WISCONSIN'S STATEWIDE TECHNICAL & ECONOMIC POTENTIAL

Published 1994 WCDSR-119-1

NOTICE

This report was prepared by the Wisconsin Center for Demand-Side Research (WCDSR). Neither WCDSR nor participants in WCDSR:

(a) makes any warranty, expressed or implied, with respect to the use of any information, apparatus, method, or process disclosed in this report or that such use may not infringe privately owned rights; or

(b) assumes any liability with respect to the use of, or damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

ACKNOWLEDGMENTS

The authors would like to acknowledge the members of the Ad Hoc STEP Committee and the other advisory groups involved in the STEP process. We would also like to thank the other staff members of the Wisconsin Center for Demand-Side Research, whose contributions were invaluable to the project.

EXECUTIVE SUMMARY

As part of Wisconsin's integrated resource planning process, the regulatory commission requires Wisconsin's Class A electrical and combination utilities to provide estimates of the potential savings from demand-side management. By consensus, a committee of utility staff, regulatory staff, and intervenors developed the estimation method reported here.

This report—which was prepared by staff at the Wisconsin Center for Demand-Side Research and submitted to the Public Service Commission of Wisconsin—documents the method and the resulting estimates of statewide savings potential over the next 20 years. The estimates are intended to provide reasonableness checks and bounds for evaluating the demand-side plans of Wisconsin's electric utilities. These estimates should also help policy makers understand the limits of, and opportunities for, demand-side management.

The results presented in this report reflect a specific set of assumptions and available data; they are not intended for use in making detailed predictions, such as the savings specific technologies could produce. Rather, the value of the report lies in the presentation of the algorithm, which could be used with appropriate data and assumptions to estimate potential in other jurisdictions.

What is "Potential"?

For this analysis, the project defined two types of potential savings.

Technical potential is the electrical load reduction that results when the most efficient demand-side measures are adopted by the entire eligible population in the base year. It was assumed that these measures are adopted regardless of economics.

Economic potential is the electrical load reduction that results when the most efficient demand-side measures are adopted by the entire eligible population *when it is economical to do so from society's overall perspective.* Measures were screened using the Technical Cost Test, as defined under Wisconsin's regulatory process.

The demand-side measures that were considered in this study can be divided into three broad categories:

- *Conservation* measures, which conserve energy
- *Load management* measures, which control or shift demand for electricity during peak hours
- *Fuel switching* measures, which eliminate the demand for electricity by switching to other forms of energy (in this study, only natural gas)

Sources of Information Used in Estimating Potential

The estimates of potential are based on technology information, market saturations, and economic projections that were provided by the participating utilities and by research conducted by Center staff. The technology and saturation information were incorporated into the Wisconsin Demand-side Options Database (W-DOD). W-DOD provides comparisons between demand-side alternatives and conventional technologies for end uses in the agricultural, commercial, industrial, and residential sectors. It is primarily used for long-term demand-side program planning.

Results

The results section of the report includes charts showing the technical and economic demand-side potential for savings in electrical consumption and demand in Wisconsin. The savings are shown for four economic sectors: agricultural, commercial, industrial, and residential.

Technical potential and economic potential are shown for several different scenarios. Technical potential was calculated using four scenarios for the types of DSM measures included: fuel switching only, conservation only, load management only, and all measures together. Economic potential was calculated for several different avoided-cost scenarios.

Again, we emphasize that the results are dependent on a set of assumptions and available data that are Wisconsin-specific. The primary external value of the report lies in its exposition of the method for estimating demand-side potential. This method could be used with suitable data and assumptions to estimate potential for other locations or for specific building types, technologies, and market segments.

CONTENTS

FIGURES

TABLES

INTRODUCTION

This report presents estimates of Wisconsin's potential for saving electricity over the next 20 years, and it fully documents the method used to produce these estimates. Before presenting the method and its results, it is helpful to understand Wisconsin's regulatory approach and history of estimating savings potential.

Background

Every two to three years, Wisconsin's investor-owned utilities submit *Advance Plans* to the Public Service Commission of Wisconsin. These Advance Plans describe how the utilities intend to provide energy services over the next 20 years. Included in an Advance Plan are plans to meet future electrical energy needs by reducing both the future consumption and demand for electricity. Such efforts are often called *demand-side management* (DSM). After analyzing the Advance Plan and hearing public testimony, the Commission prepares an Advance Plan Order accepting, modifying or rejecting the utilities' plans.

As a result of the Advance Plan 5 process, the utilities were ordered to develop a common baseline estimate of Wisconsin's potential for meeting electrical supply needs through demand-side management. This estimate was published prior to Advance Plan 6 by the Wisconsin Center for Demand-Side Research (WCDSR) under the title, *Wisconsin Statewide Technical and Economic DSM Potential* (document WCDSR-100-1).

During the Advance Plan 6 process, the Commission determined that the method used to compute the economic potential estimates described above had "a number of serious methodological flaws which cause it to underestimate the statewide economic potential significantly."* Consequently, Order 3.2 of Advance Plan 6 states that "The utilities, in consultation with Commission staff and intervenors, shall prepare a new estimate of demand-side economic potential for Advance Plan 7." In response to this order, a committee of utility staff, Commission staff and intervenors worked collaboratively to develop an improved method for estimating demand-side potential. The committee used a consensus process to develop this method, so the resulting method may not reflect each party's first choice. (The assumptions made are listed in Appendix E. This document, produced by the WCDSR, presents estimates of demand-side reduction potential for Wisconsin using the agreed upon method.

The potential estimates presented in this study were developed to provide reasonableness checks and bounds for evaluating utility demand-side plans, and to

* Public Service Commission of Wisconsin, Docket 05-EP-6, Findings of Fact, Conclusion of Law and Order, p.13

help policy makers understand the limits of and opportunities for demand-side management. The results of this study are not intended to be used to make detailed predictions, such as which specific demand-side management technologies could supply the greatest potential. This type of prediction would require additional information and calculations beyond the scope of this project. It may be helpful to understand that the method developed by the working committee was intended to produce potential estimates only to two significant digits.

What is "Potential?"

The term *potential*, as it is used in demand-side management, refers to theoretically possible energy and demand savings. (See Appendix F: Definitions.) In this study, two different potentials are discussed: *technical potential* and *economic potential*. Formally stated, *technical potential* in this analysis is the electrical load reduction that results when the most efficient demand-side measures are adopted by the entire eligible population in the base year. *Economic potential* in this analysis is the electrical load reduction that results when the most efficient demand-side measures are adopted by the entire eligible population *when it is economical to do so from society's overall perspective.*

An example will illustrate these terms: If all of Wisconsin's incandescent light bulbs could be replaced immediately with compact fluorescent lamps, the energy and demand savings associated with this replacement would be the *technical potential* associated with compact fluorescent lamps. Applications for which lamp replacement is not technically possible are specifically excluded from this calculation. When the economic factors of incandescent bulb replacement are considered, so that some technically feasible replacements are not made, the energy and demand savings are termed the *economic potential.* In this case, the applications for which lamp replacement is not cost-effective are excluded from the savings calculations.

The Information Available for Estimating "Potential"

To estimate the potential for saving electrical energy and demand, several types of information are needed. First and foremost, it is necessary to have technology information for the multitude of demand-side alternatives available in the market. This information must include costs, lifetimes, energy savings, and demand savings for each measure. To understand the potential impact of these measures, it is important to have market information such as the population of each market segment, the saturation and eligibility for each measure within each segment, and the expected growth rate in the demand for electrical energy and demand over the planning period. Finally, it is necessary to specify information such as energy costs, demand costs, and a real discount rate. (See Appendix F: Definitions.)

Most of the technology information and market information used in this analysis is taken from the Wisconsin Demand-Side Options Database (W-DOD). This database is the product of a collaborative effort—managed by WCDSR—between Wisconsin's utilities and the Public Service Commission to establish a tool for preparing long-term demand-side plans. The database compares conventional technologies to demand-side alternatives. Because W-DOD was not designed to be used for estimating potential, it is important to describe the database and its limitations for use in this calculation.

- the information in W-DOD portrays an average Wisconsin customer
- the information in W-DOD is limited to those demand-side measures that are:
  - commercially available in Wisconsin,
  - supported by reliable test data
  - candidates for utility-run demand-side programs. (Examples of technologies that are not appropriate for utility demand-side programs might include technologies that are low-cost and very cost-effective, or those that are already being rapidly adopted by customers.)

Consequently, the estimates of potential developed in this study do not account for savings from all current technologies, although they do account for the majority. Nor do they include the added savings from more efficient future technologies or for savings that might be available in niche markets.

For developing demand savings, time-of-use data for electrical equipment is needed. These data are derived from the load-shape data included in W-DOD. In some cases, these data were developed specifically for W-DOD based on Wisconsin utility data. In other instances, load shapes developed elsewhere were adjusted to be representative of Wisconsin conditions. These load shapes were analyzed during the Advance Plan 6 technical and economic potential calculation to determine, for each end use:

- the seasonal on- and off-peak distribution of energy consumption
- the ratio of summer peak demand to annual energy consumption

Because W-DOD load shapes have not been modified since that time, this information was used again in the current study. (See Table 12 in Appendix C.)

The remainder of the market information was supplied by the Demand-Side Management Task Force and the Load Forecasting Task Force of the Wisconsin utilities. This information includes statewide estimates for the following:

- base forecast growth rates for energy and demand (see Table 6 in Appendix C)
- total energy consumption and summer peak demand by economic sector (see Table 7 in Appendix C)

- avoided cost of transmission and distribution (see Table 7 in Appendix C)
- portion of the population able to switch to natural gas (see Table 7 in Appendix C)
- energy and demand savings captured between the base year of W-DOD (1991) and the base year of this study (1994) (see Tables 7 and 11 in Appendix C)
- populations by end use (see Table 10 in Appendix C)

Statewide average avoided costs for energy and demand were supplied by the utilities (see Table 8 in Appendix C.) A real discount rate was supplied by the Financial Analysis Task Force of the Wisconsin utilities. (See Table 6 in Appendix C.)

THE CALCULATION METHOD

The Wisconsin Demand-Side Options Database (W-DOD), as noted above, provides the bulk of the information for this analysis. The W-DOD is based on a list of standard (or base) technologies. For each of these base case technologies, the database presents a set of demand-side measures that can either replace or be added to this technology. The technical and economic potential calculations consider each of these sets of measures independently.

To demonstrate the steps involved in estimating technical and economic potential, one such set of measures is analyzed in this section. The sample data and formulas used to develop this example are provided in *Appendix D*. A more complete listing of the data is provided in *Appendix C*, which includes all the data used in the technical and economic potential calculations except for the W-DOD data.

Technical Potential

As noted earlier, technical potential is an estimate of the electrical load reduction that results when the most efficient demand-side measures are adopted without consideration of economics. For instance, this calculation assumes that there is no cost associated with discarding existing equipment and replacing it immediately with the most efficient available measures. Consequently, technical potential reflects the total energy and demand savings available if all the most efficient demand-side measures are adopted at the start of the base year of the study (1994), and indicates the changes in market saturations necessary to produce these savings.

The demand-side measures in W-DOD may be divided into three broad categories:

- *conservation* measures, which conserve energy
- *load management* measures, which control, reduce, or shift demand for electricity during peak hours
- *fuel switching* measures, which eliminate the demand for electricity by switching to other forms of energy. (In this study, only measures which switch to natural gas are considered.)

To gain an understanding of the potential for each category of measures individually, and for all three together, technical potential is calculated for four scenarios:

1. fuel switching measures only
2. conservation measures only
3. load management measures only
4. all three measure types considered together, with preference given first to fuel switching, then to conservation, and finally to load management.

Scenarios 3 and 4 do not place a limit on load management potential, although such potential might in practice be limited by adverse impacts on system load shapes. For example, if sufficient efforts were made to reduce the summer weekday afternoon peak by shifting load to the off-peak hours, it is conceivable that a new peak could be created. In practice, load management efforts would stop before this occurred. The committee that was developing the method judged that to limit load management arbitrarily was undesirable, however, and to limit it in a realistic way was beyond the scope of this project.

The order in which measures are considered in Scenario 4 was also determined by the committee developing the method by using the following reasoning: first, it would be more complex to consider fuel switching after the other types of measures, because the savings calculated for conservation or load management measures applied to a given end use would become meaningless once that end use was switched to another fuel. Second, the committee placed conservation measures before load management, because of the desirability of saving energy at all times.

Method for Calculating Technical Potential

In this section, the 12 steps in calculating the technical potential will be briefly described. A discussion of economic potential follows this section. The method is further illustrated through an example: the single-family domestic water heating end use. A table is provided after each step, showing the results of that step applied to this end use and its set of technologies. Further details on the calculation method may be found in *Appendix D*.

Step 1: Identify a set of measures to analyze.

The table below lists the measures for water heating in single family homes. The first measure, *Elect. Water Heater, 1992*, an electric water heater with the efficiency of those typically installed in 1992, is considered the base case. Its DSM Type is therefore listed as "not applicable." The next four measures are candidates for complete replacement of the base case. The remaining seven measures in the table may be added on to some of the first five.

The four columns in the table provide the following information:

- *Measure:* provides a one-line description of the DSM measure (More detail on each is available in W-DOD.)
- *DSM Type:* identifies each measure as one of three DSM types: fuel switching, conservation, or load management
- *Add-on/Repl:* identifies each measure as suitable for addition to an existing technology, or as a complete replacement for the existing technology

- *Add-on Repl Codes:* identifies each replacement measure by an upper case letter, and identifies each add-on measure by one or more lower case letters indicating to which replacement measure it can be applied

Example: The *Heat Pump Water Heater* is a conservation option that can replace the base case *Elect. Water Heater, 1992*. Its *Replacement Code* is *B*. The *Water Heater Wrap* is a conservation option that can be added on to some of the replacements. Its *Add-on Code* is *bcde*, indicating that it can be added on to replacement options *B*, *C*, *D*, and *E* (but not *A*, because of safety considerations and because gas conservation is not part of this study). To help clarify the example, the *Heat Pump Water Heater* and the *Water Heater Wrap*, will be followed throughout the remaining 11 steps.

Measure	DSM Type	Add-on/Repl	Add-on/Repl Codes
Elect Water Heater, 1992	NA	Replacement	E
Gas Water Heater, 1992	Fuel Switching	Replacement	A
Elect Water Heater, Efficient	Conservation	Replacement	D
Heat Pump Water Heater	Conservation	Replacement	B
Solar Water Heater	Conservation	Replacement	C
Water Heater Pipe Wrap	Conservation	Add-on	bcde
Water Heater Wrap	Conservation	Add-on	bcde
Desuperheater	Conservation	Add-on	bde
Low-flow Showerhead	Conservation	Add-on	bcde
Faucet Aerators	Conservation	Add-on	bcde
Direct Load Control	Load Management	Add-on	bde

Step 2: Adjust the eligibility values for fuel switching measures to reflect access to natural gas.

For each fuel switching measure, W-DOD indicates the fraction of the population that is eligible to adopt it. The fraction in W-DOD assumes that the entire population has access to the alternative fuel (in this case, natural gas), but that there may be other reasons why some cannot switch. Therefore, for the potential calculations, the eligibility must be further adjusted for the percentage of the population with access to natural gas, using data from Table 13 in *Appendix C*. Table 13 provides the data to calculate a weighted average percentage of electric utility customers with access to gas.

Example: The only fuel switching measure for this end use is the *Gas Water Heater, 1992*. Its original eligibility is 37%, because 37% of the households currently have electric water heaters. From Table 13 in *Appendix C*, the percentage of residential households in Wisconsin with access to natural gas is 66.2%.

Therefore,

Adjusted Eligibility = 37% x 66.2% = 25%

Fuel Switching Measures
Gas Water Heater, 1992 Original Eligibility = 37% Adjusted Eligibility = 25%

<u>Step 3</u>: Identify eligible measures for each scenario.

Of the measures listed in Step 1, identify the set to apply to the market for each of the four scenarios. The table below shows the results of this step. The four scenarios are listed in the column headings of the table.

Example: Under the *Conservation only* scenario, only the replacement and add-on measures identified under the DSM Type Conservation are included. The *Heat Pump Water Heater* and the *Water Heater Wrap*, which are the conservation measures considered in depth here, are included.

Fuel Switching only	Conservation only	Load Management only	Fuel Switching, Conservation, and Load Management
*Gas Water Heater, 1992	*Elect Water Heater, Efficient *Heat Pump Water Heater *Solar Water Heater Water Heater Pipe Wrap Water Heater Wrap Desuperheater Low-flow Showerhead Faucet Aerators	Direct Load Control	*Gas Water Heater, 1992 *Elect Water Heater, Efficient *Heat Pump Water Heater *Solar Water Heater Water Heater Pipe Wrap Water Heater Wrap Desuperheater Low-flow Showerhead Faucet Aerators Direct Load Control

* Replacement-type measure

<u>Step 4</u>: Rank the replacement measures listed in Step 1.

The replacement measures are ranked from least to greatest energy consumption and demand based on W-DOD data. In some cases the ranking according to energy consumption would differ from the ranking according to demand. Details of how these rankings are combined are provided in Step 4 in the Technical Potential Formulas section of *Appendix D*. The ranking of water heating measures is shown in the table below.

Example: The *Heat Pump Water Heater* has the second lowest energy consumption and demand of the five replacement measures.

Replacement-type Measures
A Gas Water Heater, 1992
B Heat Pump Water Heater
C Solar Water Heater
D Elect Water Heater, Efficient
E Elect Water Heater, 1992

<u>Step 5</u>: Calculate the energy and demand savings per unit replaced for each replacement measure.

Calculate the energy and demand savings for using the measures identified in Step 3 to replace those measures of lower rank shown in Step 4. The results of these calculations are shown in the table below. For this end use, a unit is one household.

Example: In the *Conservation only* column below, measure *B*, the *Heat Pump Water Heater*, can replace measure *E*, the *Elect. Water Heater, 1992*. The energy savings per unit is calculated using the following data:

- energy use per unit for the *Elect. Water Heater, 1992*, from Table 14 in *Appendix D*: 4,230 kWh/yr per unit
- energy savings for the *Heat Pump Water Heater*, from Table 14 in *Appendix D*: 50%

Therefore,

Energy Savings = 50% x 4,230 kWh/yr/unit = 2,115 kWh/yr/unit

The demand savings calculation requires the following data:

- the energy use for the *Elect. Water Heater, 1992*, as above
- the ratio of demand to energy consumption for the single family residential water heating end use, from Table 12 in *Appendix C*: 0.00009 kW per kWh/yr (data in Table 12 are based on typical load shapes for each end use)
- demand savings for the *Heat Pump Water Heater*, from Table 14 in *Appendix D*: 50%

Therefore,

Demand Savings = 50% x 0.00009 kW/(kWh/yr) x 4,230 kWh/yr/unit
= 0.190 kW/unit

Fuel Switching only	Conservation only	Load Management only	Fuel Switching, Conservation, and Load Management
A replaces *B* Energy = 2,073 kWh/yr/unit Demand = 0.183 kW/unit *A* replaces *C* Energy = 2,200 kWh/yr/unit Demand = 0.194 kW/unit *A* replaces *D* Energy = 3,976 kWh/yr/unit Demand = 0.354 kW/unit *A* replaces *E* Energy = 4,188 kWh/yr/unit Demand = 0.373 kW/unit	*B* replaces *C* Energy = 127 kWh/yr/unit Demand = 0.011 kW/unit *B* replaces *D* Energy = 1,904 kWh/yr/unit Demand = 0.171 kW/unit *B* replaces *E* Energy = 2,115 kWh/yr/unit Demand = 0.190 kW/unit *C* replaces *D* Energy = 1,777 kWh/yr/unit Demand = 0.160 kW/unit *C* replaces *E* Energy = 1,988 kWh/yr/unit Demand = 0.179 kW/unit *D* replaces *E* Energy = 212 kWh/yr/unit Demand = 0.019 kW/unit		*A* replaces *B* Energy = 2,073 kWh/yr/unit Demand = 0.183 kW/unit *A* replaces *C* Energy = 2,200 kWh/yr/unit Demand = 0.194 kW/unit *A* replaces *D* Energy = 3,976 kWh/yr/unit Demand = 0.354 kW/unit *A* replaces *E* Energy = 4,188 kWh/yr/unit Demand = 0.373 kW/unit *B* replaces *C* Energy = 127 kWh/yr/unit Demand = 0.011 kW/unit *B* replaces *D* Energy = 1,904 kWh/yr/unit Demand = 0.171 kW/unit *B* replaces *E* Energy = 2,115 kWh/yr/unit Demand = 0.190 kW/unit *C* replaces *D* Energy = 1,777 kWh/yr/unit Demand = 0.160 kW/unit *C* replaces *E* Energy = 1,988 kWh/yr/unit Demand = 0.179 kW/unit *D* replaces *E* Energy = 212 kWh/yr/unit Demand = 0.019 kW/unit

A Gas Water Heater, 1992

B Heat Pump Water Heater

C Solar Water Heater

D Elect Water Heater, Efficient

E Elect Water Heater, 1992

Step 6: Calculate the savings and potential saturations as the replacements are carried out throughout the market.

Carry out the replacements in the order shown in Step 5, calculating energy savings, demand savings, and changing saturations for each measure. In the table below, the base case and all the replacement water heating measures are included in each column. Only the replacement measures identified in Step 3 as applicable to the scenario are underlined. Current and potential saturations are shown for all measures. Energy and demand are shown for all replacement measures with non-zero potential saturation.

