sector Electric Energy Efficiency Potentials by Cost Category, Michigan

Cost Category ($ / kWh)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	kWh	%	kWh	%
A: Less than $0.03 / kWh	3,995,378,560	41%	1,375,800,654	32%
B: $0.03 to $0.06 / kWh	905,449,002	9%	387,746,379	9%
C: $0.06 to $0.10 /kWh	828,871,080	8%	437,212,005	10%
D: $0.10 to $0.15 / kWh	1,136,039,337	12%	534,540,223	12%
E: Greater than $0.15 / kWh	2,998,225,335	30%	1,562,724,228	36%
Total Savings in Year 20	9,863,963,313		4,298,023,490	
Base Case Consumption Year 20	44,905,538,379		44,905,538,379	
Percent of Base Case	22.0%		9.6%	

Table 5-17. Distributions of Residential Sector Electric Energy Efficiency Potentials by Cost Category, Minnesota

Cost Category ($ / kWh)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	kWh	%	kWh	%
A: Less than $0.03 / kWh	2,267,942,481	42%	734,493,040	33%
B: $0.03 to $0.06 / kWh	627,824,319	12%	270,780,329	12%
C: $0.06 to $0.10 /kWh	505,025,505	9%	251,469,070	11%
D: $0.10 to $0.15 / kWh	688,119,854	13%	312,260,053	14%
E: Greater than $0.15 / kWh	1,341,828,481	25%	672,963,590	30%
Total Savings in Year 20	5,430,740,641		2,241,966,081	
Base Case Consumption Year 20	26,966,953,863		26,966,953,863	
Percent of Base Case	20.1%		8.3%	

Table 5-18. Distributions of Residential Sector Electric Energy Efficiency Potentials by Cost Category, Missouri

Cost Category ($ / kWh)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	kWh	%	kWh	%
A: Less than $0.03 / kWh	2,550,028,237	23%	840,578,795	16%
B: $0.03 to $0.06 / kWh	2,245,325,850	20%	1,075,157,447	21%
C: $0.06 to $0.10 /kWh	1,732,042,004	15%	870,366,516	17%
D: $0.10 to $0.15 / kWh	1,577,509,350	14%	758,617,379	15%
E: Greater than $0.15 / kWh	3,134,222,017	28%	1,626,836,616	31%
Total Savings in Year 20	11,239,127,459		5,171,556,753	
Base Case Consumption Year 20	41,935,003,306		41,935,003,306	
Percent of Base Case	26.8%		12.3%	

Table 5-19. Distributions of Residential Sector Electric Energy Efficiency Potentials by Cost Category, Ohio

Cost Category ($ / kWh)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	kWh	%	kWh	%
A: Less than $0.03 / kWh	5,806,526,510	38%	1,949,650,844	29%
B: $0.03 to $0.06 / kWh	1,346,338,794	9%	573,679,414	9%
C: $0.06 to $0.10 /kWh	1,041,147,334	7%	537,064,897	8%
D: $0.10 to $0.15 / kWh	2,642,823,769	17%	1,272,552,220	19%
E: Greater than $0.15 / kWh	4,466,921,164	29%	2,289,724,614	35%
Total Savings in Year 20	15,303,757,571		6,622,671,989	
Base Case Consumption Year 20	65,792,417,180		65,792,417,180	
Percent of Base Case	23.3%		10.1%	

Table 5-20. Distributions of Residential Sector Electric Energy Efficiency Potentials by Cost Category, Wisconsin

Cost Category ($ / kWh)	Technical Potential in 20th Year		Achievable Potential in 20th Year	
	kWh	%	kWh	%
A: Less than $0.03 / kWh	2,260,265,394	15%	717,907,235	11%
B: $0.03 to $0.06 / kWh	556,603,013	4%	232,535,057	4%
C: $0.06 to $0.10 /kWh	438,454,560	3%	228,846,908	3%
D: $0.10 to $0.15 / kWh	798,411,257	5%	369,911,726	6%
E: Greater than $0.15 / kWh	1,554,703,508	10%	784,674,146	12%
Total Savings in Year 20	5,608,437,732		2,333,875,073	
Base Case Consumption Year 20	28,382,023,916		28,382,023,916	
Percent of Base Case	19.8%		8.2%	

Tables A-41 through A-44 in Appendix A show the electric achievable potential breakouts and levelized costs by cost category and measure for single family existing construction, single family new construction, multifamily existing construction, and multifamily new construction across the 9-state region. Again, the totals across these tables necessarily sum to the electric achievable potential column in Table 5-6.

The electric results by DSM measure are somewhat similar to the gas results. Retrofit space and water heating measures continue to be dominant if an existing home does not have insulation, or has old plumbing. As expected, lighting continues to appear cost-effective given recent CFL cost reductions. For example, in existing single family homes, savings from CFL technologies represent over 50% of the achievable potential in categories A and B – even with maximum achievable penetration rates that are about half of other end-uses.

The increase in air conditioning SEER to a national standard of 13 in 2006 has effectively reduced the potential for air conditioning and heat pump measures, and is the primary reason why the technical potential estimates reported here are somewhat less than earlier studies. While some high efficiency heat pumps (SEER 14) are in cost categories A-C, their central air conditioning counterparts are contained in cost categories D and E. Of course, most utilities and agencies are awaiting the actual implementation of the new standards to see what happens to incremental costs prior to changing existing incentive programs. Finally, again note that HVAC measures in the tables can appear more than once due to differences in levelized cost categorization across climate zones or states.

As with natural gas, the value of other resource savings – such as heating (natural gas) savings for some building envelope measures, and water savings for clothes washers, are not considered in the electric levelized cost calculations.