Example: In the *Conservation only* column, *Heat Pump Water Heater* is underlined because it is a conservation measure. The current saturation figures indicate that all the households with electric water heaters have either an *Elect. Water Heater, Efficient*, or an *Elect. Water Heater, 1992*. Gas water heaters have a current saturation of 0%, because households that already have gas water heat cannot conserve electricity for water heating. The potential saturation for the *Heat Pump Water Heater* is 37% while potential saturation for all other measures in the column is 0%. Thus, in the *Conservation only* scenario, the *Heat Pump Water Heater* would replace all the existing electric water heaters.

Energy and demand savings for the Heat Pump Water Heaters are calculated using the following data:

- the energy and demand savings per unit found in Step 5
- the current saturations of the water heaters being replaced (24.1% for *Elect. Water Heater, Efficient*, and 13.2% for *Elect. Water Heater, 1992* - these figures are rounded in the table)
- the potential saturations of the water heaters being replaced (0% for both)
- total population of households from Table 10 in *Appendix C*: 1,432,914 households

Therefore,

Energy Savings = 1,904 kWh/yr/household x (24.1% - 0%) x 1,432,914 households
+ 2,115 kWh/yr/household x (13.2% - 0%) x 1,432,914 households
= 1,057 GWh/yr

Demand Savings = 0.171 kW/household x (24.1% - 0%) x 1,432,914 households +
0.190 kW/household x (13.2% - 0%) x 1,432,914 households
= 95 MW

Fuel Switching only	Conservation only	Load Management only	Fuel Switching, Conservation, and Load Management
Gas Water Heater, 1992	*Gas Water Heater, 1992*	*Gas Water Heater, 1992*	*Gas Water Heater, 1992*
Current Sat = 0%	Current Sat = 0%	Current Sat = 0%	Current Sat = 0%
Potential Sat = 25%	Potential Sat = 0%	Potential Sat = 0%	Potential Sat = 25%
Energy = 1,433 GWh/yr			Energy = 1,433 GWh/yr
Demand = 128 MW	*Heat Pump Water Heater*	*Heat Pump Water Heater*	Demand = 128 MW
Heat Pump Water Heater	Current Sat = 0%	Current Sat = 0%	*Heat Pump Water Heater*
Current Sat = 0%	Potential Sat = 37%	Potential Sat = 0%	Current Sat = 0%
Potential Sat = 0%	Energy = 1,057 GWh/yr		Potential Sat = 13%
	Demand = 95 MW	*Solar Water Heater*	Energy = 357 GWh/yr
Solar Water Heater	*Solar Water Heater*	Current Sat = 0%	Demand = 32 MW
Current Sat = 0%	Current Sat = 0%	Potential Sat = 0%	*Solar Water Heater*
Potential Sat = 0%	Potential Sat = 0%		Current Sat = 0%
		Elect Water Heater, Efficient	Potential Sat = 0%
Elect Water Heater, Efficient	*Elect Water Heater, Efficient*	Current Sat = 24%	
Current Sat = 24%	Current Sat = 24%	Potential Sat = 24%	*Elect Water Heater, Efficient*
Potential Sat = 8%	Potential Sat = 0%		Current Sat = 24%
		Elect Water Heater, 1992	Potential Sat = 0%
Elect Water Heater, 1992	*Elect Water Heater, 1992*	Current Sat = 13%	
Current Sat = 13%	Current Sat = 13%	Potential Sat = 13%	*Elect Water Heater, 1992*
Potential Sat = 4%	Potential Sat = 0%		Current Sat = 13%
			Potential Sat = 0%

Step 7: Identify the add-on options that can be applied.

For the replacement measures having potential saturations greater than zero at the end of Step 6, identify the add-on options that can be applied to each.

Example: Recall that in Step 1, the *Add-on Code* for the *Water Heater Wrap* was *bcde*, while the *Replacement Code* for the *Heat Pump Water Heater* is *B*. The *Water Heater Wrap* is therefore one of the five add-on technologies listed as applicable to the *Heat Pump Water Heater* in the table below.

Fuel Switching only	Conservation only	Load Management only	Fuel Switching, Conservation, and Load Management
GAS WATER HEATER, 1992 (none) *ELECT WATER HEATER, EFFICIENT* (none) *ELECT WATER HEATER, 1992* (none)	*HEAT PUMP WATER HEATER* Water Heater Pipe Wrap Water Heater Wrap Desuperheater Low-flow Showerhead Faucet Aerators	*ELECT WATER HEATER, EFFICIENT* Direct Load Control *ELECT WATER HEATER, 1992* Direct Load Control	*GAS WATER HEATER, 1992* (none) *HEAT PUMP WATER HEATER* Water Heater Pipe Wrap Water Heater Wrap Desuperheater Low-flow Showerhead Faucet Aerators Direct Load Control

<u>Step 8</u>: Rank the add-on measures identified in Step 7.

For each replacement measure listed in Step 7, rank the associated add-ons from greatest to least energy and demand savings. Again, in some cases the ranking according to energy consumption would differ from the ranking according to demand. Details of how these rankings are combined are provided in Step 8 in the Technical Potential Formulas section of *Appendix D*. The ranking of water heating add-on measures is shown in the table below.

Example: The *Water Heater Wrap* has the greatest energy and demand savings of the five add-on measures listed under the *Heat Pump Water Heater* in the *Conservation only* column.

Fuel Switching only	Conservation only	Load Management only	Fuel Switching, Conservation, and Load Management
GAS WATER HEATER, 1992 (none) *ELECT WATER HEATER, EFFICIENT* (none) *ELECT WATER HEATER, 1992* (none)	*HEAT PUMP WATER HEATER* Water Heater Wrap Low-flow Showerhead Water Heater Pipe Wrap Faucet Aerators Desuperheater	*ELECT WATER HEATER, EFFICIENT* Direct Load Control *ELECT WATER HEATER, 1992* Direct Load Control	*GAS WATER HEATER, 1992* (none) *HEAT PUMP WATER HEATER* Water Heater Wrap Low-flow Showerhead Water Heater Pipe Wrap Faucet Aerators Desuperheater Direct Load Control

<u>Step 9</u>: Calculate the energy and demand savings per unit for each add-on measure.

For each replacement measure listed in Step 7, apply the corresponding add-on measures in the order determined in Step 8. To limit the double-counting of savings, each time an add-on is applied, the energy and demand of the replacement measure is recalculated to account for these savings. When the next add-on is applied, its savings potential is applied to the new baseline energy use of the replacement. The table below gives the energy and demand savings calculated for each add-on measure.

Example: The savings per unit for the *Water Heater Wrap* can be calculated using the following data:

- the energy consumption of the *Heat Pump Water Heater*, which in Step 5 was shown to be 2,115 kWh/yr/unit
- the savings expected for the *Water Heater Wrap*, from Table 14 in *Appendix D*: 15% of both energy and demand

Therefore,

Energy Savings = 15% x 2,115 kWh/yr/unit = 317 kWh/yr/unit

Similarly, demand savings would be 15% of the demand from Step 5, or 0.029 kW/unit.

To show additional implications of the order of add-ons, consider the following: the *Low-Flow Showerhead* is expected to save 10% of the energy and demand used by a water heater (from Table 14 in *Appendix D*). This savings figure is applied to the consumption of the *Heat Pump Water Heater* after a *Water Heater Wrap* has already been installed.

Therefore,

Energy Savings = 10% x (2,115 kWh/yr/unit - 317 kWh/yr/unit)
= 180 kWh/yr/unit

Demand savings are calculated the same way.

Fuel Switching only	Conservation only	Load Management only	Fuel Switching, Conservation, and Load Management
GAS WATER HEATER, 1992 (none) *ELECT WATER HEATER, EFFICIENT* (none) *ELECT WATER HEATER, 1992* (none)	*HEAT PUMP WATER HEATER* *Water Heater Wrap* Energy = 317 kWh/yr/unit Demand = 0.029 kW/unit *Low-flow Showerhead* Energy = 180 kWh/yr/unit Demand = 0.016 kW/unit *Water Heater Pipe Wrap* Energy = 65 kWh/yr/unit Demand = 0.006 kW/unit *Faucet Aerators* Energy = 62 kWh/yr/unit Demand = 0.006 kW/unit *Desuperheater* Energy = 60 kWh/yr/unit Demand = 0.005 kW/unit	*ELECT WATER HEATER, EFFICIENT* *Direct Load Control* Energy = 402 kWh/yr/unit Demand = 0.036 kW/unit *ELECT WATER HEATER, 1992* *Direct Load Control* Energy = 423 kWh/yr/unit Demand = 0.038 kW/unit	*GAS WATER HEATER, 1992* (none) *HEAT PUMP WATER HEATER* *Water Heater Wrap* Energy = 317 kWh/yr/unit Demand = 0.029 kW/unit *Low-flow Showerhead* Energy = 180 kWh/yr/unit Demand = 0.016 kW/unit *Water Heater Pipe Wrap* Energy = 65 kWh/yr/unit Demand = 0.006 kW/unit *Faucet Aerators* Energy = 62 kWh/yr/unit Demand = 0.006 kW/unit *Desuperheater* Energy = 60 kWh/yr/unit Demand = 0.005 kW/unit *Direct Load Control* Energy = 143 kWh/yr/unit Demand = 0.013 kW/unit

Step 10: Calculate the current and potential saturations for each add-on measure.

For each replacement measure shown in Step 7, determine the current and potential saturations for each add-on measure applied in Step 9. Details of these calculations are provided in Step 10 of the Technical Potential Formulas in *Appendix D*. The table below gives current and potential saturations for all the eligible add-on measures.

Example: The current saturation of the *Water Heater Wrap* on electric water heaters is 8% of households before any replacement takes place. In the *Conservation only* scenario, the *Heat Pump Water Heater* replaces all the existing electric water heaters. The *Water Heater Wrap* is still an eligible add-on for all the households in which this occurs. Therefore, its current saturation is still 8%, and its potential saturation is 37%. A slightly more complex example of saturation calculations for add-on measures, which further illustrates the assumptions made, is provided in Step 9 of the following section on Economic Potential.

Fuel Switching only	Conservation only	Load Management only	Fuel Switching, Conservation, and Load Management
GAS WATER HEATER, 1992 (none) ELECT WATER HEATER, EFFICIENT (none) ELECT WATER HEATER, 1992 (none)	HEAT PUMP WATER HEATER *Water Heater Wrap* Current Sat = 8% Potential Sat = 37% *Low-flow Showerhead* Current Sat = 14% Potential Sat = 37% *Water Heater Pipe Wrap* Current Sat = 0% Potential Sat = 37% *Faucet Aerators* Current Sat = 1% Potential Sat = 37% *Desuperheater* Current Sat = 0% Potential Sat = 37%	ELECT WATER HEATER, EFFICIENT *Direct Load Control* Current Sat = 0% Potential Sat = 24% ELECT WATER HEATER, 1992 *Direct Load Control* Current Sat = 0% Potential Sat = 13%	GAS WATER HEATER, 1992 (none) HEAT PUMP WATER HEATER *Water Heater Wrap* Current Sat = 3% Potential Sat = 13% *Low-flow Showerhead* Current Sat = 5% Potential Sat = 13% *Water Heater Pipe Wrap* Current Sat = 0% Potential Sat = 13% *Faucet Aerators* Current Sat = 0% Potential Sat = 13% *Desuperheater* Current Sat = 0% Potential Sat = 13% *Direct Load Control* Current Sat = 0% Potential Sat = 13%

Step 11: Calculate the savings as the add-on measures are applied throughout the eligible market.

Using the energy and demand savings shown in Step 9, the current and potential saturations shown in Step 10, and the population figures from Table 10 in *Appendix C*, calculate the total energy and demand savings for each add-on option.

Example: Energy and demand savings for the *Water Heater Wrap* are calculated using the following data:

- energy and demand savings per unit found in Step 9: 317 kWh/yr/household and 0.029 kW/household
- current and potential saturations found in Step 10: 8.4% and 37.3% (these figures are rounded in the tables)
- total population of households from Table 10 in *Appendix C*: 1,432,914 households

Therefore,

Energy Savings = 317 kWh/yr/household x (37.3% - 8.4%) x 1,432,914 households
= 131 GWh/yr

Demand Savings = 0.029 kW/household x (37.3% - 8.4%) x 1,432,914 households
= 12 MW

Fuel Switching only	**Conservation only**	**Load Management only**	**Fuel Switching, Conservation, and Load Management**
(none)	*Water Heater Wrap* Current Sat = 8% Potential Sat = 37% Energy = 131 GWh/yr Demand = 12 MW *Low-flow Showerhead* Current Sat = 14% Potential Sat = 37% Energy = 59 GWh/yr Demand = 5 MW *Water Heater Pipe Wrap* Current Sat = 0% Potential Sat = 37% Energy = 35 GWh/yr Demand = 3 MW *Faucet Aerators* Current Sat = 1% Potential Sat = 37% Energy = 32 GWh/yr Demand = 3 MW *Desuperheater* Current Sat = 0% Potential Sat = 37% Energy = 32 GWh/yr Demand = 3 MW	*Direct Load Control* Current Sat = 0% Potential Sat = 37% Energy = 219 GWh/yr Demand = 20 MW	*Water Heater Wrap* Current Sat = 3% Potential Sat = 13% Energy = 44 GWh/yr Demand = 4 MW *Low-flow Showerhead* Current Sat = 5% Potential Sat = 13% Energy = 20 GWh/yr Demand = 2 MW *Water Heater Pipe Wrap* Current Sat = 0% Potential Sat = 13% Energy = 12 GWh/yr Demand = 1 MW *Faucet Aerators* Current Sat = 0% Potential Sat = 13% Energy = 11 GWh/yr Demand = 1 MW *Desuperheater* Current Sat = 0% Potential Sat = 13% Energy = 11 GWh/yr Demand = 1 MW *Direct Load Control* Current Sat = 0% Potential Sat = 13% Energy = 26 GWh/yr Demand = 2 MW

<u>Step 12</u>: Adjust the energy and demand savings potential for differences between the base year of W-DOD and the base year of the study.

Two adjustments must be made to the results, due to the three-year difference between the base year of W-DOD (1991) and the base year of the present study (1994).* The energy and demand savings for each add-on and replacement measure are first adjusted from the base year of W-DOD (1991) to the base year of the study (1994) using base forecast growth rates from Table 6 in *Appendix C*. Next, these values are reduced to account for demand-side savings captured (through DSM programs and other sources of change) since the base year of W-DOD, using the data from Table 11 in *Appendix C*. Finally, the savings values are expressed as a percentage of total energy use and demand for the economic sector, from Table 7 in *Appendix C*.

Example: The energy and demand savings for the *Heat Pump Water Heater* are adjusted for the base forecast growth using the following data:

- energy and demand saved if all electric water heaters are replaced by *Heat Pump Water Heaters*, from Step 6: 1,057 GWh/yr and 95 MW
- the forecast growth from 1991 to 1994 in energy and demand, from Table 6 in *Appendix C*: 1.84% for energy and 2.05% for demand

Therefore,

$\text{Energy Savings}_{1994} = 1{,}057 \text{ GWh/yr} \times (1 + 0.0184)^{(1994-1991)} = 1{,}116 \text{ GWh/yr}$

$\text{Demand Savings}_{1994} = 95 \text{ MW} \times (1 + 0.0205)^{(1994-1991)} = 101 \text{ MW}$

The resulting energy and demand savings are adjusted for the demand-side savings captured since 1991, using the following additional data:

- the energy and demand savings captured between 1991 and 1994 for energy conservation measures in residential water heating, from Table 11 in *Appendix C*: 82.0 GWh/yr of energy and 9.6 MW of demand
- the total energy and demand savings for all energy conservation measures in the residential water heating end use (both single and multi-family), from Step 11: 1,430 GWh/yr of energy and 139 MW of demand

Therefore,

$\text{Energy Savings}_{adj} = 1{,}116 \text{ GWh/yr} \times (1 - (82.0 \text{ GWh/yr})/(1{,}430 \text{ GWh/yr}))$
$= 1{,}052 \text{ GWh/yr}$

$\text{Demand Savings}_{adj} = 101 \text{ MW} \times (1 - (9.6 \text{ MW})/(139 \text{ MW})) = 94 \text{ MW}$

---

* A more rigorous approach would have been to update the information in W-DOD to the current year, but this was beyond the scope of the project.

The savings percentages are then calculated using the following data:

Total energy and demand for the residential sector in the state, from Table 7 in *Appendix C*: 15,925 GWh/yr of energy and 3,429 MW of demand

Therefore,

% Energy Saved = (1,052 GWh/yr)/(15,925 GWh/yr) = 7%

% Demand Saved = (94 MW)/(3,429 MW) = 3%

Fuel Switching only	Conservation only	Load Management only	Fuel Switching, Conservation, and Load Management
Gas Water Heater, 1992 Current Sat = 0% Potential Sat = 25% Energy = 1,491 GWh/yr Energy = 9% Demand = 133 MW Demand = 4% *Heat Pump Water Heater* Current Sat = 0% Potential Sat = 0% *Solar Water Heater* Current Sat = 0% Potential Sat = 0% *Elect Water Heater, Efficient* Current Sat = 24% Potential Sat = 8% *Elect Water Heater, 1992* Current Sat = 13% Potential Sat = 4%	*Gas Water Heater, 1992* Current Sat = 0% Potential Sat = 0% *Heat Pump Water Heater* Current Sat = 0% Potential Sat = 37% Energy = 1,052 GWh/yr Energy = 7% Demand = 94 MW Demand = 3% *Solar Water Heater* Current Sat = 0% Potential Sat = 0% *Elect Water Heater, Efficient* Current Sat = 24% Potential Sat = 0% *Elect Water Heater, 1992* Current Sat = 13% Potential Sat = 0% *Water Heater Wrap* Current Sat = 8% Potential Sat = 37% Energy = 131 GWh/yr Energy = 1% Demand = 12 MW Demand = 0% *Low-flow Showerhead* Current Sat = 14% Potential Sat = 37% Energy = 59 GWh/yr Energy = 0% Demand = 5 MW Demand = 0% *Water Heater Pipe Wrap* Current Sat = 0% Potential Sat = 37% Energy = 34 GWh/yr Energy = 0% Demand = 3 MW Demand = 0% continued…	*Gas Water Heater, 1992* Current Sat = 0% Potential Sat = 0% *Heat Pump Water Heater* Current Sat = 0% Potential Sat = 0% *Solar Water Heater* Current Sat = 0% Potential Sat = 0% *Elect Water Heater, Efficient* Current Sat = 24% Potential Sat = 24% *Elect Water Heater, 1992* Current Sat = 13% Potential Sat = 13% *Direct Load Control* Current Sat = 0% Potential Sat = 37% Energy = 227 GWh/yr Energy = 1% Demand = 0 MW Demand = 0%	*Gas Water Heater, 1992* Current Sat = 0% Potential Sat = 25% Energy = 1,491 GWh/yr Energy = 9% Demand = 133 MW Demand = 4% *Heat Pump Water Heater* Current Sat = 0% Potential Sat = 13% Energy = 313 GWh/yr Energy = 2% Demand = 27 MW Demand = 1% *Solar Water Heater* Current Sat = 0% Potential Sat = 0% *Elect Water Heater, Efficient* Current Sat = 24% Potential Sat = 0% *Elect Water Heater, 1992* Current Sat = 13% Potential Sat = 0% *Water Heater Wrap* Current Sat = 3% Potential Sat = 13% Energy = 39 GWh/yr Energy = 0% Demand = 3 MW Demand = 0% *Low-flow Showerhead* Current Sat = 5% Potential Sat = 13% Energy = 17 GWh/yr Energy = 0% Demand = 1 MW Demand = 0% continued…

Fuel Switching only	Conservation only	Load Management only	Fuel Switching, Conservation, and Load Management
	…continued *Faucet Aerators* Current Sat = 1% Potential Sat = 37% Energy = 32 GWh/yr Energy = 0% Demand = 3 MW Demand = 0% *Desuperheater* Current Sat = 0% Potential Sat = 37% Energy = 32 GWh/yr Energy = 0% Demand = 3 MW Demand = 0%		…continued *Water Heater Pipe Wrap* Current Sat = 0% Potential Sat = 13% Energy = 10 GWh/yr Energy = 0% Demand = 1 MW Demand = 0% *Faucet Aerators* Current Sat = 0% Potential Sat = 13% Energy = 10 GWh/yr Energy = 0% Demand = 1 MW Demand = 0% *Desuperheater* Current Sat = 0% Potential Sat = 13% Energy = 9 GWh/yr Energy = 0% Demand = 1 MW Demand = 0% *Direct Load Control* Current Sat = 0% Potential Sat = 13% Energy = 23 GWh/yr Energy = 0% Demand = 0 MW Demand = 0%

Economic Potential

Economic potential is an estimate of energy and demand savings that are economically feasible, as calculated by the *technical cost test* (see *Appendix F* for a definition). Evaluating economic feasibility includes consideration of life cycle costs for existing and new equipment. Because it is sometimes not cost-effective to replace existing equipment until it stops functioning, equipment replacements can be assumed to take place throughout the planning period. To simplify consideration of life cycle costs, this analysis assumes that *all* technologies will be replaced within 20 years. This is a reasonable assumption because most of the technologies considered have lifetimes of less than 20 years. This assumption makes it possible to estimate the energy and demand savings expected by the end of the twentieth year.

The technical cost test used in this study does not include the avoided cost of natural gas in calculating the costs of fuel switching measures. This is because a true avoided societal cost for natural gas was not available, and its development was beyond the scope of this study. Cost savings associated with fuel switching measures may be somewhat overstated as a result.

Economic potential is calculated using two approaches, which differ in the way technologies are ranked. The first approach ranks technologies from greatest to least energy and demand savings, considering only those technologies that offer cost savings. The second approach ranks technologies from greatest to least cost savings, considering only those that offer energy and demand savings. Each approach includes a sensitivity analysis, to test the effects of changes in the avoided cost of energy. Statewide average avoided costs were calculated using avoided cost data that participating utilities provided. Seven different avoided cost scenarios are considered:

- statewide average avoided cost of energy, including the cost of SO_2 emissions
- statewide average avoided cost of energy, including the cost of both SO_2 emissions and greenhouse gas emissions
- statewide average avoided cost of energy, including SO_2 emissions, reduced by 1 cent/kWh
- statewide average avoided cost of energy, including SO_2 emissions, increased by 1 cent/kWh
- statewide average avoided cost of energy, including SO_2 emissions, increased by 2 cent/kWh
- statewide average avoided cost of energy, including SO_2 emissions, increased by 3 cent/kWh
- statewide average avoided cost of energy, including SO_2 emissions, increased by 4 cent/kWh

Method for Calculating Economic Potential

In this section, the 11 steps used in calculating the economic potential will be briefly described. The example of single family water heating from the previous section on technical potential is continued here. A table is provided after each step, showing the results of that step applied to this end use. Further details on the calculation method may be found in *Appendix D*.

Step 1: Identify a set of measures to analyze. See Step 1 in the preceding section on Technical Potential for more details.

Measure	DSM Type	Add-on/Repl	Add-on/Repl Codes
Elect Water Heater, 1992	NA	Replacement	E
Gas Water Heater, 1992	Fuel Switching	Replacement	A
Elect Water Heater, Efficient	Conservation	Replacement	D
Heat Pump Water Heater	Conservation	Replacement	B
Solar Water Heater	Conservation	Replacement	C
Water Heater Pipe Wrap	Conservation	Add-on	bcde
Water Heater Wrap	Conservation	Add-on	bcde
Desuperheater	Conservation	Add-on	bde
Low-flow Showerhead	Conservation	Add-on	bcde
Faucet Aerators	Conservation	Add-on	bcde
Direct Load Control	Load Management	Add-on	bde

Step 2: Adjust the eligibility values for fuel switching measures to reflect access to natural gas. See Step 2 in the preceding section on Technical Potential for more details.

Fuel Switching Measures
Gas Water Heater, 1992
Original Eligibility = 37%
Adjusted Eligibility = 25%

Step 3: Rank the replacement measures listed in Step 1.

Rank the replacement measures listed in Step 1 from least to greatest energy consumption and demand for the first approach, and from least to greatest cost for the second approach. The equations discussed in the following paragraphs may be found in the Economic Potential Formulas section of *Appendix D*.

> Approach 1 ranks the replacements based upon electric energy use and summer peak demand. Because energy and demand have different units (kWh versus kW), they are not directly comparable. Consequently, these components are each assigned dollar values using statewide marginal costs, allowing the relative values of energy and demand to be added. Measures with the lowest total cost are ranked highest. The results from

Equation 3e (in Appendix D) are used to generate the final ranking for this approach.

Approach 2 ranks the replacements based upon their total costs. This approach combines the energy and demand costs calculated in Equation 3e with the life cycle equipment costs calculated in Equation 3g. The results from Equation 3h, which is used to calculate total life-cycle cost of the measure, are used to generate the final ranking for this approach.

Example: Using the earlier example of the *Heat Pump Water Heater* (see Step 3 in the preceding section on Technical Potential), we note that Approach 1 ranks it in the same position as in Step 3 in the Technical Potential method. Under Approach 2, however, the high capital cost of the *Heat Pump Water Heater* moves it down to fourth position in the list.

— Approach 1 — **Maximizing Energy & Demand Savings**	**— Approach 2 —** **Maximizing Cost Savings**
A Gas Water Heater, 1992 *B* Heat Pump Water Heater *C* Solar Water Heater *D* Elect Water Heater, Efficient *E* Elect Water Heater, 1992	*A* Gas Water Heater, 1992 *D* Elect Water Heater, Efficient *E* Elect Water Heater, 1992 *B* Heat Pump Water Heater *C* Solar Water Heater

<u>Step 4</u>: Calculate the energy and demand savings per unit replaced for each replacement measure.

Calculate the energy, demand, and cost savings on a per unit basis that result if the replacement measures identified in Step 1 are used to replace the current saturations of lower ranked measures shown in Step 3. In the table below, the cost savings are based on avoided costs including both SO_2 and greenhouse gas emissions.

For Approach 1, lower ranked measures are only replaced when cost savings are zero or greater (denoted by the underscore.)

For Approach 2, lower ranked measures are only replaced when energy and demand savings are zero or greater (denoted by the underscore.)

Example: If the *Heat Pump Water Heater* is used to replace the *Elect. Water Heater, 1992*, in Approach 1 below, the energy and demand savings may be calculated using the method shown in Step 5 of the preceding section on Technical Potential. The cost savings are calculated using the following data:

- energy and demand savings per unit, as shown below
- energy consumed during each of six time periods (on- and off-peak in the summer, winter, and "shoulder" seasons), expressed as a fraction of the total energy use for the end use, from Table 12 in *Appendix C*
- avoided cost of energy in each of the six time periods, from Table 8 in *Appendix C*
- avoided cost of demand, from Table 8 in *Appendix C*
- capital cost, maintenance cost, and lifetime information from the W-DOD
- the real discount rate, from Table 6 in *Appendix C*

The calculation is complex and is therefore not shown here. For more information, consult Step 4 in the Economic Potential Formulas section of *Appendix C*.

Under Approach 1, if the *Heat Pump Water Heater* is used to replace the *Elect. Water Heater, 1992*, energy and demand savings will result but cost savings are negative. This is due to the high initial cost of the system. The replacement, therefore, does not take place.

Under Approach 2, if the *Elect. Water Heater, 1992*, is used to replace the *Heat Pump Water Heater*, cost savings will result but energy and demand savings are negative. The replacement, therefore, does not take place.

— Approach 1 — Maximizing Energy & Demand Savings		— Approach 2 — Maximizing Cost Savings	
A replaces *B*	*B* replaces *D*	*A* replaces *D*	*D* replaces *B*
Energy = 2,073 kWh/yr/unit	Energy = 1,904 kWh/yr/unit	Energy = 3,976 kWh/yr/unit	Energy = (1,904)
Demand = 0.183 kW/unit	Demand = 0.171 kW/unit	Demand = 0.354 kW/unit	kWh/yr/unit
Cost = 4,020 $/unit	Cost = (880) $/unit	Cost = 3,140 $/unit	Demand = (0.171) kW/unit
A replaces *C*	*B* replaces *E*	*A* replaces *E*	Cost = 880 $/unit
Energy = 2,200 kWh/yr/unit	Energy = 2,115 kWh/yr/unit	Energy = 4,188 kWh/yr/unit	*D* replaces *C*
Demand = 0.194 kW/unit	Demand = 0.190 kW/unit	Demand = 0.373 kW/unit	Energy = (1,777)
Cost = 7,520 $/unit	Cost = (880) $/unit	Cost = 3,140 $/unit	kWh/yr/unit
A replaces *D*	*C* replaces *D*	*A* replaces *B*	Demand = (0.160) kW/unit
Energy = 3,976 kWh/yr/unit	Energy = 1,777 kWh/yr/unit	Energy = 2,073 kWh/yr/unit	Cost = 4,380 $/unit
Demand = 0.354 kW/unit	Demand = 0.160 kW/unit	Demand = 0.183 kW/unit	*E* replaces *B*
Cost = 3,140 $/unit	Cost = (4,380) $/unit	Cost = 4,020 $/unit	Energy = (2,115)
A replaces *E*	*C* replaces *E*	*A* replaces *C*	kWh/yr/unit
Energy = 4,188 kWh/yr/unit	Energy = 1,988 kWh/yr/unit	Energy = 2,200 kWh/yr/unit	Demand = (0.190) kW/unit
Demand = 0.373 kW/unit	Demand = 0.179 kW/unit	Demand = 0.194 kW/unit	Cost = 880 $/unit
Cost = 3,140 $/unit	Cost = (4,380) $/unit	Cost = 7,520 $/unit	*E* replaces *C*
B replaces *C*	*D* replaces *E*	*D* replaces *E*	Energy = (1,988)
Energy = 127 kWh/yr/unit	Energy = 212 kWh/yr/unit	Energy = 212 kWh/yr/unit	kWh/yr/unit
Demand = 0.011 kW/unit	Demand = 0.019 kW/unit	Demand = 0.019 kW/unit	Demand = (0.179) kW/unit
Cost = 3,500 $/unit	Cost = 0 $/unit	Cost = 0 $/unit	Cost = 4,380 $/unit
			B replaces *C*
			Energy = 127 kWh/yr/unit
			Demand = 0.011 kW/unit
			Cost = 3,500 $/unit

A Gas Water Heater, 1992
B Heat Pump Water Heater
C Solar Water Heater
D Elect Water Heater, Efficient
E Elect Water Heater, 1992

Step 5: Calculate the savings and potential saturations as the replacements are carried out throughout the market.

Carry out the replacements in the order shown in Step 4, calculating energy savings, demand savings, and changing saturations for each measure. In the table below, current and potential saturations are shown for all measures. Energy and demand are shown for all replacement measures with non-zero potential saturation.

Example: The *Heat Pump Water Heater*, which replaced existing electric water heaters in the technical potential calculations, does not do so in the economic potential calculations, as seen below. Both its current and potential saturations are 0%. The *Gas Water Heater, 1992*, is the only replacement measure in this scenario which increases in saturation. The calculation method for energy and demand savings is the same as in Step 6 of the preceding section on technical potential. The cost savings calculation is similar.

— Approach 1 — Maximizing Energy & Demand Savings		— Approach 2 — Maximizing Cost Savings	
Gas Water Heater, 1992	*Solar Water Heater*	*Gas Water Heater, 1992*	*Elect Water Heater, 1992*
Current Sat = 0%	Current Sat = 0%	Current Sat = 0%	Current Sat = 13%
Potential Sat = 25%	Potential Sat = 0%	Potential Sat = 25%	Potential Sat = 1%
Energy = 1,433 GWh/yr	*Elect Water Heater, Efficient*	Energy = 1,433 GWh/yr	*Heat Pump Water Heater*
Demand = 128 MW	Current Sat = 24%	Demand = 128 MW	Current Sat = 0%
Cost = 1.11 billion $	Potential Sat = 12%	Cost = 1.14 billion $	Potential Sat = 0%
Heat Pump Water Heater	Energy = 11 GWh/yr	*Elect Water Heater, Efficient*	*Solar Water Heater*
Current Sat = 0%	Demand = 1 MW	Current Sat = 24%	Current Sat = 0%
Potential Sat = 0%	Cost = 7,000 $	Potential Sat = 12%	Potential Sat = 0%
	Elect Water Heater, 1992	Energy = 11 GWh/yr	
	Current Sat = 13%	Demand = 1 MW	
	Potential Sat = 1%	Cost = 7,000 $	

Step 6: Identify the add-on options that can be applied.

For the replacement measures having potential saturations greater than zero at the end of Step 5, identify the add-on options that can be applied to each.

Example: Recall that in Step 1, the *Add-on Code* for the *Water Heater Wrap* was *bcde*. It can therefore be added to either the *Elect. Water Heater, 1992*, or the *Elect. Water Heater, Effic.* in the table below.

— Approach 1 — Maximizing Energy & Demand Savings		— Approach 2 — Maximizing Cost Savings	
GAS WATER HEATER, 1992	*ELECT WATER HEATER, 1992*	*GAS WATER HEATER, 1992*	*ELECT WATER HEATER, 1992*
(none)	Water Heater Pipe Wrap	(none)	Water Heater Pipe Wrap
ELECT WATER HEATER,	Water Heater Wrap	*ELECT WATER HEATER, EFFICIENT*	Water Heater Wrap
EFFICIENT	Desuperheater	Water Heater Pipe Wrap	Desuperheater
Water Heater Pipe Wrap	Low-flow Showerhead	Water Heater Wrap	Low-flow Showerhead
Water Heater Wrap	Faucet Aerators	Desuperheater	Faucet Aerators
Desuperheater	Direct Load Control	Low-flow Showerhead	Direct Load Control
Low-flow Showerhead		Faucet Aerators	
Faucet Aerators		Direct Load Control	
Direct Load Control			

<u>Step 7</u>: Rank the add-on measures identified in Step 6.

For each replacement measure listed in Step 6, for the first approach rank the associated add-ons from greatest to least positive energy and demand savings, for those add-ons that offer cost savings. For the second approach, rank the add-ons associated with each replacement from greatest to least positive cost savings, for those add-ons that offer energy and demand savings. Details of how these rankings are combined are provided in Step 7 in the Economic Potential Formulas section of *Appendix D*. The ranking of water heating add-on measures is shown in the table below.

Example: The *Water Heater Wrap* has the greatest energy and demand savings of the six add-on measures listed under the *Elect Water Heater, 1992*. It also has the greatest cost savings. Some add-on items disappeared from the list since Step 6, because they did not offer positive savings.

— Approach 1 — Maximizing Energy & Demand Savings		— Approach 2 — Maximizing Cost Savings	
GAS WATER HEATER, 1992	*ELECT WATER HEATER, 1992*	*GAS WATER HEATER, 1992*	*ELECT WATER HEATER, 1992*
(none)	Water Heater Wrap	(none)	Water Heater Wrap
ELECT WATER HEATER,	Low-flow Showerhead	*ELECT WATER HEATER,*	Low-flow Showerhead
EFFICIENT	Direct Load Control	*EFFICIENT*	Faucet Aerators
Water Heater Wrap	Water Heater Pipe Wrap	Water Heater Wrap	Water Heater Pipe Wrap
Low-flow Showerhead	Faucet Aerators	Low-flow Showerhead	Direct Load Control
Direct Load Control		Faucet Aerators	
Water Heater Pipe Wrap		Water Heater Pipe Wrap	
Faucet Aerators		Direct Load Control	

<u>Step 8</u>: Calculate the energy, demand, and cost savings per unit for each add-on measure.

For each replacement measure listed in Step 6, apply the corresponding add-on measures in the order determined in Step 7. To limit the double-counting of savings, each time an add-on is applied, the energy, demand, and cost of the replacement measure is recalculated to account for these savings. When the next add-on is applied, its savings potential is applied to the new baseline energy use of the replacement. The table below gives the energy, demand, and cost savings calculated for each add-on measure.

Example: The savings per unit for the *Water Heater Wrap* can be calculated using the same method as shown in Step 9 of the preceding section on Technical Potential. Details of the cost calculation may be found in Step 8 of the Economic Potential Formulas section of *Appendix D*.

— Approach 1 — Maximizing Energy & Demand Savings		— Approach 2 — Maximizing Cost Savings	
GAS WATER HEATER, 1992	*ELECT WATER HEATER, 1992*	*GAS WATER HEATER, 1992*	*ELECT WATER HEATER, 1992*
(none)	*Water Heater Wrap*	(none)	*Water Heater Wrap*
ELECT WATER HEATER,	Energy = 635 kWh/yr/unit	*ELECT WATER HEATER,*	Energy = 635 kWh/yr/unit
EFFICIENT	Demand = 0.057 kW/unit	*EFFICIENT*	Demand = 0.057 kW/unit
Water Heater Wrap	*Low-flow Showerhead*	*Water Heater Wrap*	*Low-flow Showerhead*
Energy = 603 kWh/yr/unit	Energy = 360 kWh/yr/unit	Energy = 603 kWh/yr/unit	Energy = 360 kWh/yr/unit
Demand = 0.054 kW/unit	Demand = 0.032 kW/unit	Demand = 0.054 kW/unit	Demand = 0.032 kW/unit
Low-flow Showerhead	*Direct Load Control*	*Low-flow Showerhead*	*Faucet Aerators*
Energy = 342 kWh/yr/unit	Energy = 324 kWh/yr/unit	Energy = 342 kWh/yr/unit	Energy = 129 kWh/yr/unit
Demand = 0.031 kW/unit	Demand = 0.029 kW/unit	Demand = 0.031 kW/unit	Demand = 0.012 kW/unit
Direct Load Control	*Water Heater Heat Traps*	*Faucet Aerators*	*Water Heater Pipe Wrap*
Energy = 307 kWh/yr/unit	Energy = 204 kWh/yr/unit	Energy = 123 kWh/yr/unit	Energy = 124 kWh/yr/unit
Demand = 0.028 kW/unit	Demand = 0.018 kW/unit	Demand = 0.011 kW/unit	Demand = 0.011 kW/unit
Water Heater Pipe Wrap	*Water Heater Pipe Wrap*	*Water Heater Pipe Wrap*	*Direct Load Control*
Energy = 111 kWh/yr/unit	Energy = 116 kWh/yr/unit	Energy = 118 kWh/yr/unit	Energy = 298 kWh/yr/unit
Demand = 0.010 kW/unit	Demand = 0.010 kW/unit	Demand = 0.011 kW/unit	Demand = 0.023 kW/unit
Faucet Aerators	*Faucet Aerators*	*Direct Load Control*	
Energy = 106 kWh/yr/unit	Energy = 112 kWh/yr/unit	Energy = 283 kWh/yr/unit	
Demand = 0.010 kW/unit	Demand = 0.010 kW/unit	Demand = 0.025 kW/unit	

Step 9: Calculate the current and potential saturations for each add-on measure.

For each replacement measure shown in Step 6, determine the current and potential saturations for each add-on measure applied in Step 8. Details of these calculations are provided in Step 9 of the Economic Potential Formulas in *Appendix D*. The table below gives current and potential saturations for all of the eligible add-on measures.

Example: The current saturation of the *Water Heater Wrap* on electric water heaters is 8% of households before any replacement takes place. After the *Gas Water Heater, 1992*, has replaced many of the electric water heaters, it is assumed that the same proportion of the remaining electric water heaters still have *Water Heater Wraps*. Since the saturation of the *Elect. Water Heater, 1992*, has been reduced from 13% to 4%, the percentage of households that have a *Water Heater Wrap* on an *Elect. Water Heater, 1992*, is reduced to 1%. The potential saturation for *Water Heater Wraps* on *Elect. Water Heaters, 1992*, is 4%.

— Approach 1 — Maximizing Energy & Demand Savings		— Approach 2 — Maximizing Cost Savings	
GAS WATER HEATER, 1992	*ELECT WATER HEATER, 1992*	*GAS WATER HEATER, 1992*	*ELECT WATER HEATER, 1992*
(none)	*Water Heater Wrap*	(none)	*Water Heater Wrap*
ELECT WATER HEATER,	Current Sat = 0%	*ELECT WATER HEATER,*	Current Sat = 0%
EFFICIENT	Potential Sat = 1%	*EFFICIENT*	Potential Sat = 1%
Water Heater Wrap	*Low-flow Showerhead*	*Water Heater Wrap*	*Low-flow Showerhead*
Current Sat = 3%	Current Sat = 0%	Current Sat = 3%	Current Sat = 0%
Potential Sat = 12%	Potential Sat = 1%	Potential Sat = 12%	Potential Sat = 1%
Low-flow Showerhead	*Direct Load Control*	*Low-flow Showerhead*	*Faucet Aerators*
Current Sat = 5%	Current Sat = 0%	Current Sat = 5%	Current Sat = 0%
Potential Sat = 12%	Potential Sat = 4%	Potential Sat = 12%	Potential Sat = 1%
Direct Load Control	*Water Heater Heat Traps*	*Faucet Aerators*	*Water Heater Pipe Wrap*
Current Sat = 0%	Current Sat = 0%	Current Sat = 0%	Current Sat = 0%
Potential Sat = 12%	Potential Sat = 4%	Potential Sat = 12%	Potential Sat = 1%
Water Heater Heat Traps	*Water Heater Pipe Wrap*	*Water Heater Pipe Wrap*	*Direct Load Control*
Current Sat = 0%	Current Sat = 0%	Current Sat = 0%	Current Sat = 0%
Potential Sat = 8%	Potential Sat = 1%	Potential Sat = 12%	Potential Sat = 1%
Water Heater Pipe Wrap	*Faucet Aerators*	*Direct Load Control*	
Current Sat = 0%	Current Sat = 0%	Current Sat = 0%	
Potential Sat = 12%	Potential Sat = 1%	Potential Sat = 12%	
Faucet Aerators			
Current Sat = 0%			
Potential Sat = 12%			

Step 10: Calculate the savings as the add-on measures are applied throughout the market.

Using the energy and demand savings shown in Step 8, the current and potential saturations shown in Step 9, and the population figures from Table 10 in *Appendix C*, calculate the total energy, demand and cost savings for each add-on option.