As shown in Figure 5.6, expected savings from space heating DSM measures (Central Heat, Room Heat and Heat Pumps) are the largest components of the achievable electric energy efficiency potential in the

residential sector across all cost categories, and account for 30% of the electric achievable potential. Expected savings in lighting (20%), water heating (20%), and central air conditioning (15%) provide a majority of the remaining savings. Retrofit measures to existing construction accounts for the largest share (62%) of achievable electric energy-efficiency potentials in the residential sector, with the installation of replacement measures in existing construction accounting for 13% of the potential. New construction accounts for the remaining 25% (Figure 5.7).

State-specific breakouts of achievable potential again approximately follow population patterns, with Illinois, Ohio, and Michigan constituting approximately 44% of the estimated savings (Figure 5.8). Additionally, those states further south (Missouri and Kentucky) constitute approximately 27% of the estimated savings due to higher saturations of electric HVAC and Water Heating equipment, and a lower incidence of DSM intervention programs The achievable potential electric savings, as a percent of the baseline usage, averages approximately 10% across states but there is more variation between states than was seen in the gas model. (Figure 5.10).

Single-family dwellings account for the largest share (80%) of achievable electric energy-efficiency potentials in the residential sector. Multi-family dwellings account for 20% of the electric energy-efficiency potential in the residential sector (Figure 5.9).

Figure 5-6. Distribution of Residential Sector Achievable Electric Energy Efficiency Potential by End-Use

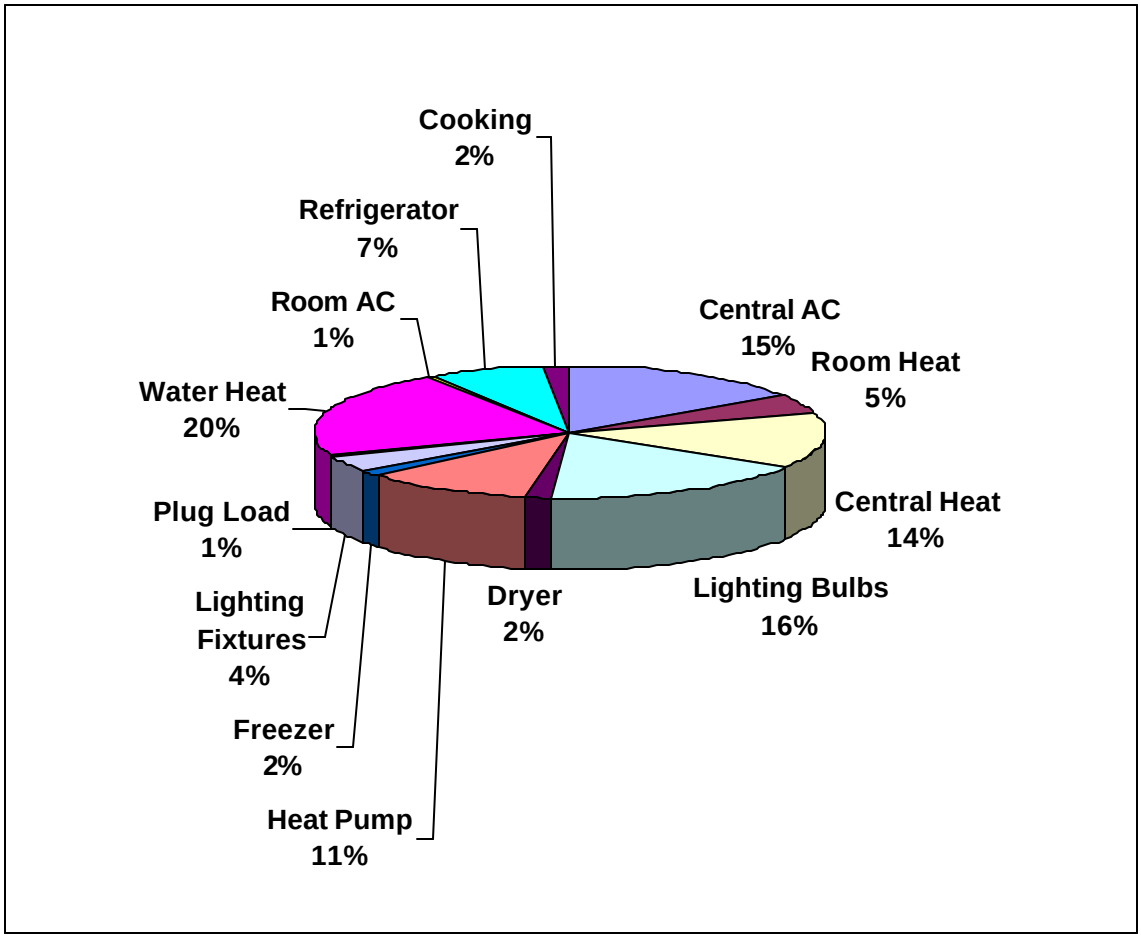


Figure 5-7. Distribution of Achievable Electric Energy Efficiency Potential by Market Type

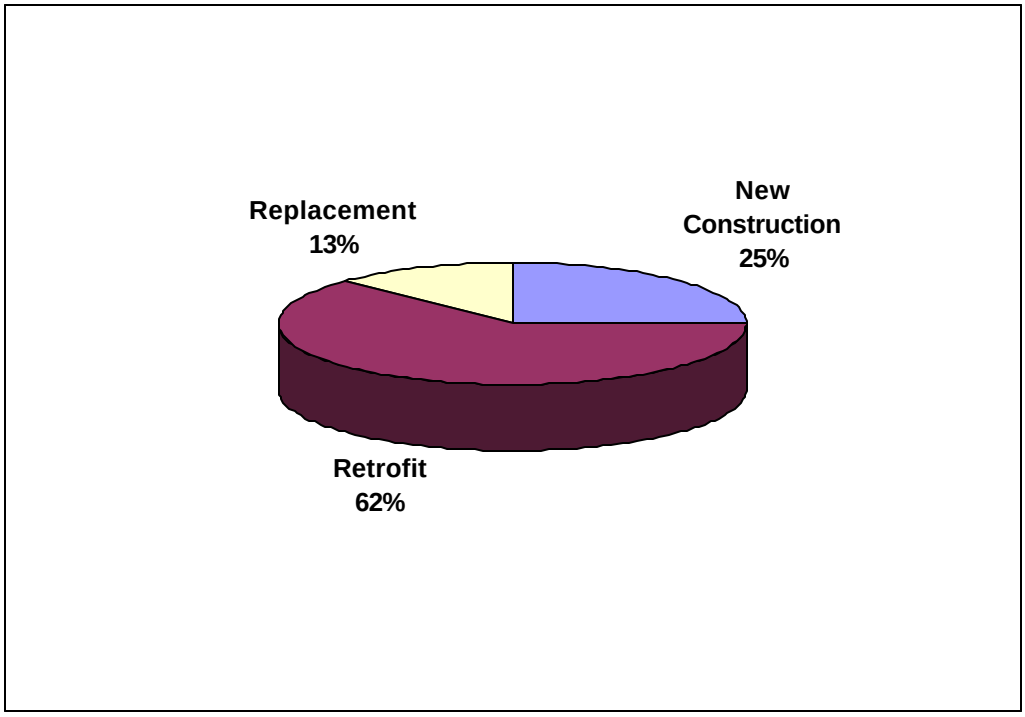


Figure 5-8. Distribution of Achievable Electric Energy Efficiency Potential by State

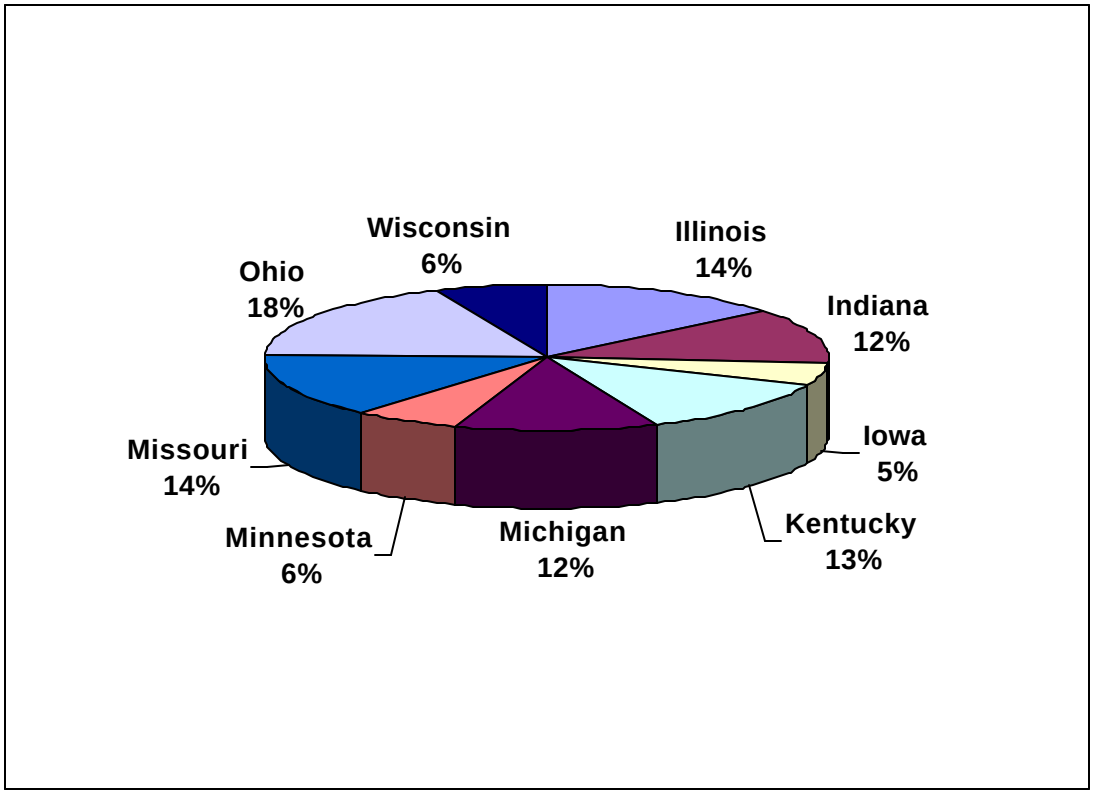


Figure 5-9. Distribution of Achievable Electric Energy Efficiency Potential by Dwelling Type