Example: Energy and demand savings for the *Water Heater Wrap* applied to the *Elect. Water Heater, 1992*, is calculated using the following data:

- energy, demand, and cost savings per unit found in Step 8: 635 kWh/yr/household, 0.057 kW/household, and 29 $/household
- current and potential saturations found in Step 9: 1.0% and 4.5% (these figures are rounded in the tables)
- total population of households from Table 10 in *Appendix C*: 1,432,914 households

Therefore,

Energy Savings = 635 kWh/yr/household x (4.5% - 1.0%) x 1,432,914 households
= 32 GWh/yr

Demand Savings = 0.057 kW/household x (4.5% - 1.0%) x 1,432,914 households
= 3 MW

Cost Savings = 29 $/household x (4.5% - 1%) x 1,432,914 households
= 1,450,000 $

The additional savings attributed to the *Water Heater Wrap* in the table are from applying it to the *Elect. Water Heater, Effic.*

— Approach 1 — Maximizing Energy & Demand Savings		**— Approach 2 — Maximizing Cost Savings**	
Water Heater Wrap	*Water Heater Pipe Wrap*	*Water Heater Wrap*	*Water Heater Pipe Wrap*
Current Sat = 3%	Current Sat = 0%	Current Sat = 3%	Current Sat = 0%
Potential Sat = 13%	Potential Sat = 13%	Potential Sat = 13%	Potential Sat = 13%
Energy = 86 GWh/yr	Energy = 20 GWh/yr	Energy = 85 GWh/yr	Energy = 21 GWh/y
Demand = 8 MW	Demand = 2 MW	Demand = 8 MW	Demand = 2 MW
Cost = 73,000,000 $	Cost = 25,000,000 $	Cost = 73,000,000 $	Cost = 25,000,000 $
Low-flow Showerhead	*Faucet Aerators*	*Low-flow Showerhead*	
Current Sat = 5%	Current Sat = 0%	Current Sat = 5%	
Potential Sat = 13%	Potential Sat = 13%	Potential Sat = 13%	
Energy = 38 GWh/yr	Energy = 19 GWh/yr	Energy = 38 GWh/yr	
Demand = 3 MW	Demand = 2 MW	Demand = 3 MW	
Cost = 38,000,000 $	Cost = 25,000,000 $	Cost = 38,000,000 $	
Direct Load Control		*Faucet Aerators*	
Current Sat = 0%		Current Sat = 0%	
Potential Sat = 13%		Potential Sat = 13%	
Energy = 56 GWh/yr		Energy = 22 GWh/yr	
Demand = 5 MW		Demand = 2 MW	
Cost = 20,000,000 $		Cost = 25,000,000 $	

Step 11: Adjust the energy, demand, and cost savings potential for differences between the base year of W-DOD and the base year of the study.

This step is essentially the same as Step 12 in the preceding section on Technical Potential for more details. Further details on the calculations may be found in Step 11 of the Economic Potential Formulas section of *Appendix D*.

— Approach 1 — Maximizing Energy & Demand Savings		**— Approach 2 — Maximizing Cost Savings**	
Gas Water Heater, 1992	*Low-flow Showerhead*	*Gas Water Heater, 1992*	*Low-flow Showerhead*
Current Sat = 0%	Current Sat = 5%	Current Sat = 0%	Current Sat = 5%
Potential Sat = 25%	Potential Sat = 13%	Potential Sat = 25%	Potential Sat = 13%
Energy = 1,491 GWh/yr	Energy = 22 GWh/yr	Energy = 1,491 GWh/yr	Energy = 22 GWh/yr
Energy = 9%	Energy = 0%	Energy = 9%	Energy = 0%
Demand = 133 MW	Demand = 2 MW	Demand = 133 MW	Demand = 2 MW
Demand = 4%	Demand = 0%	Demand = 4%	Demand = 0%
Cost = 1,178,000,000 $	Cost = 22,000,000 $	Cost = 1,178,000,000 $	Cost = 23,000,000 $
Heat Pump Water Heater	*Direct Load Control*	*Elect Water Heater, Efficient*	*Faucet Aerators*
Current Sat = 0%	Current Sat = 0%	Current Sat = 24%	Current Sat = 0%
Potential Sat = 0%	Potential Sat = 13%	Potential Sat = 12%	Potential Sat = 13%
Solar Water Heater	Energy = 55 GWh/yr	Energy = 6 GWh/yr	Energy = 13 GWh/yr
Current Sat = 0%	Energy = 0%	Energy = 0%	Energy = 0%
Potential Sat = 0%	Demand = 0 MW	Demand = 0 MW	Demand = 1 MW
Elect Water Heater, Efficient	Demand = 0%	Demand = 0%	Demand = 0%
Current Sat = 24%	Cost = 25,000,000 $	Cost = 1,000,000 $	Cost = 15,000,000 $
Potential Sat = 12%	*Water Heater Pipe Wrap*	*Elect Water Heater, 1992*	*Water Heater Pipe Wrap*
Energy = 6 GWh/yr	Current Sat = 0%	Current Sat = 13%	Current Sat = 0%
Energy = 0%	Potential Sat = 13%	Potential Sat = 1%	Potential Sat = 13%
Demand = 0 MW	Energy = 12 GWh/yr	*Heat Pump Water Heater*	Energy = 11 GWh/yr
Demand = 0%	Energy = 0%	Current Sat = 0%	Energy = 0%
Cost = 1,000,000 $	Demand = 1 MW	Potential Sat = 0%	Demand = 1 MW
Elect Water Heater, 1992	Demand = 0%	*Solar Water Heater*	Demand = 0%
Current Sat = 13%	Cost = 14,000,000 $	Current Sat = 0%	Cost = 15,000,000 $
Potential Sat = 1%	*Faucet Aerators*	Potential Sat = 0%	
Water Heater Wrap	Current Sat = 0%	*Water Heater Wrap*	
Current Sat = 3%	Potential Sat = 13%	Current Sat = 3%	
Potential Sat = 13%	Energy = 11 GWh/yr	Potential Sat = 13%	
Energy = 49 GWh/yr	Energy = 0%	Energy = 50 GWh/yr	
Energy = 0%	Demand = 1 MW	Energy = 0%	
Demand = 3 MW	Demand = 0%	Demand = 3 MW	
Demand = 0%	Cost = 15,000,000 $	Demand = 0%	
Cost = 42,000,000 $		Cost = 43,000,000 $	

SUMMARY OF THE RESULTS

Appendices A and B present the final results. Each page consists of a table followed by two charts. The table shows absolute energy and demand savings potential, and the two charts show these savings potentials relative to the usage for the entire state or for the economic sector being considered.

A complete set of the results, containing the information calculated as shown in Step 12 of the Technical Potential section and Step 11 of the Economic Potential section, is available to those with access to W-DOD. These tables can be downloaded using the Center's on-line service.*

The results presented in this report are disaggregated to only the point of individual end uses. The STEP analysis was not intended to assess the DSM potential of individual technologies, and the results should not be used for that purpose.

Technical & Economic Potential Compared

In this study, technical potential is assumed to be achieved immediately, while economic potential is achieved gradually over 20 years. Figures 1 and 2 illustrate these potential impacts on the statewide load over the planning period and compare these to the baseline energy consumption and demand, including expected growth during the period. Note that technical and economic potential savings are comparable only at the end of the planning period because it is assumed that only then has the full economic potential been reached. Consequently, Table 1 compares technical and economic potential on a relative basis instead of an absolute basis.

* For more information, contact the Wisconsin Center for Demand-Side Research, 595 Science Drive, Suite A, Madison, Wisconsin 53711 (phone: 608/238-4601).

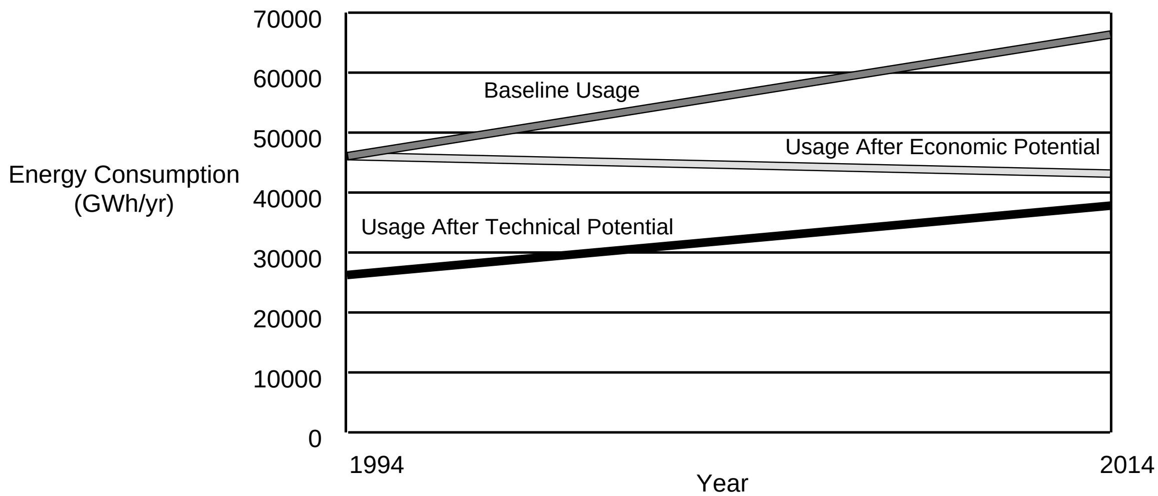

Figure 1 Energy consumption over the planning period

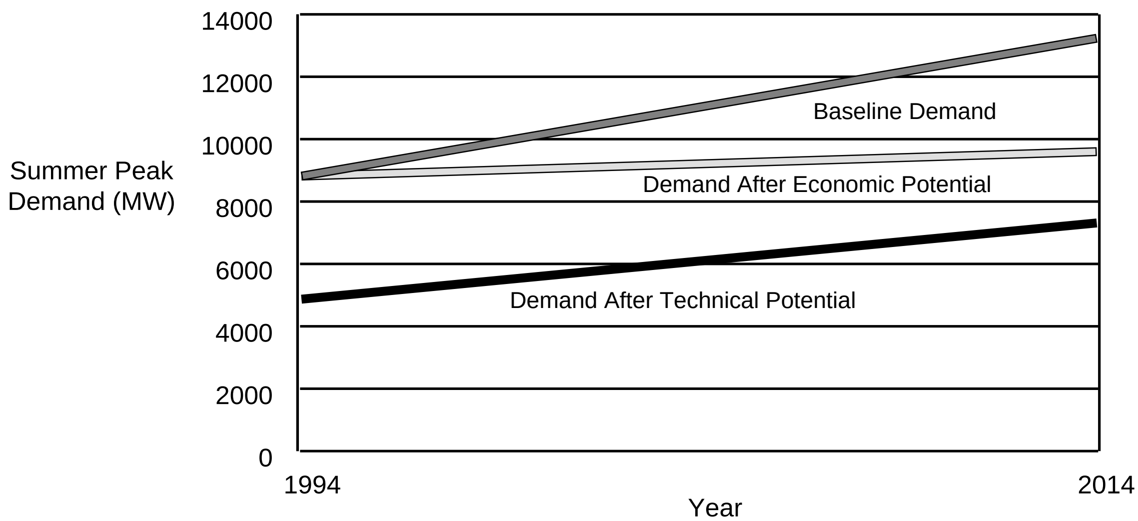

Figure 2 Summer peak demand over the planning period

Sector	Energy Consumption Technical Potential	Energy Consumption Economic Potential*	Summer Peak Demand Technical Potential	Summer Peak Demand Economic Potential*
Agricultural	1%	0%	0%	0%
Commercial	14%	11%	16%	12%
Industrial	9%	7%	16%	5%
Residential	20%	17%	12%	10%
TOTAL	43%	35%	45%	27%

Table 1 A comparison of technical and economic potential†

* The economic potential used in this table is based on maximization of energy and demand savings, and includes the cost of both SO_2 and greenhouse gas emissions.

† The percentages in this table are percentage of total statewide consumption or demand.

Technical Potential

The technical potential for electrical energy consumption savings in Wisconsin estimated by this study is 20,000 GWh/yr, or 43% of total statewide electrical energy consumption. The technical potential for summer peak demand savings in Wisconsin estimated by this study is 3,900 MW, or 45% of total statewide summer peak demand.

This analysis considers four scenarios. Tables 2 and 3 compare the energy and demand savings estimated for each scenario and express them as a percentage of the total consumption or demand for the state. The table shows that the savings potential when considering all measures is usually less than the sum of the savings potentials for each of the categories separately. This is because the *All measures* scenario forces the *fuel switching*, *conservation*, and *load management* measures to compete against each other.

Sector	considering ALL measures together	considering Fuel Switching measures only	considering Conservation measures only	considering Load Management measures only
Agricultural	1%	0%	1%	0%
Commercial	14%	3%	12%	0%
Industrial	9%	1%	10%	-2%
Residential	20%	10%	14%	1%
TOTAL	43%	14%	36%	-1%

Table 2 Technical Potential—Energy savings by scenario

Sector	considering ALL measures together	considering Fuel Switching measures only	considering Conservation measures only	considering Load Management measures only
Agricultural	0%	0%	0%	0%
Commercial	16%	4%	13%	3%
Industrial	16%	1%	4%	11%
Residential	12%	4%	9%	3%
TOTAL	45%	9%	27%	17%

Table 3 Technical Potential—Demand savings by scenario

Economic Potential

Economic potential is estimated for two approaches: (1) maximizing *energy and demand savings* that are cost effective and (2) maximizing *cost savings* that save energy and demand. Also, these approaches are analyzed for two sets of avoided costs: (1) costs that include only SO_2 adders and (2) costs that include SO_2 as well as greenhouse gas adders.

The presentation of the economic potential results is similar to that of the technical potential, in order to make them easily comparable. Economic potential is achieved gradually: the results presented are those for the entire 20-year planning period.

Maximizing energy and demand savings

Using Approach 1 and the avoided cost scenario that includes adders for both SO_2 and greenhouse gas, the economic potential for electrical energy consumption savings in Wisconsin estimated by this study is 35% by the end of the planning period. The economic potential for summer peak demand savings in Wisconsin estimated by this study is 27% by the end of the planning period.

Table 4 compares savings for avoided energy costs that include SO_2 with those that include both SO_2 and greenhouse gas. The percentages shown in the table reflect savings of total statewide consumption or demand by the end of the planning period.

	Energy Savings		Summer Peak Demand Savings	
Sector	**SO_2**	**SO_2 plus greenhouse gas**	**SO_2**	**SO_2 plus greenhouse gas**
Agricultural	0%	0%	0%	0%
Commercial	10%	11%	12%	12%
Industrial	6%	7%	4%	5%
Residential	14%	17%	10%	10%
TOTAL	30%	35%	26%	27%

Table 4 Savings by avoided cost of energy—economic potential, maximizing energy and demand savings

Maximizing cost savings

Using Approach 2 and the avoided cost scenario that includes adders for both SO_2 and greenhouse gas, the economic potential for electrical energy consumptions savings in Wisconsin estimated by this study is 35% by the end of the planning period. The economic potential for summer peak demand savings in Wisconsin estimated by this study is 28% by the end of the planning period.

Table 5 compares savings for avoided energy costs that include SO_2 with those that include SO_2 and greenhouse gas. The percentages shown in the table reflect savings of total statewide consumption or demand by the end of the planning period.

	Energy Savings		Summer Peak Demand Savings	
Sector	**SO_2**	**SO_2 plus greenhouse gas**	**SO_2**	**SO_2 plus greenhouse gas**
Agricultural	0%	0%	0%	0%
Commercial	10%	11%	11%	12%
Industrial	6%	7%	4%	5%
Residential	14%	17%	10%	10%
TOTAL	30%	35%	26%	28%

Table 5 Savings by avoided cost of energy—economic potential, maximizing cost savings

APPENDIX A: RESULTS, TECHNICAL POTENTIAL

The following pages present the findings of the technical potential analysis. The results portray four scenarios,

considering:

APPENDIX B: RESULTS, ECONOMIC POTENTIAL

The following pages present the findings of the economic potential analysis. The results portray two approaches:

Maximizing cost effective energy and demand savings for:

avoided costs that include SO_2 costs
Page 40

avoided costs that include SO_2 and greenhouse gas costs
Page 50

a range of avoided costs
Page 60

Maximizing cost savings:

avoided costs that include SO_2 costs
Page 65

avoided costs that include SO_2 and greenhouse gas costs
Page 75

a range of avoided costs
Page 85

APPENDIX C: INPUT DATA

The information necessary to perform this technical and economic potential calculation is contained in eight tables. The remainder of this appendix lists and defines the contents of these tables. The contents of W-DOD are not listed due to their proprietary nature.

Economic and Forecast Information

Table 6 lists the economic and forecast information used in this calculation.

Description	Value
Base year of this study	1994
Base year of W-DOD	1991
Inflation Rate (1991 through 1993)	0.00%
Planning Period	20 years
Discount Rate (1994 through 2013)	5.50%
Energy Forecast Growth Rate	1.84%
Demand Forecast Growth Rate	2.05%
Energy Adder A	-1 cent/kWh
Energy Adder B	+1 cent/kWh
Energy Adder C	+2 cents/kWh
Energy Adder D	+3 cents/kWh
Energy Adder E	+4 cents/kWh

Table 6 Economic and forecast information

Base year of this study

This calculation of technical and economic potential uses 1994 as the base year because utility programs for 1993 are already in progress.

Base year of W-DOD

The Wisconsin Demand-Side Options Database contains data representative of 1991. Consequently, load impacts are adjusted to the base year using forecast growth rates and DSM capture rates. Capital and maintenance cost information in W-DOD was not adjusted for the difference between the two base years (see *inflation rate* below).

Inflation rate

The STEP method, as implemented, has the capability to escalate W-DOD's cost information from its base year of 1991 to the base year of the study, 1994. The committee that developed the method selected an inflation rate of zero percent for the purposes of this study. This was determined because, although the capital and maintenance costs of some technologies increased from 1991 to 1994, the costs of others decreased. Rather than conduct an extensive review of costs for all technologies, the committee decided to use the 1991 costs unaltered.

Planning period

The planning period for this study is 20 years—from the start of the base year, 1994, until the end of 2013.

Discount rate

This study uses a real discount rate to discount cash flows to the base year of the study, 1994. This discount rate is furnished by Wisconsin's Financial Analysis Task Force.

Energy & Demand forecast growth rates

This study assumes that Wisconsin's demand for energy and peak generating capacity will grow at constant rates of 1.84% and 2.05%, respectively. This analysis assumes that energy and demand savings potential will grow at these same rates. These values are furnished by Wisconsin's Forecasting Data Approval Group.

Adders to the avoided cost of energy

The five adders, listed A through E in Table 6, are used for the sensitivity analysis performed as part of the economic potential calculation. These adders have the units of cents/kWh because they are applied to the avoided cost of *energy*. Adders are not applied to the avoided costs of *demand* for two reasons: (1) a single set of adders limits the complexity of the sensitivity analysis to one variable and (2) the *energy* portion of the avoided cost (which accounts for variable costs) is more uncertain than the *demand* portion (which accounts for fixed costs).

Total Energy and Demand by Economic Sector

Table 7 lists the total annual energy consumption and summer peak demand for each economic sector.

Economic Sector	Annual Energy (GWh)	Summer Peak Demand (MW)
Agricultural	1,599	335
Commercial	14,975	3,206
Industrial	21,360	3,367
Residential	15,925	3,429

Table 7 Total energy, demand, and losses

The annual energy values contained in this table reflect Wisconsin's total electrical energy consumption by economic sector for the year 1994. Likewise, the demand values reflect Wisconsin's summer peak electrical demand for each economic sector.

Avoided Costs for Energy and Demand

Table 8 lists avoided costs for two scenarios—one set of costs accounts for SO_2 emissions, while the other set accounts for SO_2 plus greenhouse gas emissions. The energy costs vary by time period.

Description/Time Period	Avoided Costs including SO_2 emissions	Avoided Costs including SO_2 & Greenhouse gas emissions
Summer Peak Demand	72.67 $/kW-yr	72.67 $/kW-yr
Summer: on-peak	2.772 cents/kWh	4.471 cents/kWh
Summer: off-peak	1.767 cents/kWh	3.388 cents/kWh
Winter: on-peak	3.129 cents/kWh	4.796 cents/kWh
Winter: off-peak	2.187 cents/kWh	3.792 cents/kWh
Spring/Fall: on-peak	2.803 cents/kWh	4.420 cents/kWh
Spring/Fall: off-peak	1.937 cents/kWh	3.556 cents/kWh

Table 8 Avoided costs for energy and demand

The values found in the table are based upon marginal cost estimates furnished by Wisconsin utilities representing avoided energy costs at the generator and avoided capacity costs for generation. Nearly all of the participating utilities furnished 15-minute marginal energy cost data for the 20-year planning period, for both scenarios. The cost estimates were reported in 1994 dollars. The avoided costs for demand in Table 8 include the reductions in investment in new electric transmission and distribution facilities.

Using the scheme shown in Table 9, the marginal cost data for each utility were organized by seasonal on- and off-peak time periods. (These time periods do not necessarily portray each individual utility's system load shape.) For each utility, a table was constructed of average costs for each time period and for each year of the planning period. The values for each time period were averaged to develop a table similar to Table 8 for each utility. Then the numbers for each utility were combined using a weighted average based upon each utility's share of the statewide demand.

Time Period	Months	Hours
Summer: on-peak	June through September	9 am to 9 pm*
Summer: off-peak	June through September	all other times
Winter: on-peak	December through March	9 am to 9 pm
Winter: off-peak	December through March	all other times
Spring/Fall: on-peak	April, May, October, November	9 am to 9 pm
Spring/Fall: off-peak	April, May, October, November	all other times

*Weekdays only

Table 9 Seasonal on- and off-peak time periods

End Use Specific Information

Table 10 provides population estimates for Wisconsin. For instance, there are 1,432,914 single family households in Wisconsin. As another example, the industrial sector demands 798,750 Hp of compressed air. Populations are essential for estimating the total potential for saving energy and demand in the state. This information is supplied by Wisconsin's Load Forecasting Task Force.

Economic Sector	Market Segment or End Use	Units	Population	Economic Sector	Market Segment or End Use	Units	Population
	All Farms	Farm	82,316		Air Conditioning	Ton	293,047
	Brooder Farms	Lamp	157,775		Compressed Air	Hp	798,750
	Dairy Farms	Farm	34,421		Drying Fans	Hp	768,968
Agricultural	Dairy Farms	Lamp	688,421		Freezer Control	kW	19,996
	Irrigation	Well	2,103		General Mechanical	kW	151,966
	Other Farms	Farm	47,895		Hydraulics	Hp	53,012
	Other Farms	Lamp	957,895		Lighting	Lamp	5,906,003
	College	KSF	64,641	Industrial	Materials Handling	Hp	256,124
	Grocery	KSF	26,888		Motors	Hp	2,648,802
	Health	KSF	79,879		Process Cooling	Hp	647,458
	Lodging	KSF	39,899		Pumping	Hp	1,330,059
	Miscellaneous	KSF	217,164		Refrigeration	kW	100,867
Commercial	Office	KSF	215,318		Space Heating	kW	51,100
	Restaurant	KSF	54,036		Total Facility	kW	2,943,000
	Retail	KSF	180,186		Ventilation	Hp	268,395
	School	KSF	133,725	Residential	Multi-family	HH	422,062
	Warehouse	KSF	176,871		Single Family	HH	1,432,914

Table 10 Populations

Table 11 provides estimates of the energy and demand savings achieved between the base year of W-DOD, 1991, and the base year of this study, 1994. These estimates are used to reduce W-DOD's savings estimates because they do not account for savings that may have been achieved by 1994.

Table 11 was developed using data from the demand-side tables produced by Wisconsin's Demand Side Management Task Force (DSMTF) as part of their Advance Plan filing process. DSMTF's tables included historical demand-side savings in the column labeled *1991 and before*. The values in Table 11, however, are intended to include only the savings captured between 1991 and 1993 inclusive. Therefore, to exclude the pre-1991 savings for each end use, DSMTF's *1991 and before* figure for energy was multiplied by 29.0%. The figure for demand was multiplied by 20.1%. These multipliers were calculated by dividing the total savings for 1991 by the total savings for 1991 and before. (Pre-1992 figures disagreggated by end use were not available.) The 1991 results were then added to the 1992 and 1993 figures to obtain the 1991-1993 savings captured.

In many cases, the end use classifications corresponded exactly to the end uses in this study. Thus, the 1991-1993 savings attributed to residential water heating by DSMTF could be entered in Table 11 without change. In cases where a DSMTF end use corresponds to several end uses in the present study, the savings had to be distributed. For example, the residential appliance end use in DSMTF's demand-side tables includes both the clothes drying and cooking end uses in this study. The savings were divided between them in proportion to the economic potentials for these two end uses, as calculated in an earlier draft of this study. The resulting savings figures were entered in Table 11.

A more rigorous approach would have been to iterate, using the new economic potential results to modify the captured savings figures Table 11 and then using these new captured savings figures to repeat the potential calculations. This approach was not used because it was expected that it would not have a large enough effect on the results to change the two significant figures reported.

Market Sector	End Use	Captured Energy (GWh/yr) Fuel Switching	Captured Energy (GWh/yr) Conservation	Captured Energy (GWh/yr) Load Management	Captured Demand (MW) Fuel Switching	Captured Demand (MW) Conservation	Captured Demand (MW) Load Management
Agricultural	Irrigation	0.0	0.0	0.0	0.0	0.0	0.0
	Lighting	0.0	6.6	0.0	0.0	0.9	0.0
	Other/General	0.0	16.1	0.0	0.0	0.0	0.0
	Process Related	0.0	0.0	0.0	0.0	0.0	0.0
	Stock Watering	0.0	2.1	0.0	0.0	0.0	0.0
	Ventilation	0.0	2.1	0.0	0.0	4.4	0.1
	Water Heating	0.0	10.7	0.0	0.0	0.9	0.0
Commercial	Air Conditioning	0.6	64.8	0.4	0.7	26.8	1.6
	Cooking	1.0	1.4	0.0	0.2	0.6	0.0
	Lighting	0.0	588.3	0.0	0.0	124.9	0.0
	Refrigeration	0.0	38.2	0.0	0.4	5.7	0.0
	Space Heating	0.5	9.6	0.0	0.0	0.2	0.0
	Ventilation	0.0	10.9	0.0	0.0	0.6	0.0
	Water Heating	0.7	13.8	0.0	0.3	2.3	0.0
Industrial	Air Conditioning	0.0	3.5	0.0	0.0	1.1	0.0
	Compressed Air	0.8	15.4	0.1	0.3	2.5	0.1
	Drying Fans	2.7	50.8	0.4	0.5	4.6	0.3
	Freezer Control	0.0	0.0	0.0	0.0	0.0	0.0
	General Mechanical	0.0	0.5	0.0	0.0	0.3	0.0
	Hydraulics	0.0	0.4	0.0	0.0	0.1	0.0
	Lighting	0.0	154.9	0.0	0.0	23.0	0.0
	Materials Handling	2.3	41.7	0.3	0.8	6.7	0.4
	Motors	0.0	60.7	0.0	0.0	14.0	0.0
	Process Cooling	0.6	10.4	0.1	0.0	0.0	0.0
	Pumping	0.5	10.0	0.1	0.2	1.6	0.1
	Refrigeration	0.5	8.7	0.1	0.2	1.4	0.1
	Space Heating	0.0	6.3	0.0	0.0	1.9	0.0
	Total Facility	0.0	0.0	0.0	0.0	0.0	0.0
	Ventilation	0.2	4.2	0.0	0.1	0.7	0.0
Residential	Building Shell	0.0	0.3	0.1	0.0	0.2	0.2
	Clothes Drying	2.4	7.2	0.0	0.2	0.3	0.0
	Cooking	1.5	4.4	0.0	0.6	0.8	0.0
	Dehumidification	0.0	3.7	0.8	0.0	2.5	6.3
	Freezing	0.0	93.0	0.0	0.0	12.0	0.0
	Lighting	0.0	95.0	0.1	0.0	8.0	0.0
	Outdoor Lighting	0.0	107.0	0.1	0.0	9.0	0.0
	Refrigeration	0.0	148.0	0.0	0.0	20.0	0.0
	Space Cooling	0.0	45.5	0.6	0.0	86.0	105.5
	Space Heating	0.5	18.6	0.0	0.0	0.7	0.0
	Swimming Pool	0.0	0.0	0.0	0.0	0.4	0.3
	Water Heating	23.4	82.0	4.0	2.7	9.6	26.5
	Waterbed Heating	0.0	3.9	1.6	0.0	0.0	0.0

Table 11 Captured energy and demand

Table 12 provides load shape information, showing the seasonal on- and off-peak distribution of energy consumption for each end use. This distribution is in the form of fractions such that the six numbers should add up to 1.00. These fractions are used in conjunction with the avoided costs of energy which vary according to the same six time periods. This information also includes a ratio for converting an end use's annual energy use (in kWh/yr) to its corresponding summer peak demand (in kW). Because Wisconsin is, on average, a summer peaking state, summer peak demand offers the greatest potential savings. This table is based upon the table developed as part of the 1990 technical and economic potential study.

Description	Data				
Economic Sector	Agricultural	Commercial	Commercial	Commercial	Commercial
Market Segment	ALL	College	College	College	College
End Use	ALL	Air Conditioning	Cooking	Lighting	Space Heating
Summer: on-peak	0.170686	0.373303	0.21134	0.148718	0
Summer: off-peak	0.188705	0.334656	0.075428	0.128611	0
Winter: on-peak	0.143537	0	0.283884	0.205765	0.056968
Winter: off-peak	0.179216	0	0.100015	0.183674	0.752086
Spring/Fall: on-peak	0.144008	0.150924	0.243304	0.18013	0.00865
Spring/Fall: off-peak	0.173845	0.141114	0.086027	0.1531	0.182294
Summer: D/E ratio	0.000235	0.000563	0.000229	0.000114	0

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	College	College	Grocery	Grocery	Grocery
End Use	Ventilation	Water Heating	Air Conditioning	Cooking	Lighting
Summer: on-peak	0.099157	0.161766	0.475959	0.142154	0.144631
Summer: off-peak	0.189206	0.083808	0.372557	0.189471	0.185224
Winter: on-peak	0.124754	0.282923	0	0.188683	0.150417
Winter: off-peak	0.228938	0.144834	0	0.152405	0.191536
Spring/Fall: on-peak	0.127248	0.213179	0.084291	0.182556	0.143224
Spring/Fall: off-peak	0.230694	0.113487	0.067191	0.144729	0.184965
Summer: D/E ratio	0.000112	0.000175	0.000986	0.000213	0.000145

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	Grocery	Grocery	Grocery	Grocery	Health
End Use	Refrigeration	Space Heating	Ventilation	Water Heating	Air Conditioning
Summer: on-peak	0.128956	0	0.114715	0.083673	0.294316
Summer: off-peak	0.231323	0	0.194726	0.208322	0.466237
Winter: on-peak	0.108692	0.198779	0.123048	0.202166	0.004585
Winter: off-peak	0.198827	0.552073	0.229299	0.181121	0.003112
Spring/Fall: on-peak	0.116504	0.044329	0.117163	0.167311	0.087217
Spring/Fall: off-peak	0.215695	0.204817	0.221046	0.157404	0.14453
Summer: D/E ratio	0.000146	0	0.000129	0.000139	0.000484

Table 12a Load shape information

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	Health	Health	Health	Health	Health
End Use	Cooking	Lighting	Space Heating	Ventilation	Water Heating
Summer: on-peak	0.156706	0.140097	0	0.138247	0.104754
Summer: off-peak	0.182685	0.191377	0	0.229203	0.324529
Winter: on-peak	0.146866	0.143596	0.171549	0.103454	0.043852
Winter: off-peak	0.190351	0.207079	0.592708	0.201067	0.083529
Spring/Fall: on-peak	0.146795	0.130572	0.032051	0.116526	0.138686
Spring/Fall: off-peak	0.176595	0.187277	0.20369	0.211499	0.304647
Summer: D/E ratio	0.000131	0.000142	0	0.000157	0.000043

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	Lodging	Lodging	Lodging	Lodging	Lodging
End Use	Air Conditioning	Cooking	Lighting	Space Heating	Ventilation
Summer: on-peak	0.310059	0.115441	0.113742	0	0.097422
Summer: off-peak	0.501012	0.166727	0.167058	0	0.164495
Winter: on-peak	0	0.158586	0.154186	0.152493	0.133456
Winter: off-peak	0	0.214151	0.21938	0.606131	0.249772
Spring/Fall: on-peak	0.068484	0.142818	0.139899	0.01884	0.122364
Spring/Fall: off-peak	0.120443	0.202274	0.205733	0.222534	0.232488
Summer: D/E ratio	0.000554	0.000077	0.000106	0	0.000112

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	Lodging	Miscellaneous	Miscellaneous	Miscellaneous	Miscellaneous
End Use	Water Heating	Air Conditioning	Cooking	Lighting	Space Heating
Summer: on-peak	0.084185	0.475158	0.126607	0.155644	0
Summer: off-peak	0.165432	0.317419	0.1577	0.125701	0
Winter: on-peak	0.169765	0	0.233374	0.22229	0.199251
Winter: off-peak	0.24138	0	0.127521	0.138443	0.632836
Spring/Fall: on-peak	0.133026	0.127908	0.19873	0.205127	0.024539
Spring/Fall: off-peak	0.20621	0.079513	0.156066	0.152793	0.143373
Summer: D/E ratio	0.000062	0.000893	0.000196	0.000188	0

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	Miscellaneous	Miscellaneous	Office	Office	Office
End Use	Ventilation	Water Heating	Air Conditioning	Cooking	Lighting
Summer: on-peak	0.083032	0.13238	0.27877	0.216598	0.180187
Summer: off-peak	0.175857	0.121062	0.300447	0.126804	0.162859
Winter: on-peak	0.118265	0.248729	0.053643	0.222558	0.177332
Winter: off-peak	0.243718	0.146505	0.066279	0.111821	0.153752
Spring/Fall: on-peak	0.111586	0.20126	0.132634	0.209501	0.169914
Spring/Fall: off-peak	0.26754	0.150061	0.168224	0.112716	0.155953
Summer: D/E ratio	0.000094	0.000159	0.000494	0.00035	0.000184

Table 12b Load shape information

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	Office	Office	Office	Restaurant	Restaurant
End Use	Space Heating	Ventilation	Water Heating	Air Conditioning	Cooking
Summer: on-peak	0	0.127821	0.141534	0.381696	0.166029
Summer: off-peak	0	0.221546	0.166567	0.425077	0.173341
Winter: on-peak	0.137014	0.113337	0.229309	0	0.165248
Winter: off-peak	0.63925	0.200166	0.141871	0	0.161691
Spring/Fall: on-peak	0.011688	0.11916	0.179919	0.095153	0.162029
Spring/Fall: off-peak	0.212045	0.217967	0.140797	0.098072	0.171659
Summer: D/E ratio	0	0.000141	0.000121	0.000806	0.000177

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	Restaurant	Restaurant	Restaurant	Restaurant	Retail
End Use	Lighting	Space Heating	Ventilation	Water Heating	Air Conditioning
Summer: on-peak	0.151718	0	0.111776	0.096096	0.409298
Summer: off-peak	0.186389	0	0.204519	0.204076	0.274967
Winter: on-peak	0.155639	0.0554	0.113404	0.169829	0
Winter: off-peak	0.171919	0.757149	0.22495	0.198027	0
Spring/Fall: on-peak	0.151314	0.001361	0.112525	0.128955	0.213084
Spring/Fall: off-peak	0.183019	0.186088	0.232823	0.203013	0.102649
Summer: D/E ratio	0.000198	0	0.000168	0.000114	0.000703

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	Retail	Retail	Retail	Retail	Retail
End Use	Cooking	Lighting	Space Heating	Ventilation	Water Heating
Summer: on-peak	0.177975	0.155546	0	0.114541	0.136181
Summer: off-peak	0.142544	0.163415	0	0.184883	0.14568
Winter: on-peak	0.220394	0.172622	0.152892	0.129917	0.239453
Winter: off-peak	0.136295	0.185437	0.635507	0.237423	0.160897
Spring/Fall: on-peak	0.161241	0.152149	0.008048	0.115021	0.153382
Spring/Fall: off-peak	0.161549	0.170829	0.203551	0.218212	0.164405
Summer: D/E ratio	0.000172	0.000183	0	0.000141	0.000085

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	School	School	School	School	School
End Use	Air Conditioning	Cooking	Lighting	Space Heating	Ventilation
Summer: on-peak	0.599483	0.200489	0.146725	0	0.101367
Summer: off-peak	0.117023	0.047162	0.117788	0	0.174362
Winter: on-peak	0	0.292911	0.211347	0.172017	0.130544
Winter: off-peak	0	0.076823	0.164442	0.597914	0.249983
Spring/Fall: on-peak	0.241368	0.307454	0.210591	0.08607	0.116276
Spring/Fall: off-peak	0.042124	0.075158	0.149105	0.143998	0.227465
Summer: D/E ratio	0.001185	0.000248	0.000142	0	0.000069

Table 12c Load shape information

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Commercial	Commercial
Market Segment	School	Warehouse	Warehouse	Warehouse	Warehouse
End Use	Water Heating	Air Conditioning	Cooking	Lighting	Refrigeration
Summer: on-peak	0.131909	0.634236	0.253246	0.212593	0.126995
Summer: off-peak	0.085769	0.275564	0.083048	0.137837	0.215561
Winter: on-peak	0.263456	0	0.25598	0.19543	0.121699
Winter: off-peak	0.15066	0	0.099794	0.127983	0.207912
Spring/Fall: on-peak	0.24235	0.069853	0.214627	0.19503	0.123603
Spring/Fall: off-peak	0.125855	0.020345	0.093301	0.131124	0.204228
Summer: D/E ratio	0.000031	0.002265	0.000333	0.000286	0.000146

Description	Data				
Economic Sector	Commercial	Commercial	Commercial	Industrial	Residential
Market Segment	Warehouse	Warehouse	Warehouse	ALL	Multi-family
End Use	Space Heating	Ventilation	Water Heating	ALL	Clothes Drying
Summer: on-peak	0	0.127203	0.252719	0.147045	0.103101
Summer: off-peak	0	0.199678	0.067335	0.188794	0.168656
Winter: on-peak	0.389109	0.123328	0.289588	0.143625	0.160835
Winter: off-peak	0.395532	0.21407	0.063934	0.189206	0.275834
Spring/Fall: on-peak	0.093283	0.122218	0.257019	0.141916	0.111951
Spring/Fall: off-peak	0.122075	0.2135	0.069402	0.189412	0.179621
Summer: D/E ratio	0	0.000158	0.000521	0.000151	0.00003

Description	Data				
Economic Sector	Residential	Residential	Residential	Residential	Residential
Market Segment	Multi-family	Multi-family	Multi-family	Multi-family	Multi-family
End Use	Cooking	Freezing	Lighting	Outdoor Lighting	Refrigeration
Summer: on-peak	0.140611	0.135714	0.082359	0.043459	0.193408
Summer: off-peak	0.118337	0.262815	0.113762	0.233975	0.223337
Winter: on-peak	0.211035	0.110041	0.161729	0.078955	0.130139
Winter: off-peak	0.188246	0.211292	0.307357	0.304522	0.147068
Spring/Fall: on-peak	0.176571	0.095388	0.117576	0.062662	0.140764
Spring/Fall: off-peak	0.165197	0.184747	0.217213	0.276424	0.16528
Summer: D/E ratio	0.0001	0.00013	0.00001	0	0.00018

Description	Data				
Economic Sector	Residential	Residential	Residential	Residential	Residential
Market Segment	Multi-family	Multi-family	Multi-family	Multi-family	Single Family
End Use	Space Cooling	Space Heating	Water Heating	Waterbed Heating	Building Shell
Summer: on-peak	0.43941	0	0.125287	0.078524	0.289276
Summer: off-peak	0.555981	0	0.208224	0.147473	0.710723
Winter: on-peak	0	0.177334	0.119022	0.150826	0
Winter: off-peak	0	0.561982	0.213353	0.287288	0
Spring/Fall: on-peak	0.004608	0.048511	0.120537	0.113837	0
Spring/Fall: off-peak	0	0.212173	0.213574	0.222049	0
Summer: D/E ratio	0.001962	0	0.00009	0	0.000722

Table 12d Load shape information

Description	Data				
Economic Sector	Residential	Residential	Residential	Residential	Residential
Market Segment	Single Family	Single Family	Single Family	Single Family	Single Family
End Use	Clothes Drying	Cooking	Dehumidification	Freezing	Lighting
Summer: on-peak	0.103101	0.160217	0.25917	0.135714	0.082375
Summer: off-peak	0.168656	0.123816	0.492208	0.262815	0.113925
Winter: on-peak	0.160835	0.210739	0	0.110041	0.164273
Winter: off-peak	0.275834	0.183047	0	0.211292	0.310449
Spring/Fall: on-peak	0.111951	0.170801	0.085591	0.095388	0.114743
Spring/Fall: off-peak	0.179621	0.151378	0.16303	0.184747	0.214232
Summer: D/E ratio	0.00003	0.00014	0.000279	0.00013	0.00001

Description	Data				
Economic Sector	Residential	Residential	Residential	Residential	Residential
Market Segment	Single Family	Single Family	Single Family	Single Family	Single Family
End Use	Outdoor Lighting	Refrigeration	Space Cooling	Space Heating	Swimming Pool
Summer: on-peak	0.043459	0.132925	0.289276	0	0.514368
Summer: off-peak	0.233975	0.228394	0.710723	0	0.485631
Winter: on-peak	0.078955	0.111403	0	0.177334	0
Winter: off-peak	0.304522	0.202461	0	0.561982	0
Spring/Fall: on-peak	0.062662	0.114216	0	0.048511	0
Spring/Fall: off-peak	0.276424	0.210599	0	0.212173	0
Summer: D/E ratio	0	0.00013	0.000722	0	0.000683

Description	Data	
Economic Sector	Residential	Residential
Market Segment	Single Family	Single Family
End Use	Water Heating	Waterbed Heating
Summer: on-peak	0.126921	0.078524
Summer: off-peak	0.204441	0.147473
Winter: on-peak	0.119781	0.150826
Winter: off-peak	0.213294	0.287288
Spring/Fall: on-peak	0.120867	0.113837
Spring/Fall: off-peak	0.214692	0.222049
Summer: D/E ratio	0.00009	0

Table 12e Load shape information

Table 12 Load shape information

Wisconsin Demand-Side Options Database (W-DOD)

This analysis is based on version 1.05 of W-DOD released on August 23, 1993. However, numerous adjustments have been made to enhance the meaningfulness of the results.

1. The market information for all of the measures in the database was reviewed and adjusted as necessary by utility and PSCW representatives.
2. Residential and commercial saturations and eligibilities have been updated using better estimates of 1991 values.
3. The eligible percentages listed for the fuel switching measures assume that all customers have access to natural gas. Because this is not true, these eligible percentages are adjusted downward by multiplying by 22.9%, 69.4%, 82.3%, and 66.2% for the agricultural, commercial, industrial, and residential sectors, respectively. See Table 13 for a summary of the method used to estimate these percentages.

Please note that W-DOD is proprietary and is therefore not published as part of this document. The database supplied the following information for each measure.

Technology

This field provides a brief description of the base case technology or DSM option.

End Use

This field indicates the purpose served by the measure. For example, central air conditioners provide space cooling, and compact fluorescent lamps provide lighting. Space cooling and lighting are end uses.