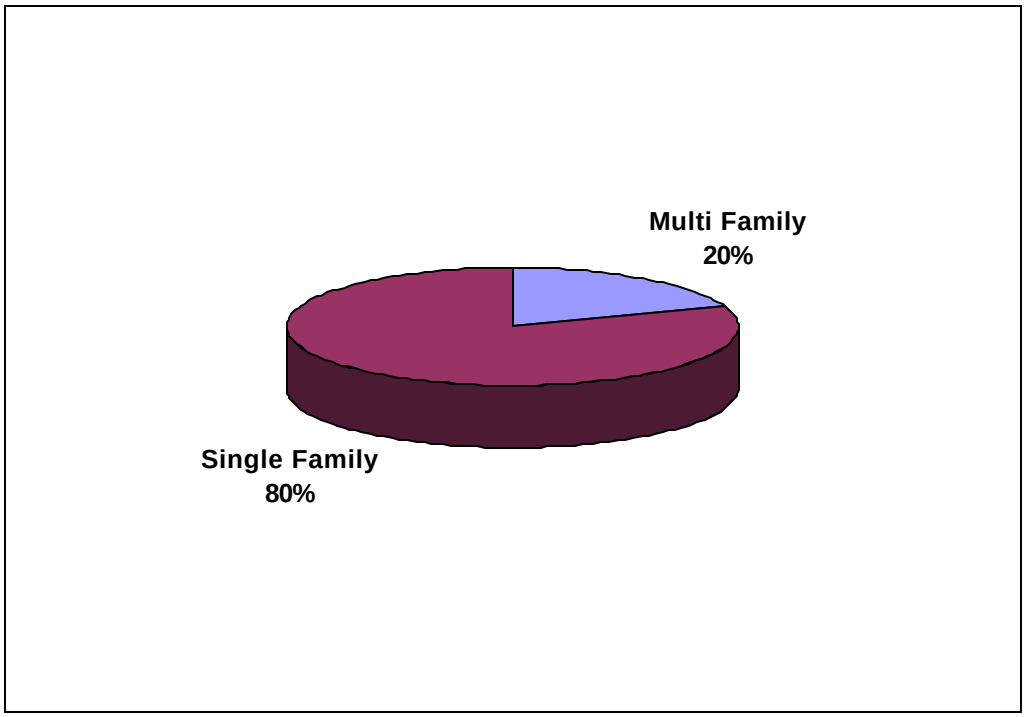
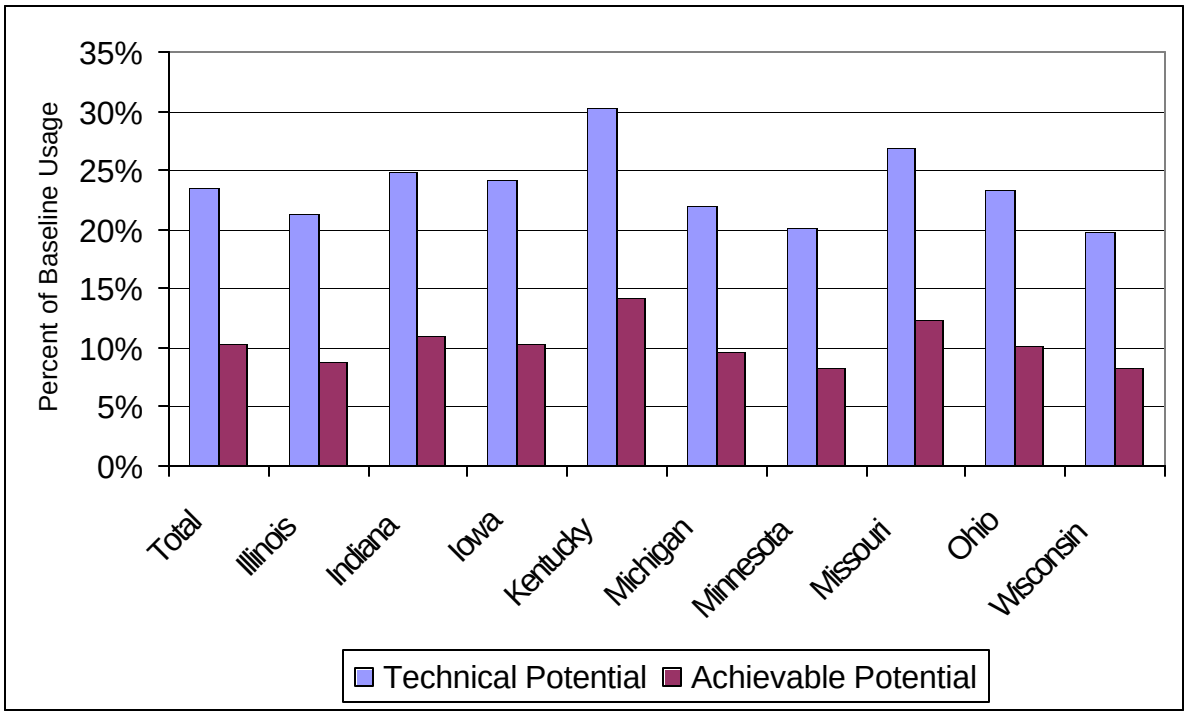


Figure 5-10: Technical and Achievable Electric Potential By State and Total as a Percent of the Baseline Usage



6. CONCLUSIONS AND RECOMMENDATIONS

The results of this study demonstrate that while there are differences across Midwest states in terms of residential customer characteristics, energy use, and historical DSM program activity and related measure saturations, significant electric and natural gas DSM opportunities remain.

6.1 Housing Characteristics and Energy Use

The residential customer surveys revealed significant differences in housing size and heating equipment system characteristics across the Midwest. Customers in half of the states analyzed report mean house sizes of 1,600 to 1,800 square feet, while customers in the other half of the states report mean house sizes of 1,900 to 2,100 square feet. Illinois, Wisconsin, Minnesota, and Michigan are the states with the smaller house sizes, while Indiana, Kentucky, Missouri, and Ohio report larger house sizes.

More importantly, the relative fuel shares of electric and gas space heating and water heating also vary across the states. For example, electric space heating shares exceed 25% in Kentucky and Missouri, while in the northern states of Minnesota, Wisconsin, and Michigan the electric space heating share is less than 10%. This is the primary reason behind the fact that residential electricity use is 50% higher in the southern Midwest region. Similarly, variations in natural gas use are influenced by saturations of natural gas space heating and water heating, as well as climate, dwelling envelope characteristics, and average gas space heating efficiencies.

6.2 DSM Program Activity and Measure Saturations

The most prevalent residential Midwestern DSM programs are rebates, energy audits, and other types of energy information programs. Direct load control programs and low-income programs are also relatively common in the Midwest.

Despite the successes of many of these programs, most dwellings can benefit from one or more energy efficiency measures:

- ***Insulation***. Approximately 5 – 15% of customers have either uninsulated ceilings or walls in their homes. The percentage of customers with uninsulated attics varies from 3% to 11% from state to state, while the percentage of homes with uninsulated walls varies from 5% to 27%. However, more than half of these percentages were self-reported by customers through a telephone survey. Such self-reported responses sometimes over-estimate the actual amount of insulation present in homes.