Economic Sector

The economy is separated into four sectors—agricultural, commercial, industrial, and residential. Measures can be applied in one or more of these sectors.

Market Segment

Each economic sector is subdivided into categories. For instance, office and retail buildings form two market segments in the commercial sector. Similarly, single family and multi-family homes are two residential market segments.

Units

The data supplied by W-DOD were on a *per unit* basis. For instance, industrial motor measures express costs and savings in terms of horsepower, while commercial air conditioning measures express these values in terms of thousands of square feet.

Fuel Type

This term indicates the energy source(s) for a given technology. In this analysis, electricity and natural gas are the only two fuel types considered.

DSM Type

For this analysis, demand-side measures are classified as one of the following: *conservation*, *load management*, or *fuel switching*. Although these classifications can be subjective, in general those measures that conserve energy are termed *conservation*, those that shift the demand for electricity to off-peak hours are termed *load management*, and those that eliminate the demand for electricity by switching to other forms of energy are termed *fuel switching*.

Replacement versus Add-on

Each measure is classified as either a replacement or an add-on. For example, a heat pump water heater is a replacement measure because it is installed in place of a standard water heater. However, a low-flow shower head is an add-on measure because it is installed in addition to a standard water heater. Because there may be technical reasons why a given add-on may not be applied to a certain replacement type measure, valid add-on and replacement combinations are identified.

Installed Capital Cost

The installed capital cost includes the purchase and installation of the measure.

Annual Operation and Maintenance Costs

The annual operation and maintenance costs reflect the yearly expense of using the measure. These costs do not include fuel.

Lifetime

The lifetime indicates the expected duration of the measure's impact on the system-wide demand for energy.

Electrical Energy Use

Electrical energy use indicates the average annual energy consumed by the measure.

Electrical Energy Savings

The electrical energy savings derived from implementing a demand-side measure indicates the percentage reduction in electrical energy use relative to the base case technology. For the case of add-on measures, this analysis assumes that these relative savings can be applied to any replacement type measure, not just the base case technology. Furthermore, this analysis allows multiple add-on technologies to be assigned to a single replacement type measure by applying these percentage savings in succession to limit double-counting.

Summer Demand Savings

The summer demand savings derived from implementing a demand-side measure indicates the percentage reduction in electrical demand relative to the base case technology. Like the electrical energy savings term described above, this term is expressed in a relative format to accommodate the add-on measures.

Saturation

The saturation indicates the percentage of the population that employs the given technology in the base year.

Eligibility

The eligibility indicates the percentage of the population that is technically able to employ the given technology.

The utilities supplied answers to the following questions:

(1) In 1991, how many electric customers did your utility have in each economic sector?

(2) Of these electric customers, what percentage had the ability to switch to natural gas?

The following table presents the data provided for question (1).

	The number of electric customers in 1991			
Utility	**Agricultural**	**Commercial**	**Industrial**	**Residential**
Dairyland Power	61,121	5,624	65	95,599
Madison Gas & Electric	349	14,650	80	97,205
Northern States Power	4,600	20,000	1,450	171,000
Wisconsin Power & Light	0	40,170	621	300,000
Wisconsin Public Power	0	10,639	844	81,044
Wisconsin Public Service	8,289	27,143	212	266,829
Wisconsin Electric Power	15,400	73,800	8,100	798,700

The following table presents the data provided for question (2) and concludes with the statewide average values. The statewide average values are the mean of the percentages provided by each utility, weighted by each utility's number of customers.

	Fraction of electric customers with access to natural gas			
Utility	**Agricultural**	**Commercial**	**Industrial**	**Residential**
Dairyland Power	10%	10%	10%	10%
Madison Gas & Electric	84%	100%	100%	84%
Northern States Power	0%	50%	50%	40%
Wisconsin Power & Light	0%	55%	75%	41%
Wisconsin Public Power*	—	—	—	—
Wisconsin Public Service	4%	45%	47%	54%
Wisconsin Electric Power	90%	90%	90%	90%
Statewide Average	**22.9%**	**69.4%**	**82.3%**	**66.2%**

* Wisconsin Public Power does not collect this information. It is assumed that Wisconsin Public Power's values are identical to the weighted statewide averages of the numbers produced by the other utilities.

Table 13 Adjustment to fuel switching eligibilities

APPENDIX D: SAMPLE DATA AND FORMULAS

The section of this text entitled *The Calculation Method* uses an example to describe the method for estimating technical and economic potential. This appendix defines the formulas that comprise this method. The reader can generate the numbers shown in *The Calculation Method* section using these formulas and the technology-specific information presented below in Table 14 and the data presented in Tables 6, 7, 8, 10, 11, 12, and 13 of *Appendix C.*

Technology	DSM Type	Replacement / Add-on	Lifetime (years)	Saturation (%)	Eligibility (%)
DLC: Elec. Water Heater	LM	bde	15	0	37
Desuperheater	C	bde	15	0	37
Elect Water Heater 1992	NA	E	15	13	37
Elect Water Heater: Efficient	C	D	15	24	37
Faucet Aerators	C	bcde	15	1	37
Gas Water Heat.: New 1992	FS	A	12	0	28
Heat Pump Water Heater	C	B	15	0	37
Low-Flow Showerhead	C	bcde	15	14	37
Solar Water Heater	C	C	15	0	37
Water Heater Pipe Wrap	C	bcde	15	0	37
Water Heater Wrap	C	bcde	13	8	37

	Installed Capital Cost ($)	Annual O&M Cost ($/year)	Energy Use (kWh/yr)	Electric Energy Savings (%)	Summer Demand Savings (%)
DLC: Elec. Water Heater	115	0	0	10	10
Desuperheater	900	0	0	4	4
Elect Water Heater 1992	245	0	4230	0	0
Elect Water Heater: Efficient	330	0	0	5	5
Faucet Aerators	1.5	0	0	4	4
Gas Water Heat.: New 1992	480	0	0	99	98
Heat Pump Water Heater	1500	0	0	50	50
Low-Flow Showerhead	12	0	0	10	10
Solar Water Heater	3000	0	0	47	47
Water Heater Pipe Wrap	5	0	0	4	4
Water Heater Wrap	15	0	0	15	15

Table 14 W-DOD—Alternative measures for single family residential water heating

Technical Potential Formulas

Step 1: Identify a set of measures to analyze.

The technologies in W-DOD are stored in distinct groups, each consisting of a base case technology and its associated DSM options. Table 14 illustrates one such group. The method defined in this document is used for each such group.

The column titled *DSM Type* in Table 14 identifies each measure as a base case technology (NA), fuel switching option (FS), conservation option (C), or load management option (LM).

The column titled *Replacement/Add-on* in Table 14 identifies each measure as a replacement, denoted by one uppercase letter, or an add-on, denoted by one or more lowercase letters. The lower case letters correspond to their uppercase counterparts to indicate replacement measures that can accept a given add-on measure.

Step 2: Adjust the eligibility values for fuel switching measures to reflect access to natural gas.

For each fuel switching measure, W-DOD indicates the fraction of the population that is eligible to adopt it. This fraction assumes that the entire population has access to the alternative fuel (in this case, natural gas), but that there may be other reasons why some cannot switch. For the potential calculations, the eligibility is further adjusted for the percentage of the population with access to natural gas, using data from Table 13 in *Appendix C*.

Equation 2: Adjust the eligibility for a given fuel switching measure.

$$a_f = b_f \supseteq c_f$$

Where,

a_f = *the portion of the population that is eligible to fuel switch to measure f, expressed as a fraction of the population.*

b_f = the portion of the population that is eligible to employ measure f shown in Table 14, expressed as a fraction of the population.

c_f = the portion of the population with access to natural gas shown in Table 13, expressed as a fraction of the population.

Step 3: Identify eligible measures for each scenario.

Of the measures listed in Step 1, identify the set to apply to the market for each of the four scenarios.

Each measure, except for the base case technology, is categorized as a certain *DSM Type* in Table 14. This analysis estimates technical potential for four scenarios that differ only in terms of the DSM types considered.

<u>Step 4</u>: Rank the replacement measures listed in Step 1 from least to greatest energy consumption and demand.

This step ranks the replacements based upon electric energy use and summer peak demand. Because energy and demand have different units (kWh versus kW), they are not directly comparable. Consequently, these components are each assigned dollar values using statewide marginal costs, allowing the relative values of energy and demand to be added. Measures with the lowest total cost are ranked highest. The results from Equation 4e are used to generate the final ranking.

Equation 4a: Calculate the energy consumption for a given replacement measure.

$$a_i = (1 - b_i) \supseteq c$$

Where,

a_i = *the energy use of replacement measure i, listed in Step 1, expressed in kWh per year per unit.*

b_i = the energy savings of measure i shown in Table 14, relative to the base case technology, expressed as a fraction.

c = the energy use of the base case technology shown in Table 14 (the measure showing "NA" as its DSM type), expressed in kWh per year per unit.

Equation 4b: Calculate the cost of energy for a given replacement measure.

$$a_i = b_i \supseteq (c_1d_1 + c_2d_2 + c_3d_3 + c_4d_4 + c_5d_5 + c_6d_6)$$

Where,

a_i = the cost of energy for replacement measure i, listed in Step 1, expressed in $ per year per unit.

b_i = the energy use calculated in Equation 4a for measure i, expressed in kWh per year per unit.

c_n = the avoided cost of energy, including SO_2 and greenhouse gas emissions, during the time period n shown in Table 8, expressed in $ per kWh.

d_n = the energy consumed during the time period n shown in Table 12, expressed as a fraction.

Equation 4c: Calculate the demand for a given replacement measure.

$$a_i = (1 - b_i) \supseteq c \supseteq d$$

Where,

a_i = the demand of replacement measure i, listed in Step 1, expressed in kW per unit.

b_i = the demand savings of measure i shown in Table 14, relative to the base case technology, expressed as a fraction.

c = the ratio of demand to energy for the end use shown in Table 12, expressed in kW per kWh.

d = the energy use of the base case technology shown in Table 14 (the measure showing "NA" as its DSM type), expressed in kWh per year per unit.

Equation 4d: Calculate the cost of demand for a given replacement measure.

$$a_i = b_i \supseteq c$$

Where,

a_i = the cost of demand for replacement measure i, listed in Step 1, expressed in $ per year per unit.

b_i = the demand calculated in Equation 4c for measure i, expressed in kW per unit.

c = the avoided cost of demand, including SO_2 and greenhouse gas emissions shown in Table 8, expressed in $ per kW.

Equation 4e: Sum the costs for energy and demand for a given replacement measure. Use the results of this equation to rank the replacement measures.

$$a_i = b_i + c_i$$

Where,

a_i = the cost of energy and demand for replacement measure i, listed in Step 1, expressed in $ per year per unit.

b_i = the cost of energy calculated in Equation 4b for measure i, expressed in $ per year per unit.

c_i = the cost of demand calculated in Equation 4d for measure i, expressed in $ per year per unit.

Step 5: Calculate the energy and demand savings per unit replaced for each replacement measure.

Calculate the energy and demand savings for using the measures identified in Step 3 to replace those measures of lower rank shown in Step 4.

Equation 5a: Calculate the energy savings from performing a replacement.

$$a_{ij} = b_j - c_i$$

Where,

a_{ij} = the energy savings for using replacement measure i, listed in Step 3, to replace measure j of lower rank, listed in Step 4, expressed in kWh per year per unit.

b_j = the energy use calculated in Equation 4a for measure j, expressed in kWh per year per unit.

c_i = the energy use calculated in Equation 4a for measure i, expressed in kWh per year per unit.

Equation 5b: Calculate the demand savings from performing a replacement.

$$a_{ij} = b_j - c_i$$

Where,

a_{ij} = the demand savings for using replacement measure i, listed in Step 3, to replace measure j of lower rank, listed in Step 4, expressed in kW per unit.

b_j = the demand calculated in Equation 4c for measure j, expressed in kW per unit.

c_i = the demand calculated in Equation 4c for measure i, expressed in kW per unit.

<u>Step 6</u>: Calculate the savings and potential saturations as the replacements are carried out throughout the market.

Carry out the replacements in the order shown in Step 5, calculating energy savings, demand savings, and changing saturations for each measure.

The following terms are used frequently in this step.

Current saturation: the initial saturation of a measure provided by W-DOD, or, for fuel switching measures, calculated in Equation 2.

Revised saturation: the saturation of a measure that results as replacements occur. (If an equation calls for a revised saturation and no such revision has occurred, the *revised saturation* is equivalent to the *current saturation*.)

Potential saturation: the final saturation of a measure after all replacements have occurred. The *potential saturation* is equivalent to the last *revised saturation*.

Equations 6a through 6d must be performed in sequence for each replacement pair. Equation 6a calculates the revised saturation for a measure being replaced. Equation 6b calculates the revised saturation for the measure performing the replacement in Equation 6a. Equations 6c and 6d calculate the energy and demand savings, respectively, resulting from the replacement.

Equation 6a: Revise the saturation for the measure being replaced.

$$a_j = \frac{b - c_i}{d} \supseteq e_j$$

Where,

a_j = the revised saturation for replacement measure j being replaced by measure i listed in Step 5, expressed as a fraction of the population.

b = the sum of the previously revised (or current) saturations for all of the replacement measures, expressed as a fraction of the population.

c_i = the portion of the population that is eligible to employ measure i shown in Table 14 or, for fuel switching measures, calculated in Equation 2, expressed as a fraction of the population.

d = the sum of the previously revised (or current) saturations for all of the replacement measures less that of measure i, expressed as a fraction of the population.

e_j = the previously revised (or current) saturation of measure j, expressed as a fraction of the population.

Equation 6b: Revise the saturation for the measure doing the replacing.

$$a_i = b_i + \Re(c_j - d_j)$$

Where,

a_i = the revised saturation for replacement measure i replacing measure j, expressed as a fraction of the population.

b_i = the previously revised (or current) saturation of measure i, expressed as a fraction of the population.

c_j = the previously revised (or current) saturation of measure j, expressed as a fraction of the population.

d_j = the revised saturation calculated in Equation 6a of measure j, expressed as a fraction of the population.

Equation 6c: Calculate the energy savings due to the replacement.

$$a_{ij} = b \supseteq (c_j - d_j) \supseteq e_{ij}$$

Where,

a_{ij} = the energy savings derived from replacing measure j with measure i, expressed in kWh per year.

b = the population shown in Table 10, expressed in units.

c_j = the previously revised (or current) saturation of measure j, expressed as a fraction of the population.

d_j = the revised saturation calculated in Equation 6a of measure j, expressed as a fraction of the population.

e_{ij} = the energy savings calculated in Equation 5a for using measure i to replace measure j, expressed in kWh per year per unit.

Equation 6d: Calculate the demand savings due to the replacement.

$$a_{ij} = b \supseteq (c_j - d_j) \supseteq e_{ij}$$

Where,

a_{ij} = the demand savings derived from replacing measure j with measure i, expressed in kW.

b = the population shown in Table 10, expressed in units.

c_j = the previously revised (or current) saturation of measure j, expressed as a fraction of the population.

d_j = the revised saturation calculated in Equation 6a of measure j, expressed as a fraction of the population.

e_{ij} = the demand savings calculated in Equation 5b for using measure i to replace measure j, expressed in kW per unit.

Equation 6e: Sum the energy savings attributable to a single measure for all of the replacements it performed.

$$a_i = \Re(b_{ij})$$

Where,

a_i = the energy savings derived using measure i as a replacement, expressed in kWh per year.

b_{ij} = the energy savings calculated in Equation 6c derived from replacing measure j with measure i, expressed in kWh per year.

Equation 6f: Sum the demand savings attributable to a single measure for all of the replacements it performed.

$$a_i = \Re(b_{ij})$$

Where,

a_i = the demand savings derived using measure i as a replacement, expressed in kW.

b_{ij} = the demand savings calculated in Equation 6d derived from replacing measure j with measure i, expressed in kW.

Step 7: Identify the add-on options that can be applied.

For the replacement measures having potential saturations greater than zero at the end of Step 6, identify the add-on options that can be applied to each.

For each replacement measure remaining in the population after Step 6, note the uppercase letter appearing in the *Replacement/Add-on* column of Table 14. Next, identify the add-on measures with the lowercase version of that letter.

Step 8: Rank the add-on measures identified in Step 7.

For each replacement measure listed in Step 7, rank the associated add-ons from greatest to least energy and demand savings.

In order to develop this ranking, the savings potential must be calculated for each combination of add-on and replacement. The results from Equation 8c are used to rank the add-on measures. For the scenario that considers fuel switching, conservation, and load management measures together, the ranking is performed within each of these categories separately, and then the categories are listed in the order just shown.

Equation 8a: Calculate the dollar value of energy savings for applying an add-on to a given replacement.

$$a_{jk} = b_j \supseteq c_k \supseteq (d_1e_1 + d_2e_2 + d_3e_3 + d_4e_4 + d_5e_5 + d_6e_6)$$

Where,

a_{jk} = the value of energy savings derived from applying add-on measure k to replacement measure j listed in Step 7, expressed in \$ per year per unit.

b_j = the energy use calculated in Equation 4a for measure j, expressed in kWh per year per unit.

c_k = the energy saved due to implementing measure k shown in Table 14, expressed as a fraction.

d_n = the avoided cost of energy, including SO_2 and greenhouse gas emissions, during the time period n shown in Table 8, expressed in \$ per kWh.

e_n = the energy consumed during the time period n shown in Table 12, expressed as a fraction.

Equation 8b: Calculate the dollar value of demand savings for applying an add-on to a given replacement.

$$a_{jk} = b_j \supseteq c_k \supseteq d$$

Where,

a_{jk} = the value of demand savings derived from applying add-on measure k to replacement measure j listed in Step 7, expressed in $ per year per unit.

b_j = the demand calculated in Equation 4c for measure j, expressed in kW per unit.

c_k = the demand saved due to implementing measure k shown in Table 14, expressed as a fraction.

d = the avoided cost of demand, including SO_2 and greenhouse gas emissions shown in Table 8, expressed in $ per kW.

Equation 8c: Sum the energy and demand savings values for applying an add-on to a given replacement. Use the results of this equation to rank the add-on measures.

$$a_{jk} = b_{jk} + c_{jk}$$

Where,

a_{jk} = the value of energy and demand savings derived from applying add-on measure k to replacement measure j listed in Step 6, expressed in $ per year per unit.

b_{jk} = the value of energy savings calculated in Equation 8a for applying the add-on measure k to the replacement measure j, expressed in $ per year per unit.

c_{jk} = the value of demand savings calculated in Equation 8b for applying the add-on measure k to the replacement measure j, expressed in $ per year per unit.

Step 9: Calculate the energy and demand savings per unit for each add-on measure.

For each replacement measure listed in Step 7, apply the corresponding add-on measures in the order determined in Step 8. To limit the double-counting of savings, each time an add-on is applied, the energy and demand of the replacement measure is recalculated to account for these savings. When the next add-on is applied, its savings potential is applied to the new baseline energy use of the replacement.

The following equations are performed for each combination of add-on and replacement measures.

Equation 9a: Calculate the energy savings for applying an add-on to a given replacement.

$$a_{jk} = (b_j - c_j) \supseteq d_k$$

Where,

a_{jk} = the energy savings derived from applying add-on measure k to replacement measure j in the order listed in Step 8, expressed in kWh per year per unit.

b_j = the energy use calculated in Equation 4a for measure j, expressed in kWh per year per unit.

c_j = the sum of the energy savings calculated using this equation (Equation 9a) for measure j, expressed in kWh per year per unit.

d_k = the energy saved due to implementing measure k shown in Table 14, expressed as a fraction.

Equation 9b: Calculate the demand savings for applying an add-on to a given replacement.

$$a_{jk} = (b_j - c_j) \supseteq d_k$$

Where,

a_{jk} = the demand savings derived from applying add-on measure k to replacement measure j in the order listed in Step 8, expressed in kW per unit.

b_j = the demand calculated in Equation 4c for measure j, expressed in kW per unit.

c_j = the sum of the demand savings calculated using this equation (Equation 9b) for measure j, expressed in kW per unit.

d_k = the demand saved due to implementing measure k shown in Table 14, expressed as a fraction.

Step 10: Calculate the current and potential saturations for each add-on measure.

For each replacement measure shown in Step 7, determine the current and potential saturations for each add-on measure applied in Step 9.

The following terms are used frequently in this step.

Current saturation: the portion of an add-on's initial saturation provided by W-DOD, or, for fuel switching measures, calculated in Equation 2, that corresponds to the *potential saturation* of a replacement measure.

Potential saturation: the final saturation of an add-on relative to a replacement measure.

Equation 10a: Calculate the current saturation of an add-on measure relative to a replacement measure. This analysis assumes that each add-on is uniformly distributed among the newly calculated (potential) saturation of replacements that can accept it.

$$a_{jk} = \frac{b_j}{c} \supseteq d_k$$

Where,

a_{jk} = *the current saturation of add-on measure k relative to replacement measure j, expressed as a fraction of the population.*

b_j = the potential saturation of replacement measure j calculated in Equation 6a or 6b, expressed as a fraction of the population.

c = the sum of the potential saturations for all of the replacement measures calculated using Equation 6a or 6b, expressed as a fraction of the population.

d_k = the current saturation of the add-on measure k shown in Table 14, or, for fuel switching measures, calculated in Equation 2, expressed as a fraction of the population.