- ***Windows***. Generally 20%-36% of homes have single-paned windows. The lowest percentages of single-paned windows are found in Minnesota (20%) and Ohio (22%), while the highest percentages are found in Illinois (36%) and Wisconsin (35%).

- ***Compact Fluorescent Lamps***. Less than half of the homes in any Midwest state have one or more compact fluorescent lamps (CFLs). The percentage of homes with one or more CFLs varies from 13% in Wisconsin to 43% in Kentucky. (However, Wisconsin's data is the oldest of the states analyzed, so the saturation of CFLs there is likely higher currently.) The median percentage of homes with one or more CFLs is 33%.

- ***Space Conditioning Systems***. The market shares of efficient gas space heating systems are estimated to be the highest in Iowa, Minnesota, and Wisconsin at 74%, 67%, and 50% respectively. For Indiana, Kentucky, Michigan, Missouri, and Ohio, energy auditors estimate the shares of more efficient gas furnaces at 23% on average, but slightly higher in Missouri. The highest percentages of more efficient central air conditioners are found in Iowa (74% total) and Minnesota (48% total). These percentages are much higher than the 24% market share estimated by energy auditors for efficient air conditioners in Indiana, Kentucky, Michigan, Missouri, and Ohio, or the 6% market share found from the on-site audits in Wisconsin. (Again, the Wisconsin data are older, and the efficient units' market shares have certainly increased there since 1999.) The high penetrations of efficient gas furnaces and/or central air conditioners in Iowa, Minnesota, and Wisconsin are presumably due to the effects of longstanding DSM programs promoting those technologies in those states.

- ***Water Heaters***. Midwest electric and gas water heaters are mainly minimum efficiency units. Among electric water heaters, minimum efficiency units' market shares range from at least 66% to 87%, while the minimum efficiency market share for natural gas water heaters ranges from at least 63% to 83%. These estimates may over-estimate the penetrations of efficient water heaters throughout the Midwest, as energy auditors that examined water heaters on-site in Minnesota concluded that only 1% of water heaters met ENERGY STAR® standards.

- ***Appliances***. The saturations of ENERGY STAR® appliances in the Midwest are low, with the range between 3% and 6% depending on the appliance. The most accurate estimates of ENERGY STAR® appliance saturations should be those provided by the energy auditors in Illinois and Minnesota, who conducted on-site inspections of appliances to determine whether they met ENERGY STAR® standards or not. Customers estimate that far higher percentages of their appliances are ENERGY STAR® units, usually ranging from 16% to 49%, depending upon the appliances and the state of residence. However, most residential customers likely do not know enough about ENERGY STAR® standards to accurately estimate whether their appliances meet these standards or not.

- ***Programmable Thermostats***. The saturation of programmable thermostats varies widely from state to state in the Midwest. It ranges from lows of 17% and 19% in Indiana and Kentucky, respectively, to a high of 47% in Illinois. The mean programmable thermostat saturation in the states analyzed is 29%.

6.3 Natural Gas DSM Potentials

The total DSM potentials for natural gas DSM measures are remarkably consistent from state to state in the Midwest. The total 20-year technical potential for gas DSM varies only from 44% to 48% of base case consumption between states. Similarly the total achievable potential for gas DSM varies between states from about 23% to 27% of base case consumption. This lack of variation is due to the fact that two end-uses – space and water heat – comprise over 90% of average customer consumption, and over 99% of potential. Not surprisingly, space heating natural gas DSM measures account for over 80% of total achievable gas DSM potential, with water heating gas DSM measures accounting for almost all of the remaining achievable gas DSM potential. Also not surprisingly, single-family homes account for over 80% of total achievable residential gas DSM potential.

In total, the maximum achievable gas potential is about 54% of the gas technical potential. Of this amount, the levelized cost calculations, which include measure interaction and stacking effects, reveal that:

- About 12% of the total achievable potential is available from measures whose cost of conserved energy is $0.30 per therm or less.

- Approximately 31% of the total achievable potential is available from DSM measures whose cost of conserved energy is between $0.30 and $1.00 per therm.

- About 57% of the total achievable potential is from measures whose costs of conserved energy are more than $1.00 per therm, at or above the currently high commodity cost for natural gas.

The most cost-effective natural gas DSM measures are insulating uninsulated attics, ENERGY STAR® programmable thermostats, low flow showerheads, hot water pipe insulation, and faucet aerators. These measures have costs of conserved energy of $0.30 per therm or less in existing single-family homes. High efficiency furnaces, comprehensive air sealing/infiltration reductions, water heater thermostat setbacks, and multi-family wall insulation are in the second tier of cost-effectiveness, with costs of conserved energy of $0.60 per them or less.

6.4 Electric DSM Potentials

Electric DSM potentials are much smaller shares of base case consumption than gas DSM potentials. Total electric DSM technical potential equals about 24% of base case consumption, compared to about 47% for gas technical potential. Total electric achievable potential accounts for about 10% of base case consumption, compared to about 25% for gas achievable potential. These differences are due to two primary factors: first, the electric base case consumption estimates include electricity savings from the significant forthcoming federal efficiency standards for central air conditioners and heat pumps that will take effect in 2006. Second, electric space heating, water heating, and lighting account for less than half of total base case electric consumption, but almost all of natural gas base case consumption. The DSM potentials for other electric loads such as appliances are considerably smaller percentages of base case consumption than the DSM potentials for space heating, water heating, and lighting DSM measures.

Electric DSM potentials vary much more from state to state than gas DSM potentials. Electric technical DSM potential varies from about 20% to 30% of base case consumption between states, while electric achievable DSM potential varies from about 8% to 14% between states. Minnesota and Wisconsin have the lowest relative amounts of DSM potential, while Kentucky and Missouri have the largest relative amounts of DSM potential. The amounts of electric DSM potential are proportionate to the saturations of electric space heating and water heating equipment in a state, and inversely proportionate to the magnitudes of historical DSM activity.

In total, about 39% of the total electric achievable potential is available from DSM measures whose cost of conserved energy is 6¢/kWh or less. On the other hand, 51% of total electric potential comes from DSM measures whose costs of conserved energy are 10¢/kWh or more, at or above most current Midwest electric rates.

The most cost-effective and largest impact electric DSM measures are insulating uninsulated attics, installing ENERGY STAR® heat pumps, installing CFLs, removing or replacing secondary or inefficient refrigerators or freezers, and low flow showerheads.

In total, these measures comprise over 75% of the achievable DSM potential for measures with costs of conserved energy of 6¢/kWh or less. In fact, most of these measures have costs of conserved energy of 3¢/kWh or less.

6.5 Recommendations

This section focuses on the DSM measures that have the largest DSM potentials and are the most cost-effective based on the simplified cost of conserved energy calculations done for this project. The study authors do not intend to imply that other DSM measures beyond those discussed in this section are without merit or inappropriate for Midwest DSM programs. We conclude with how the residential natural gas and electric achievable potentials may influence program offerings in the region.

6.5.1 Key Natural Gas Measures

Natural gas DSM measures in total show greater DSM potential as a percentage of baseline consumption than is the case for electric DSM measures. Natural gas DSM potentials are also more consistent percentages of baseline natural gas forecast consumption between Midwest states. Natural gas prices are currently quite high in the Midwest, and MEEA's Midwest Natural Gas Initiative has a main goal of reducing long-term natural gas prices through energy conservation efforts.

Four residential natural gas measures account for about 83% of the DSM potential with a cost of conserved energy of $1 per therm or less. The remaining DSM potential at this cost of conserved energy is accounted for by a variety of measures, each with relatively small impacts. Each of the four major measures is discussed below.

Insulating Uninsulated Attics

The total achievable potential for this measure over the 20 year forecast period is approximately 390 million therms. This represents about two percent of total residential base case natural gas consumption over this period. The total cost of conserved energy for this measure in most Midwest single-family homes is about $0.25 per therm. This cost is based on the total installed cost for the insulation.

Residential attic insulation measures are usually covered by large-scale utility or agency DSM portfolios. For example, Xcel Energy, the main sponsor of this study, in December 2005 proposed a revised incentive for attic insulation, a rebate of $300, for its Minnesota residential customers that is currently under regulatory review. As a second example, MidAmerican Energy offers its Iowa residential customers rebates for 70% of the cost of attic insulation, up to a maximum of $600.

MEEA requested a discussion of the economics and cost-effectiveness of sample gas and electric DSM programs. As the gas example, we will discuss the economics of Xcel Energy's recently proposed attic insulation program. [47] This information is contained in a public document, and contains updated assumptions about natural gas prices.

This program is cost-effective from all four perspectives considered for natural gas programs in Minnesota:

- The program has a benefit-cost ratio to program participants of 5.10, meaning that the energy savings to program participants have a net present value (NPV) of slightly more than five times the net (after rebate) cost of the insulation.

[47] Xcel Energy, "Accelerated Gas CIP Proposal for 2006, Docket No. E,G002/CIP-04-820", (Xcel Energy, Minneapolis, MN, December 21, 2005).

- The societal benefit-cost ratio is 3.22, meaning that the NPV of the conserved gas is slightly more than three times the sum of the installed cost of the attic insulation and program administrative costs.

- The revenue requirements test has a benefit-cost ratio of 4.44. This test is similar to the utility test used for electric program benefit-cost analysis in Minnesota, and compares the NPV of the conserved energy to the total program costs.

- The cost comparison test has a benefit-cost ratio of 3.58. This test is similar to but different from the rate impact test used in electric DSM benefit-cost analysis. This test compares the NPV of the conserved energy to the NPV sum of the program costs and the lost margins that the utility experiences from not selling the gas conserved by the program.

Attic insulation is often not covered by smaller scale DSM portfolios. Sponsors of smaller scale DSM program portfolios may be most interested in a MEEA program promoting attic insulation, but no market research was conducted to specifically assess this matter.

Enrolling customers with uninsulated attics in a DSM program covering attic insulation is likely to be somewhat challenging, for two reasons. First, the survey results indicate that generally only 5%-10% of homes in any state have no attic insulation. Secondly, many customers having inadequate insulation are not aware of that fact. As part of ECW's Energy and Housing Study in Wisconsin study, it was found that only 27% of homeowners that had inadequate insulation were aware of that situation.[48] However, energy audits conducted by qualified energy auditors are ideal methods for identifying such customers. Many utilities and agencies offer such energy audits to their customers at a reduced cost through their DSM programs.

ENERGY STAR® Programmable Thermostats

The total achievable potential for this measure over the 20 year forecast period is approximately 210 million therms. This represents about one percent of total residential base case natural gas consumption. The total cost of conserved energy for this measure in most Midwest single-family homes is about $0.17 per therm. This cost is based on the total installed cost for the thermostat. Since the current saturations for programmable thermostats are less than 50% in all Midwest states studied, and vary by over a factor of two from state to state in the Midwest, considerable market potential exists for this measure.

However, concerns exist about the actual in-the-field energy savings impacts from programmable thermostats. For example, ECW's Energy and Housing Study in Wisconsin found that although homeowners with programmable thermostats had a 2.5% lower energy intensity than homes with manual thermostats, the statistical uncertainty associated with such savings was +/- 7%, or several times larger than the savings estimate. Furthermore, few homeowners with manual thermostats that participated in detailed interviews that were done as part of that project were interested in installing programmable thermostats.[49]

Nevertheless, utilities and agencies sponsoring large-scale DSM portfolios often include programmable thermostats as a measure covered by their DSM programs. For example, MidAmerican Energy offers its residential customers in Iowa a programmable thermostat as part of its HomeCheck™ energy audit

[48] ECW: 2000, op.cit., p. 21.