Equation 10b: Calculate the potential saturation of an add-on measure relative to a replacement measure.

$$a_{jk} = \frac{b_j}{c} \supseteq d_k$$

Where,

a_{jk} = the potential saturation of add-on measure k relative to replacement measure j, expressed as a fraction of the population.

b_j = the potential saturation of replacement measure j calculated in Equation 6a or 6b, expressed as a fraction of the population.

c = the sum of the potential saturations for all of the replacement measures calculated using Equation 6a or 6b, expressed as a fraction of the population.

d_k = the eligibility of the add-on measure k shown in Table 14, expressed as a fraction of the population.

<u>Step 11</u>: Calculate the savings as the add-on measures are applied throughout the market.

Using the energy and demand savings shown in Step 9, the current and potential saturations shown in Step 10, and the population figures from Table 10 in *Appendix C*, calculate the total energy and demand savings for each add-on option.

Equation 11a: Calculate the energy savings for applying an add-on to a given replacement.

$$a_{jk} = b \supseteq (c_{jk} - d_{jk}) \supseteq e_{jk}$$

Where,

a_{jk} = the energy savings derived from adding measure k to replacement measure j, expressed in kWh per year.

b = the population shown in Table 10, expressed in units.

c_{jk} = the potential saturation calculated in Equation 10b of measure k relative to measure j, expressed as a fraction of the population.

d_{jk} = the current saturation calculated in Equation 10a of measure k relative to measure j, expressed as a fraction of the population.

e_{jk} = the energy savings calculated in Equation 9a from applying measure k to measure j, expressed in kWh per year per unit.

Equation 11b: Calculate the demand savings for applying an add-on to a given replacement.

$$a_{jk} = b \supseteq (c_{jk} - d_{jk}) \supseteq e_{jk}$$

Where,

a_{jk} *= the demand savings derived from adding measure k to replacement measure j, expressed in kW.*

b = the population shown in Table 10, expressed in units.

c_{jk} = the potential saturation calculated in Equation 10b of measure k relative to measure j, expressed as a fraction of the population.

d_{jk} = the current saturation calculated in Equation 10a of measure k relative to measure j, expressed as a fraction of the population.

e_{jk} = the demand savings calculated in Equation 9b from applying measure k to measure j, expressed in kW per unit.

Equation 11c: Sum the energy savings attributable to a single add-on measure for all of the replacements it is applied to.

$$a_k = \Re(b_{jk})$$

Where,

a_k *= the energy savings derived from adding measure k, expressed in kWh per year.*

b_{jk} = the energy savings calculated in Equation 11a derived from adding measure k to replacement measure j, expressed in kWh per year.

Equation 11d: Sum the demand savings attributable to a single add-on measure for all of the replacements it is applied to.

$$a_k = \Re(b_{jk})$$

Where,

a_k *= the demand savings derived from adding measure k, expressed in kW.*

b_{jk} = the demand savings calculated in Equation 11b derived from adding measure k to replacement measure j, expressed in kW.

Equation 11e: Sum the current saturations attributable to a single add-on measure for all of the replacements it can be applied to. Note that this sum may be less than the current saturation shown in Table 14, because replacement measures entering the market may not have been able to employ the existing add-on.

$$a_k = \Re(b_{jk})$$

Where,

a_k = the current saturation of add-on measure k, expressed as a fraction of the population.

b_{jk} = the current saturation calculated in Equation 10a for measure k relative to replacement measure j, expressed as a fraction of the population.

Equation 11f: Sum the potential saturations attributable to a single add-on measure for all of the replacements it is applied to.

$$a_k = \Re(b_{jk})$$

Where,

a_k = the potential saturation of add-on measure k, expressed as a fraction of the population.

b_{jk} = the potential saturation calculated in Equation 10b for measure k relative to replacement measure j, expressed as a fraction of the population.

Step 12: Adjust the energy and demand savings potential for differences between the base year of W-DOD and the base year of the study.

Two adjustments must be made to the results, due to the three-year difference between the base year of W-DOD (1991) and the base year of the study (1994). A more rigorous approach would have been to update the information in W-DOD to the current year, but this was beyond the scope of the project. The energy and demand savings for each add-on and replacement measure are first adjusted from the base year of W-DOD (1991) to the base year of the study (1994) using base forecast growth rates from Table 6 in *Appendix C*. Next, these values are reduced to account for demand-side savings captured (through DSM programs and other sources of change) since the base year of W-DOD, using the data from Table 11 in *Appendix C*. Finally, the final savings values are expressed as a percentage of total energy use and demand for the economic sector, from Table 7 in *Appendix C*.

This step cannot be performed until all of W-DOD's groups of measures are analyzed through Step 11.

Equation 12a: Adjust the energy savings for each measure for the difference between the base years.

$$a_m = b_m \supseteq (1 + c)^{d-e}$$

Where,

a_m = the energy savings for the base year of the study for measure m, expressed in kWh per year.

b_m = the energy savings for measure m calculated in Equation 6e or 11c, expressed in kWh per year.

c = the base energy forecast growth rate shown in Table 6, expressed as a fraction.

d = the base year of the study shown in Table 6.

e = the base year of W-DOD shown in Table 6.

Equation 12b: Adjust the demand savings for each measure for the difference between the base years.

$$a_m = b_m \supseteq (1 + c)^{d-e}$$

Where,

a_m = the demand savings for the base year of the study for measure m, expressed in kW.

b_m = the demand savings for measure m calculated in Equation 6f or 11d, expressed in kW.

c = the base demand forecast growth rate shown in Table 6, expressed as a fraction.

d = the base year of the study shown in Table 6.

e = the base year of W-DOD shown in Table 6.

Equation 12c: Adjust the energy savings for each measure to reflect the savings that have been captured between the base year of W-DOD and the base year of the study. The available data estimating captured savings is listed by economic sector, end use, and DSM type in Table 11. It is assumed that these captured savings are proportionally distributed among the savings of the measures with that classification. However, if captured savings are greater than potential savings, then potential savings become zero.

If $\Re(b_n) = 0$ or If $\Re(b_n) < c$

Then $a_m = 0$

Otherwise $a_m = d_m \supseteq (1 - \frac{c}{\Re(b_n)})$

Where,

a_m = the energy savings for the base year of the study for measure m, expressed in kWh per year.

b_n = the energy savings for measure n calculated in Equation 12a and having the same classification of economic sector, end use, and DSM type as measure m, expressed in kWh per year.

c = the captured energy shown in Table 11, expressed in kWh per year.

d_m = the energy savings for measure m calculated in Equation 12a, expressed in kWh per year.

Equation 12d: Adjust the demand savings for each measure to reflect the savings that have been captured between the base year of W-DOD and the base year of the study. The available data estimating captured savings is listed by economic sector, end use, and DSM type in Table 11. It is assumed that these captured savings are proportionally distributed among the savings of the measures with that classification. However, if captured savings are greater than potential savings, potential savings become zero.

$$\text{If } \Re(b_n) = 0 \text{ or If } \Re(b_n) < c$$

$$\text{Then } a_m = 0$$

$$\text{Otherwise } a_m = d_m \supseteq \left(1 - \frac{c}{\Re(b_n)}\right)$$

Where,

a_m = the demand savings for the base year of the study for measure m, expressed in kW.

b_n = the demand savings for measure n calculated in Equation 12b and having the same classification of economic sector, end use, and DSM type as measure m, expressed in kW.

c = the captured demand shown in Table 11, expressed in kW.

d_m = the demand savings for measure m calculated in Equation 12b, expressed in kW.

Equation 12e: Express the energy savings for each measure as a fraction of the total energy consumption for the economic sector.

$$a_m = \frac{b_m}{c}$$

Where,

a_m = the ratio of the energy savings for measure m to the total energy use of the economic sector, expressed as a fraction.

b_m = the energy savings calculated in Equation 12c for measure m, expressed in kWh per year.

c = the total energy use for the economic sector shown in Table 7, expressed in kWh per year.

Equation 12f: Express the demand savings for each measure as a fraction of the total demand for the economic sector.

$$a_m = \frac{b_m}{c}$$

Where,

a_m = the ratio of the demand savings for measure m to the total demand of the economic sector, expressed as a fraction.

b_m = the demand savings calculated in Equation 12d for measure m, expressed in kW.

c = the total demand for the economic sector shown in Table 7, expressed in kW.

Economic Potential Formulas

<u>Step 1</u>: Identify a set of measures to analyze.

The technologies in W-DOD are stored in distinct groups, each consisting of a base case technology and its associated DSM options. Table 14 illustrates one such group. The method defined in this document is used for each such group.

The column titled *DSM Type* in Table 14 identifies each measure as a base case technology (NA), fuel switching option (FS), conservation option (C), or load management option (LM).

The column titled *Replacement/Add-on* in Table 14 identifies each measure as a replacement, denoted by one uppercase letter, or an add-on, denoted by one or more lowercase letters. The lower case letters correspond to their uppercase counterparts to indicate replacement measures that can accept a given add-on measure.

<u>Step 2</u>: Adjust the eligibility values for fuel switching measures to reflect access to natural gas.

For each fuel switching measure, W-DOD indicates the fraction of the population that is eligible to adopt it. However, this fraction assumes that the entire population has access to the alternative fuel (in this case, natural gas,) and that there may be other reasons why some cannot switch. Because the population with access to natural gas is limited, eligibilities are adjusted for the fuel switching measures listed in Step 1.

Equation 2: Adjust the eligibility for a given fuel switching measure.

$$a_f = b_f \supseteq c_f$$

Where,

a_f = the portion of the population that is eligible to fuel switch to measure f, expressed as a fraction of the population.

b_f = the portion of the population that is eligible to employ measure f shown in Table 14, expressed as a fraction of the population.

c_f = the portion of the population with access to natural gas shown in Table 13, expressed as a fraction of the population.

Step 3: Rank the replacement measures listed in Step 1.

Rank the replacement measures listed in Step 1 from least to greatest energy consumption and demand for the first approach, and from least to greatest cost for the second approach.

Approach 1 ranks the replacements based upon electric energy use and summer peak demand. Because energy and demand have different units (kWh versus kW), they are not directly comparable. Consequently, these components are each assigned dollar values using statewide marginal costs, allowing the relative values of energy and demand to be added. Measures with the lowest total cost are ranked highest. The results from Equation 3e are used to generate the final ranking for this approach.

Approach 2 ranks the replacements based upon their total costs. This approach combines the energy and demand costs calculated in Equation 3e with the life cycle equipment costs calculated in Equation 3g. The results from Equation 3h are used to generate the final ranking for this approach.

Equation 3a: Calculate the energy consumption for a given replacement measure.

$$a_i = (1 - b_i) \supseteq c$$

Where,

a_i = the energy use of replacement measure i, listed in Step 1, expressed in kWh per year per unit.

b_i = the energy savings of measure i shown in Table 14, relative to the base case technology, expressed as a fraction.

c = the energy use of the base case technology shown in Table 14 (the measure showing "NA" as its DSM type), expressed in kWh per year per unit.

Equation 3b: Calculate the cost of energy for a given replacement measure.

$$a_i = b_i \supseteq (c_1 d_1 + c_2 d_2 + c_3 d_3 + c_4 d_4 + c_5 d_5 + c_6 d_6)$$

Where,

a_i = the cost of energy for replacement measure i, listed in Step 1, expressed in $ per year per unit.

b_i = the energy use calculated in Equation 3a for measure i, expressed in kWh per year per unit.

c_n = the avoided cost of energy during the time period n shown in Table 8, expressed in $ per kWh. This entire analysis, Steps 1 through 11, is performed for both sets of avoided costs listed in Table 8 and for each adder listed in Table 6.

d_n = the energy consumed during the time period n shown in Table 12, expressed as a fraction.

Equation 3c: Calculate the demand for a given replacement measure.

$$a_i = (1 - b_i) \supseteq c \supseteq d$$

Where,

a_i = the demand of replacement measure i, listed in Step 1, expressed in kW per unit.

b_i = the demand savings of measure i shown in Table 14, relative to the base case technology, expressed as a fraction.

c = the ratio of demand to energy for the end use shown in Table 12, expressed in kW per kWh.

d = the energy use of the base case technology shown in Table 14 (the measure showing “NA” as its DSM type), expressed in kWh per year per unit.

Equation 3d: Calculate the cost of demand for a given replacement measure.

$$a_i = b_i \supseteq c$$

Where,

a_i = the cost of demand for replacement measure i, listed in Step 1, expressed in $ per year per unit.

b_i = the demand calculated in Equation 3c for measure i, expressed in kW per unit.

c = the avoided cost of demand shown in Table 8, expressed in $ per kW.

Equation 3e: Sum the cost of energy and demand for a given replacement measure. Use the results of this equation to rank the replacement measures for Approach 1.

$$a_i = b_i + c_i$$

Where,

a_i = the cost of energy and demand for replacement measure i, listed in Step 1, expressed in $ per year per unit.

b_i = the cost of energy calculated in Equation 3b for measure i, expressed in $ per year per unit.

c_i = the cost of demand calculated in Equation 3d for measure i, expressed in $ per year per unit.

Equation 3f: Escalate the installed capital cost and the annual operations and maintenance cost for a given replacement measure from the base year of W-DOD to the base year of the study.

$$a_i = b_i \supseteq (1 + c)^{d-e}$$

Where,

a_i = the installed capital cost or annual operations and maintenance cost for replacement measure i, listed in Step 1, expressed in $ per unit and $ per year per unit, respectively.

b_i = the installed capital cost or annual operations and maintenance cost shown in Table 14 for measure i, expressed in $ per unit and $ per year per unit, respectively, for the base year of W-DOD.

c = the inflation rate shown in Table 6, expressed as a fraction. For the purposes of this study, the inflation rate is 0%.

d = the base year of the study shown in Table 6.

e = the base year of W-DOD shown in Table 6.

Equation 3g: Calculate the levelized cost for a given replacement measure, including installed capital and annual operations and maintenance costs.

$$a_i = \frac{b_i}{\frac{1 - (1 + d)^{-e_i}}{d}} + c_i$$

Where,

a_i = the levelized cost for replacement measure i, listed in Step 1, expressed in $ per year per unit.

b_i = the installed capital cost calculated in Equation 3f for measure i, expressed in $ per unit.

c_i = the annual operations and maintenance cost calculated in Equation 3f for measure i, expressed in $ per year per unit.

d = the real discount rate shown in Table 6, expressed as a fraction.

e_i = the expected lifetime of measure i shown in Table 14, expressed in years.

Equation 3h: Calculate the total levelized cost for a given replacement measure, including equipment, energy, and demand costs. Use the results of this equation to rank the replacement measures for Approach 2.

$$a_i = (b_i + c_i) \supseteq d$$

Where,

a_i = the total levelized cost for replacement measure i, listed in Step 1, expressed in $ per year per unit.

b_i = the cost of energy and demand calculated in Equation 3e for the replacement measure i, expressed in $ per year per unit.

c_i = the levelized cost calculated in Equation 3g for measure i, expressed in $ per year per unit.

d = the planning period shown in Table 6, expressed in years

<u>Step 4</u>: Calculate the energy and demand savings per unit replaced for each replacement measure.

Calculate the energy, demand, and cost savings on a per unit basis that result if the replacement measures identified in Step 1 are used to replace the current saturations of lower ranked measures shown in Step 3.

For Approach 1, lower ranked measures are only replaced when cost savings are zero or greater.

For Approach 2, lower ranked measures are only replaced when energy and demand savings are zero or greater.

Equation 4a: Calculate the energy savings from performing a replacement.

$$a_{ij} = b_j - c_i$$

Where,

a_{ij} = the energy savings for using replacement measure i, listed in Step 1, to replace measure j of lower rank, listed in Step 3, expressed in kWh per year per unit.

b_j = the energy use calculated in Equation 3a for measure j, expressed in kWh per year per unit.

c_i = the energy use calculated in Equation 3a for measure i, expressed in kWh per year per unit.

Equation 4b: Calculate the demand savings from performing a replacement.

$$a_{ij} = b_j - c_i$$

Where,

a_{ij} = the demand savings for using replacement measure i, listed in Step 1, to replace measure j of lower rank, listed in Step 3, expressed in kW per unit.

b_j = the demand calculated in Equation 3c for measure j, expressed in kW per unit.

c_i = the demand calculated in Equation 3c for measure i, expressed in kW per unit.

Equation 4c: Calculate the cost savings from performing a replacement.

$$a_{ij} = b_j - c_i$$

Where,

a_{ij} = the cost savings for using replacement measure i, listed in Step 1, to replace measure j of lower rank, listed in Step 3, expressed in $ per unit.

b_j = the total levelized cost calculated in Equation 3h for measure j, expressed in $ per unit.

c_i = the total levelized cost calculated in Equation 3h for measure i, expressed in $ per unit.

<u>Step 5</u>: Calculate the savings and potential saturations as the replacements are carried out throughout the market.

Carry out the replacements in the order shown in Step 4, calculating energy savings, demand savings, and changing saturations for each measure. The savings reflect those that would be expected if all of the savings were captured at the start of W-DOD's base year.

The following terms are used frequently in this step.

Current saturation: the initial saturation of a measure provided by W-DOD, or, for fuel switching measures, calculated in Equation 2.

Revised saturation: the saturation of a measure that results as replacements occur. (If an equation calls for a revised saturation and no such revision has occurred, the *revised saturation* is equivalent to the *current saturation*.)

Potential saturation: the final saturation of a measure after all replacements have occurred. The *potential saturation* is equivalent to the last *revised saturation*.

Equations 5a through 5e must be performed in sequence for each replacement pair. Equation 5a calculates the revised saturation for a measure being replaced. Equation 5b calculates the revised saturation for the measure performing the replacement in Equation 5a. Equations 5c, 5d, and 5e calculate the energy, demand, and cost savings, respectively, resulting from the replacement.

Equation 5a: Revise the saturation for the measure being replaced.

$$a_j = \frac{b - c_i}{d} \supseteq e_j$$

Where,

a_j = the revised saturation for replacement measure j being replaced by measure i listed in Step 5, expressed as a fraction of the population.

b = the sum of the previously revised (or current) saturations for all of the replacement measures, expressed as a fraction of the population.

c_i = the portion of the population that is eligible to employ measure i shown in Table 14 or, for fuel switching measures, calculated in Equation 2, expressed as a fraction of the population.

d = the sum of the previously revised (or current) saturations for all of the replacement measures less that of measure i, expressed as a fraction of the population.

e_j = the previously revised (or current) saturation of measure j, expressed as a fraction of the population.

Equation 5b: Revise the saturation for the measure doing the replacing.

$$a_i = b_i + \Re(c_j - d_j)$$

Where,

a_i = the revised saturation for the replacement measure i replacing measure j, expressed as a fraction of the population.

b_i = the previously revised (or current) saturation of measure i, expressed as a fraction of the population.

c_j = the previously revised (or current) saturation of measure j, expressed as a fraction of the population.

d_j = the revised saturation calculated in Equation 5a of measure j, expressed as a fraction of the population.

Equation 5c: Calculate the energy savings due to the replacement.

$$a_{ij} = b \supseteq (c_j - d_j) \supseteq e_{ij}$$

Where,

a_{ij} = the energy savings derived from replacing measure j with measure i, expressed in kWh per year.

b = the population shown in Table 10, expressed in units.

c_j = the previously revised (or current) saturation of measure j, expressed as a fraction of the population.

d_j = the revised saturation calculated in Equation 5a of measure j, expressed as a fraction of the population.

e_{ij} = the energy savings calculated in Equation 4a for using measure i to replace measure j, expressed in kWh per year per unit.

Equation 5d: Calculate the demand savings due to the replacement.

$$a_{ij} = b \supseteq (c_j - d_j) \supseteq e_{ij}$$

Where,

a_{ij} = the demand savings derived from replacing measure j with measure i, expressed in kW.

b = the population shown in Table 10, expressed in units.

c_j = the previously revised (or current) saturation of measure j, expressed as a fraction of the population.

d_j = the revised saturation calculated in Equation 5a of measure j, expressed as a fraction of the population.

e_{ij} = the demand savings calculated in Equation 4b for using measure i to replace measure j, expressed in kW per unit.

Equation 5e: Calculate the cost savings due to the replacement.

$$a_{ij} = b \supseteq (c_j - d_j) \supseteq e_{ij}$$

Where,

a_{ij} = the cost savings derived from replacing measure j with measure i, expressed in $.

b = the population shown in Table 10, expressed in units.

c_j = the previously revised (or current) saturation of measure j, expressed as a fraction of the population.

d_j = the revised saturation calculated in Equation 5a of measure j, expressed as a fraction of the population.

e_{ij} = the cost savings calculated in Equation 4c for using measure i to replace measure j, expressed in $ per unit.

Equation 5f: Sum the energy savings attributable to a single measure for all of the replacements it performed.

$$a_i = \Re(b_{ij})$$

Where,

a_i = the energy savings derived using measure i as a replacement, expressed in kWh per year.

b_{ij} = the energy savings calculated in Equation 5c derived from replacing measure j with measure i, expressed in kWh per year.

Equation 5g: Sum the demand savings attributable to a single measure for all of the replacements it performed.

$$a_i = \Re(b_{ij})$$

Where,

a_i = the demand savings derived using measure i as a replacement, expressed in kW.

b_{ij} = the demand savings calculated in Equation 5d derived from replacing measure j with measure i, expressed in kW.

Equation 5h: Sum the cost savings attributable to a single measure for all of the replacements it performed.

$$a_i = \Re(b_{ij})$$

Where,

a_i = *the cost savings derived using measure i as a replacement, expressed in $.*

b_{ij} = the cost savings calculated in Equation 5e derived from replacing measure j with measure i, expressed in $.

<u>Step 6</u>: Identify the add-on options that can be applied.

For the replacement measures having potential saturations greater than zero at the end of Step 5, identify the add-on options that can be applied to each.