[49] Ibid, p. 32-33.

program. The energy auditor will install a unit for an additional $30 charge.[50] Xcel Energy includes programmable thermostats as part of its Home Energy residential new construction program, but not as part of its DSM programs for customers in existing homes, due to concerns about the energy savings impacts of the measure in that application.

High Efficiency Gas Furnaces

The total achievable potential for this measure over the 20 year forecast period with a cost of conserved energy of $1 per therm or less is approximately 930 million therms. This represents about five percent of total residential base case natural gas consumption. The cost of conserved energy for this measure varies between housing types, and whether a 92% or 96% efficient furnace is analyzed. Interestingly, the 96% efficient furnaces were found to have a lower total cost of conserved energy than the 92% efficient furnaces.

Efficient furnaces have a cost of conserved energy between $1.10 per therm and $1.20 per therm in the more southern states of the Midwest where the annual savings are lower. The total DSM potential from efficient furnaces in those states is about 600 million therms, or about three percent of total residential base case consumption. Whether this conservation is considered cost-effective or not depends on projections for the price of natural gas.

Efficient natural gas furnaces are often covered by larger-scale utility or agency DSM programs. For example, Alliant Energy offers its residential customers in Iowa rebates for efficient furnaces that range from $200 for a 90% efficient furnace to $350 for a 96% efficient furnace.[51] As a second example, the Wisconsin Focus on Energy offers Wisconsin residents a rebate of $150 for a gas furnace with at least a 90% efficiency rating and two stages of firing.[52]

The current penetrations for efficient gas furnaces vary widely in the Midwest, from highs of 50% to 74% in Iowa, Minnesota, and Wisconsin to about 23% in the rest of the region. The DSM potential for efficient gas furnaces will be highest in the states where the current penetrations are the lowest. Again, utilities or agencies in these states may be the most interested in a MEEA program promoting efficient gas furnaces, but no market research was conducted to specifically assess this matter. Another option that can be considered to increase the installation of efficient gas furnaces is issuing statewide minimum efficiency standards for these products. The U.S. DOE has been conducting a rulemaking on a national gas furnace efficiency standard since 1997, but has not yet issued a proposed standard. States would have to apply to DOE for a waiver to issue a state energy efficiency standard for this product.

Conduct Comprehensive Shell Air Sealing and Infiltration Reduction

Comprehensive air sealing includes sealing all visible cracks and penetrations, plus using enhanced leak detection techniques such as a blower door test and/or thermal imaging if outdoor conditions merit. In general, we assumed a 50% reduction in infiltration heating and cooling loads in existing construction and a much smaller reduction to a minimum one-third air changes per hour in new construction. Tighter air sealing can raise indoor air quality issues without added ventilation.

The total achievable potential for this measure over the 20 year forecast period is approximately 280 million therms, or about 1.4% of base case natural gas consumption over this period. This measure is

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[50] See MidAmerican's Energy's web site: midamericanenergy.com/html/energy3g.asp

[51] See Alliant Energy's web site: alliantenergy.com.

[52] See the Focus on Energy web site: focusonenergy.com.

most applicable and cost-effective in existing single-family homes. The cost of conserved energy for this measure in most of the Midwest states analyzed is about $0.85 per therm, but in some of the northern states where the annual savings are larger than average, the cost of conserved energy is about $0.57 per therm.

Utilities and energy agencies most commonly promote these types of DSM measures through energy audit programs. Energy auditors will estimate how much energy installing these measures will save, often using a blower door test to estimate infiltration levels in homes. Energy auditing programs are very common elements of DSM program portfolios in the Midwest, but programs specifically focused on promoting comprehensive shell air sealing are not common. These measures are part of the Home Performance with ENERGY STAR® program that the Wisconsin Focus on Energy is conducting.[53]

6.5.2 Electric DSM Measures

While electric residential DSM potential is not as high in percentage terms as natural gas DSM potential, there are many electric measures that are or may be cost-effective. The six measures discussed below account for 78% of the DSM potential for measures with costs of conserved energy of 10¢/kWh or less. As discussed previously, the costs of conserved energy are calculated based on the total installed costs of the DSM measures.

Compact Fluorescent Lamps (CFLs)

The total achievable potential for this measure over the 20 year forecast period is approximately 5,800 GWh, or about 1.6% of total residential base case electric consumption over this period. The total cost of conserved energy for this measure varies with how many hours per day the lamps are used. For lamps that are used six hours per day, the cost of conserved energy is about 1.2¢/kWh, while for CFLs that are used 2.5 or 0.5 hours per day, the cost of conserved energy is 2.3¢/kWh or 11¢/kWh, respectively.

DSM programs promoting CFLs to residential customers are widespread in the Midwest. The Change-A-Light, Change-The-World program is MEEA's most popular program in the Midwest, with over a dozen sponsors, and many utilities and agencies in the Midwest also operate their own residential lighting DSM programs that are focused on promoting CFLs. The CFL potential estimates demonstrate that despite the success of these efforts, lighting potential remains very high in the Midwest.

MEEA requested a discussion of the economics and cost-effectiveness of sample gas and electric DSM programs. As the electric example, we will discuss the economics of Xcel Energy's Residential Lighting Programs.[54] This information is contained in a public document, and the project team is very familiar with the analysis done for this regulatory filing.

This program is cost-effective from four of the five perspectives considered for electric DSM programs in Minnesota:

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[53] Ibid.

[54] Xcel Energy, "2005/2006 Biennial Plan, Minnesota Natural Gas and Electric Conservation Improvement Program", (Xcel Energy, Minneapolis, MN, June 1, 2004), p. 220. This analysis covers both Xcel Energy's Home Lighting Direct Purchase program, and its sponsorship of the Change-A-Light, Change-the-World program in its service area.

- The program has a benefit-cost ratio to program participants of 18.81. This means that the energy savings to program participants have a net present value (NPV) of almost 19 times the net cost of CFLs to program participants.

- The societal benefit-cost ratio is 1.43, meaning that the NPV of the avoided electric costs is 43% more than the sum of the CFL's costs and program administrative costs.

- The total resource cost (TRC) test benefit-cost ratio is 1.26. The TRC test is very similar to the societal test, but does not include the benefits of reduced pollution costs from the conserved energy.

- The utility cost test has a benefit-cost ratio of 1.47. This test compares the NPV of the avoided electric costs from the conserved energy from the CFLs to the program costs.

- The rate impact test has a benefit-cost ratio of 0.36. This test compares the NPV of the avoided electric costs from the conserved energy from the CFLs to the sum of the program costs and the lost revenues that the utility experiences from not selling the electricity conserved by the CFLs. The benefit-cost ratio of less than one indicates that this program will tend to cause long-term electric rates to be somewhat higher than they would be if the utility were not operating this program, if all other factors were equal. This benefit-cost ratio for this program is lower than for many electric conservation programs. This is due to the fact that the probability that residential indoor lights will be operating during the utility's summer peak (afternoon) times (the "coincidence factor") is rather low, about 3% in this case.

ENERGY STAR® Heat Pumps

ENERGY STAR® heat pumps have minimum cooling efficiencies of 14 SEER and minimum heating system performance factors of 8.5 starting in 2006. The total achievable potential for this measure over the 20 year forecast period is approximately 3,400 GWh, or about 1.0% of total residential base case electric consumption over this period. The total cost of conserved energy for this measure varies considerably with climate, and ranges from about 1.4¢/kWh to 9.4¢/kWh, and even higher. Almost all of the DSM potential for this measure is in single-family homes.

Most of the DSM potential for this measure comes from replacing less efficient electric heating systems with heat pumps. The saturations for heat pumps in the Midwest are quite low, five percent or less in every state analyzed except Kentucky, where the saturation is 8%.

Air source heat pumps are often covered in utility DSM programs. For example, Xcel Energy offers its Minnesota customers a $150 rebate for purchasing these units, while Alliant Energy offers its Iowa customers a $100 rebate for purchasing these units.

Insulating Uninsulated Attics

This measure is also a large electric savings measure, primarily in states with significant electric space heating saturations. The total achievable potential for this measure over the 20 year forecast period is approximately 1,800 GWh, or about 0.5% of total residential base case electric consumption over this period. The total cost of conserved energy for this measure in most Midwest single-family homes is about 1.8¢/kWh. This measure was discussed at some length in the previous section.

Removing Secondary Refrigerators

The total achievable potential for this measure over the 20 year forecast period is approximately 1,500 GWh, or about 0.3% of total residential base case electric consumption over this period. The total cost of conserved energy for this measure is about 6.1¢/kWh.

The saturations of secondary refrigerators vary considerably throughout the Midwest, from a low of 13% in Ohio to a high of 30% in Kentucky. The median saturation of secondary refrigerators is about 20%, so considerable technical potential exists for these programs.

Ameren has contracted with MEEA to run a DSM program promoting this practice for the past several years in their Missouri service area. The 2005 version of this program offered customers a $50 rebate for recycling a working refrigerator while buying an ENERGY STAR® unit, and an additional $50 rebate was offered to customers for recycling a second refrigerator at the same time. Alliant Energy also offers its Iowa customers a $35 rebate for turning in a working secondary refrigerator.

ENERGY STAR® Refrigerators

The total achievable potential for this measure over the 20 year forecast period is approximately 900 GWh, or about 0.3% of total residential base case electric consumption over this period. The total cost of conserved energy for this measure is about 9.3¢/kWh. All the DSM potential for this measure that costs 10¢/kWh or less is from single-family homes.

Efficient Water Heaters

The total achievable potential for high efficiency and heat pump water heaters over the 20 year forecast period is approximately 770 GWh, or about 0.2% of total residential base case electric consumption over this period. The total cost of conserved energy for high efficiency water heaters is about 6.9¢/kWh, while the cost of conserved energy for heat pump water heaters is about 9.9¢/kWh.

6.5.3 Residential Program Recommendations

This DSM potential study provides a wealth of information that can be readily used as a starting point for residential DSM program planning in the Midwest. However, the scope of work for this study did not include DSM program design or detailed DSM benefit-cost analysis. MEEA, utilities, and energy agencies in the Midwest must factor in other considerations and conduct program development and benefit-cost analyses before turning the DSM potential estimates in this report into concrete program designs and goals. Such other considerations could include historical experiences with certain types of DSM measures and programs, utility or state-specific benefit-cost analysis assumptions, and the specific circumstances or needs of a utility or state.

Still, the potential analysis yields several important insights relating to program development:

- ***Midwest Natural Gas Initiative***. There is certainly enough cost-effective DSM potential to achieve the residential sector share of the 1% per year reduction for five years goal set by the sponsors of this initiative. This study suggests that high efficiency furnace replacements and building envelope retrofit programs (insulation, comprehensive air sealing, and programmable thermostats) will form the cornerstone of these efforts.

- ***Electric HVAC Programs***. Despite the changes in central air conditioning and heat pump standards, efficient heat pumps (SEER 14+) are likely to continue to be cost-effective. This holds

for both the replacement of central electric furnaces and in the normal replacement of existing heat pumps. Additionally, since attic insulation and possibly other envelope measures are likely to be cost-effective, there are opportunities to jointly deliver natural gas and electric building envelope measures.

- ***Change-A-Light, Change-The-World***. While MEEA's flagship program has had a very successful five-year run, much work remains to be done in residential lighting. There is more than enough savings potential to continue this program for several years.

- ***Electric Appliances***. Appliance recycling, particularly older refrigerators and freezers, continue to offer high, and likely cost-effective, savings potential. High efficiency water heaters and refrigerators also offer potential savings in replacement markets.