For each replacement measure remaining in the population after Step 5, note the uppercase letter appearing in the *Replacement/Add-on* column of Table 14. Next, identify the add-on measures with the lowercase version of that letter.

<u>Step 7</u>: Rank the add-on measures identified in Step 6.

For each replacement measure listed in Step 6, for the first approach rank the associated add-ons from greatest to least positive energy and demand savings, for those add-ons that offer cost savings. For the second approach, rank the add-ons associated with each replacement from greatest to least positive cost savings, for those add-ons that offer energy and demand savings.

In order to develop these rankings, one must calculate the savings potential for each combination of add-on and replacement. For Approach 1, the results from Equation 7c are used to rank the add-on measures. For Approach 2, the sum of the results from Equations 7e and 7f is used to rank the add-on measures.

Equation 7a: Calculate the dollar value of energy savings for applying an add-on to a given replacement.

$$a_{jk} = b_j \supseteq c_k \supseteq (d_1e_1 + d_2e_2 + d_3e_3 + d_4e_4 + d_5e_5 + d_6e_6)$$

Where,

a_{jk} = the value of energy savings derived from applying add-on measure k to replacement measure j having a positive potential saturation in Step 5, expressed in $ per year per unit.

b_j = the energy use calculated in Equation 3a for measure j, expressed in kWh per year per unit.

c_k = the energy saved due to implementing measure k shown in Table 14, expressed as a fraction.

d_n = the avoided cost of energy during the time period n shown in Table 8, expressed in $ per kWh. This analysis is performed for both sets of avoided costs listed in Table 8 and for each adder listed in Table 6.

e_n = the energy consumed during the time period n shown in Table 12, expressed as a fraction.

Equation 7b: Calculate the dollar value of demand savings for applying an add-on to a given replacement.

$$a_{jk} = b_j \supseteq c_k \supseteq d$$

Where,

a_{jk} = the value of demand savings derived from applying add-on measure k to replacement measure j having a positive potential saturation in Step 5, expressed in $ per year per unit.

b_j = the demand calculated in Equation 3c for measure j, expressed in kW per unit.

c_k = the demand saved due to implementing measure k shown in Table 14, expressed as a fraction.

d = the avoided cost of demand shown in Table 8, expressed in $ per kW.

Equation 7c: Sum the energy and demand savings for applying an add-on to a given replacement. Use the results of this equation to rank the add-ons for Approach 1.

$$a_{jk} = \mathrm{b}_{\mathrm{jk}} + \mathrm{c}_{\mathrm{jk}}$$

Where,

a_{jk} = the value of energy and demand savings derived from applying add-on measure k to replacement measure j having a positive potential saturation in Step 5, expressed in $ per year per unit.

b_{jk} = the value of energy savings calculated in Equation 7a for applying the add-on measure k to the replacement measure j, expressed in $ per year per unit.

c_{jk} = the value of demand savings calculated in Equation 7b for applying the add-on measure k to the replacement measure j, expressed in $ per year per unit.

Equation 7d: Escalate the installed capital cost and the annual operations and maintenance cost for a given add-on measure from the base year of W-DOD to the base year of the study.

$$a_k = \mathrm{b}_{\mathrm{k}} \supseteq (1 + \mathrm{c})^{\mathrm{d} - \mathrm{e}}$$

Where,

a_k = the installed capital cost or annual operations and maintenance cost for add-on measure k, expressed in $ per unit and $ per year per unit, respectively.

b_{k} = the installed capital cost or annual operations and maintenance cost shown in Table 14 for measure k, expressed in $ per unit and $ per year per unit, respectively, for the base year of W-DOD.

c = the inflation rate shown in Table 6, expressed as a fraction. For the purposes of this study, the inflation rate is 0%.

d = the base year of the study shown in Table 6.

e = the base year of W-DOD shown in Table 6.

Equation 7e: Calculate the levelized cost for a given add-on measure, including installed capital and annual operations and maintenance costs.

$$a_k = \frac{b_k}{\frac{1 - (1 + d)^{-e_k}}{d}} + c_k$$

Where,

a_k = the levelized cost for add-on measure k, expressed in $ per year per unit.

b_k = the installed capital cost calculated in Equation 7d for measure k, expressed in $ per unit.

c_k = the annual operations and maintenance cost calculated in Equation 7d for measure k, expressed in $ per year per unit.

d = the real discount rate shown in Table 6, expressed as a fraction.

e_k = the expected lifetime of measure k shown in Table 14, expressed in years.

Equation 7f: Calculate the cost savings for applying an add-on to a given replacement including energy, demand, and equipment costs. Use the results of this equation to rank the add-ons for Approach 2.

$$a_{jk} = (b_{jk} - c_k) \supseteq d$$

Where,

a_{jk} = the cost savings derived from applying add-on measure k to replacement measure j having a positive potential saturation in Step 5, expressed in $ per unit.

b_{jk} = the value of energy and demand savings calculated in Equation 7c derived from applying measure k to measure j, expressed in $ per year per unit.

c_k = the levelized cost calculated in Equation 7e for measure k, expressed in $ per year per unit.

d = the planning period shown in Table 6, expressed in years

Step 8: Calculate the energy and demand savings per unit for each add-on measure.

For each replacement measure listed in Step 6, apply the corresponding add-on measures in the order determined in Step 7. To limit the double-counting of savings, each time an add-on is applied, the energy and demand of the replacement measure is recalculated to account for these savings. When the next add-on is applied, its savings potential is applied to the new baseline energy use of the replacement.

The following equations are performed for each combination of add-on and replacement measures.

Equation 8a: Calculate the energy savings for applying an add-on to a given replacement.

$$a_{jk} = (b_j - c_j) \supseteq d_k$$

Where,

a_{jk} = the energy savings derived from applying add-on measure k to replacement measure j in the order listed in Step 7, expressed in kWh per year per unit.

b_j = the energy use calculated in Equation 3a for measure j, expressed in kWh per year per unit.

c_j = the sum of the energy savings calculated using this equation (Equation 8a) for measure j, expressed in kWh per year per unit.

d_k = the energy saved due to implementing measure k shown in Table 14, expressed as a fraction.

Equation 8b: Calculate the demand savings for applying an add-on to a given replacement.

$$a_{jk} = (b_j - c_j) \supseteq d_k$$

Where,

a_{jk} = the demand savings derived from applying add-on measure k to replacement measure j in the order listed in Step 7, expressed in kW per unit.

b_j = the demand calculated in Equation 3c for measure j, expressed in kW per unit.

c_j = the sum of the demand savings calculated using this equation (Equation 8b) for measure j, expressed in kW per unit.

d_k = the demand saved due to implementing measure k shown in Table 14, expressed as a fraction.

Step 9: Calculate the current and potential saturations for each add-on measure.

For each replacement measure shown in Step 6, determine the current and potential saturations for each add-on measure applied in Step 8.

The following terms are used frequently in this step.

Current saturation: the portion of an add-on's initial saturation provided by W-DOD, or, for fuel switching measures, calculated in Equation 2, that corresponds to the *potential saturation* of a replacement measure.

Potential saturation: the final saturation of an add-on relative to a replacement measure.

Equation 9a: Calculate the current saturation of an add-on measure relative to a replacement measure. This analysis assumes that each add-on is uniformly distributed among the newly calculated (potential) saturation of replacements that can accept it.

$$a_{jk} = \frac{b_i}{c} \supseteq d_k$$

Where,

a_{jk} = the current saturation of add-on measure k relative to replacement measure j, expressed as a fraction of the population.

b_j = the potential saturation of replacement measure j calculated in Equation 5a or 5b, expressed as a fraction of the population.

c = the sum of the potential saturations for all of the replacement measures calculated using Equation 5a or 5b, expressed as a fraction of the population.

d_k = the current saturation of the add-on measure k shown in Table 14, or, for fuel switching measures, calculated in Equation 2, expressed as a fraction of the population.

Equation 9b: Calculate the potential saturation of an add-on measure relative to a replacement measure.

$$a_{jk} = \frac{b_i}{c} \supseteq d_k$$

Where,

a_{jk} = the potential saturation of add-on measure k relative to replacement measure j, expressed as a fraction of the population.

b_j = the potential saturation of replacement measure j calculated in Equation 5a or 5b, expressed as a fraction of the population.

c = the sum of the potential saturations for all of the replacement measures calculated using Equation 5a or 5b, expressed as a fraction of the population.

d_k = the eligibility of the add-on measure k shown in Table 14, expressed as a fraction of the population.

<u>Step 10</u>: Calculate the savings as the add-on measures are applied throughout the market.

Using the energy and demand savings shown in Step 8, the current and potential saturations shown in Step 9, and the population figures from Table 10 in *Appendix C*, calculate the total energy, demand and cost savings for each add-on option.

Equation 10a: Calculate the energy savings for applying an add-on to a given replacement.

$$a_{jk} = b \supseteq (c_{jk} - d_{jk}) \supseteq e_{jk}$$

Where,

a_{jk} = the energy savings derived from adding measure k to replacement measure j, expressed in kWh per year.

b = the population shown in Table 10, expressed in units.

c_{jk} = the potential saturation calculated in Equation 9b of measure k relative to measure j, expressed as a fraction of the population.

d_{jk} = the current saturation calculated in Equation 9a of measure k relative to measure j, expressed as a fraction of the population.

e_{jk} = the energy savings calculated in Equation 8a from applying measure k to measure j, expressed in kWh per year per unit.

Equation 10b: Calculate the demand savings for applying an add-on to a given replacement.

$$a_{jk} = b \supseteq (c_{jk} - d_{jk}) \supseteq e_{jk}$$

Where,

a_{jk} = the demand savings derived from adding measure k to replacement measure j, expressed in kW.

b = the population shown in Table 10, expressed in units.

c_{jk} = the potential saturation calculated in Equation 9b of measure k relative to measure j, expressed as a fraction of the population.

d_{jk} = the current saturation calculated in Equation 9a of measure k relative to measure j, expressed as a fraction of the population.

e_{jk} = the demand savings calculated in Equation 8b from applying measure k to measure j, expressed in kW per unit.

Equation 10c: Calculate the cost savings for applying an add-on to a given replacement.

$$a_{jk} = b \supseteq (c_{jk} - d_{jk}) \supseteq e_{jk}$$

Where,

a_{jk} = the cost savings derived from adding measure k to replacement measure j, expressed in $.

b = the population shown in Table 10, expressed in units.

c_{jk} = the potential saturation calculated in Equation 9b of measure k relative to measure j, expressed as a fraction of the population.

d_{jk} = the current saturation calculated in Equation 9a of measure k relative to measure j, expressed as a fraction of the population.

e_{jk} = the cost savings calculated in Equation 7f from applying measure k to measure j, expressed in $ per unit.

Equation 10d: Sum the energy savings attributable to a single add-on measure for all of the replacements it is applied to.

$$a_k = \Re(b_{jk})$$

Where,

a_k = the energy savings derived from adding measure k, expressed in kWh per year.

b_{jk} = the energy savings calculated in Equation 10a derived from adding measure k to replacement measure j, expressed in kWh per year.

Equation 10e: Sum the demand savings attributable to a single add-on measure for all of the replacements it is applied to.

$$a_k = \Re(b_{jk})$$

Where,

a_k = the demand savings derived from adding measure k, expressed in kW.

b_{jk} = the demand savings calculated in Equation 10b derived from adding measure k to replacement measure j, expressed in kW.

Equation 10f: Sum the cost savings attributable to a single add-on measure for all of the replacements it is applied to.

$$a_k = \Re(b_{jk})$$

Where,

a_j = the cost savings derived from adding measure k, expressed in $.

b_{jk} = the cost savings calculated in Equation 10c derived from adding measure k to replacement measure j, expressed in $.

Equation 10g: Sum the current saturations attributable to a single add-on measure for all of the replacements it can be applied to. Note that this sum may be less than the current saturation shown in Table 14, because replacement measures entering the market may not have been able to employ the existing add-on.

$$a_k = \Re(b_{jk})$$

Where,

a_k = the current saturation of add-on measure k, expressed as a fraction of the population.

b_{jk} = the current saturation calculated in Equation 9a for measure k relative to replacement measure j, expressed as a fraction of the population.

Equation 10h: Sum the potential saturations attributable to a single add-on measure for all of the replacements it is applied to.

$$a_k = \Re(b_{jk})$$

Where,

a_k = the potential saturation of add-on measure k, expressed as a fraction of the population.

b_{jk} = the potential saturation calculated in Equation 9b for measure k relative to replacement measure j, expressed as a fraction of the population.

<u>Step 11</u>: Adjust the energy, demand, and cost savings potential for differences between the base year of W-DOD and the base year of the study.

Two adjustments must be made to the results, due to the three-year difference between the base year of W-DOD (1991) and the base year of the study (1994). A more rigorous approach would have been to update the information in W-DOD to the current year, but this was beyond the scope of the project. The energy and demand savings for each add-on and replacement measure are first adjusted from the base year of W-DOD (1991) to the base year of the study (1994) using base forecast growth rates from Table 6 in *Appendix C*. Next, these values are reduced to account for demand-side savings captured (through DSM programs and other sources of change) since the base year of W-DOD, using the data from Table 11 in *Appendix C*. Finally, the final savings values are expressed as a percentage of total energy use and demand for the economic sector, from Table 7 in *Appendix C*.

This step cannot be performed until all of W-DOD's groups of measures are analyzed through Step 10.

Equation 11a: Adjust the energy savings for each measure.

$$a_m = b_m \supseteq (1 + c)^{d - e}$$

Where,

a_m *= the energy savings for the base year of the study for measure m, expressed in kWh per year.*

b_m = the energy savings for measure m calculated in Equation 5f or 10d, expressed in kWh per year.

c = the base energy forecast growth rate shown in Table 6, expressed as a fraction.

d = the base year of the study shown in Table 6.

e = the base year of W-DOD shown in Table 6.

Equation 11b: Adjust the demand savings for each measure.

$$a_m = b_m \supseteq (1 + c)^{d - e}$$

Where,

a_m *= the demand savings for the base year of the study for measure m, expressed in kW.*

b_m = the demand savings for measure m calculated in Equation 5g or 10e, expressed in kW.

c = the base demand forecast growth rate shown in Table 6, expressed as a fraction.

d = the base year of the study shown in Table 6.

e = the base year of W-DOD shown in Table 6.

Equation 11c: Adjust the cost savings for each measure.

$$a_m = b_m \supseteq (1 + c)^{d - e}$$

Where,

a_m = the cost savings for the base year of the study for measure m, expressed in $.

b_m = the cost savings for measure m calculated in Equation 5h or 10f, expressed in $.

c = the base energy forecast growth rate shown in Table 6, expressed as a fraction.

d = the base year of the study shown in Table 6.

e = the base year of W-DOD shown in Table 6.

Equation 11d: Adjust the energy savings for each measure to reflect the savings that have been captured between the base year of W-DOD and the base year of the study. The available data estimating captured savings is listed by economic sector, end use, and DSM type in Table 11. It is assumed that these captured savings are proportionally distributed among the savings of the measures with that classification. However, if captured savings are greater than potential savings, then potential savings become zero.

$$\text{If } \Re(b_n) = 0 \text{ or If } \Re(b_n) < c$$

$$\text{Then } a_m = 0$$

$$\text{Otherwise } a_m = d_m \supseteq \left(1 - \frac{c}{\Re(b_n)}\right)$$

Where,

a_m = the energy savings for the base year of the study for measure m, expressed in kWh per year.

b_n = the energy savings for measure n calculated in Equation 11a and having the same classification of economic sector, end use, and DSM type as measure m, expressed in kWh per year.

c = the captured energy shown in Table 11, expressed in kWh per year.

d_m = the energy savings for measure m calculated in Equation 11a, expressed in kWh per year.

Equation 11e: Adjust the demand savings for each measure to reflect the savings that have been captured between the base year of W-DOD and the base year of the study. The available data estimating captured savings is listed by economic sector, end use, and DSM type in Table 11. It is assumed that these captured savings are proportionally distributed among the savings of the measures with that classification. However, if captured savings are greater than potential savings, potential savings become zero.

$$\text{If } \Re(b_n) = 0 \text{ or If } \Re(b_n) < c$$

$$\text{Then } a_m = 0$$

$$\text{Otherwise } a_m = d_m \supseteq \left(1 - \frac{c}{\Re(b_n)}\right)$$

Where,

a_m = the demand savings for the base year of the study for measure m, expressed in kW.

b_n = the demand savings for measure n calculated in Equation 11b and having the same classification of economic sector, end use, and DSM type as measure m, expressed in kW.

c = the captured demand shown in Table 11, expressed in kW.

d_m = the demand savings for measure m calculated in Equation 11b, expressed in kW.

Equation 11f: Adjust the cost savings for each measure to reflect the savings that have been captured between the base year of W-DOD and the base year of the study. The available data estimating captured savings is listed by economic sector, end use, and DSM type in Table 11. It is assumed that these captured savings are proportionally distributed among the savings of the measures with that classification. However, if captured savings are greater than potential savings, then potential savings become zero.

$$\text{If } \Re(b_n) = 0 \text{ or If } \Re(b_n) < c$$
$$\text{Then } a_m = 0$$
$$\text{Otherwise } a_m = d_m \supseteq (1 - \frac{c}{\Re(b_n)})$$

Where,

a_m = the cost savings for the base year of the study for measure m, expressed in \$.

b_n = the energy savings for measure n calculated in Equation 11c and having the same classification of economic sector, end use, and DSM type as measure m, expressed in kWh per year.

c = the captured energy shown in Table 11, expressed in kWh per year.

d_m = the cost savings for measure m calculated in Equation 11c, expressed in $.

Equation 11g: Express the energy savings for each measure as a fraction of the total energy consumption for the economic sector.

$$a_m = \frac{b_m}{c}$$

Where,

a_m = the ratio of the energy savings for measure m to the total energy use of the economic sector, expressed in the final results as a percentage.

b_m = the energy savings calculated in Equation 11d for measure m, expressed in kWh per year.

c = the total energy use for the economic sector shown in Table 7, expressed in kWh per year.

Equation 11h: Express the demand savings for each measure as a fraction of the total demand for the economic sector.

$$am = \frac{bm}{c}$$

Where,

a_m = the ratio of the demand savings for measure m to the total demand of the economic sector, expressed in the final results as a percentage.

b_m = the demand savings calculated in Equation 11e for measure m, expressed in kW.

c = the total demand for the economic sector shown in Table 7, expressed in kW.

APPENDIX E: ASSUMPTIONS

Below is a list of the assumptions used in this method for calculating technical and economic potential. Many of these assumptions are necessary to permit the use of the W-DOD data. Each assumption is followed by an indication of the bias it might introduce to the analysis.

Add-on measures

a. For each add-on measure, the energy and demand savings specified in W-DOD are expressed as percentages relative to a base case technology. It is assumed that these same proportional savings apply in the following situations: 1) when the add-on is applied to a replacement type measure other than the base case technology and 2) when the add-on is applied to a replacement measure that is already employing other add-on options. This assumption suggests that the relationship between savings and usage among measures is linear. However, true relationships usually involve diminishing returns. Therefore, this assumption is likely to overstate savings.

b. For cases where a certain portion of the population is ineligible (or "technically unable") to adopt an add-on measure, it is assumed that this "technically unable" population is evenly distributed among the populations employing the replacement type measures. This assumption will affect each end use differently, overstating savings for some, while understating it for others.

c. The current saturation listed for each add-on measure is assumed to be uniformly distributed across the replacement measures that can employ it. This assumption will affect each end use differently, overstating savings for some, while understating it for others.

d. This analysis uses replacement type measures to displace others in the current saturation in order to capture energy and demand savings. However, as this happens, some of the existing add-on measures might no longer be usable due to incompatibility with a new replacement measure. This analysis does not attempt to readjust the original add-on saturations to account for these replacements because data are not available to support such a calculation. This assumption will affect each end use differently, overstating savings for some, while understating it for others.

e. The add-on options in the market at the start of this analysis generate savings for the replacement measures to which they are applied. However, because these savings already exist, they are not included as part of the potential. Also, due to the lack of sufficiently detailed saturation information, replacement measures are compared without regard to these initial equipment mixes. This assumption will affect each end use differently, overstating savings for some, while understating it for others.

Avoided demand costs

This analysis uses statewide average avoided costs of generating capacity for placing value on demand savings. This value for generation includes the reserve margin. Transmission and distribution capacity costs are also included.

Avoided energy costs

This analysis uses statewide average avoided costs of energy for placing value on energy savings. For technical potential, energy savings are valued using avoided costs that include SO_2 and greenhouse gasses. For economic potential, the analysis is performed for costs that include SO_2 and greenhouse gas as well as for costs that include SO_2 only. Then, a sensitivity analysis is performed using adders to the costs that include SO_2. These adders are -1, +1, +2, +3, and +4 cents per kWh.

Demand savings

Demand savings are estimated for *summer* only. Because Wisconsin's statewide summer peak is greater than its winter peak, it is more important to assess DSM impacts on summer demand.

DSM capture rates

Because the W-DOD has a base year of 1991 and the study has a base year of 1994, this analysis reduces the DSM potential for 1994 to account for *naturally occurring* and *utility program induced* savings since 1991. This procedure assumes that all of these captured savings persist throughout the planning period.

Economic potential

a. Most of the technologies considered in this analysis have lifetimes shorter than the planning period of 20 years. This analysis assumes that all existing technologies will be replaced at some time during the planning period.

b. This analysis estimates the energy, demand, and cost savings for the planning period as though they occur at the start of the planning period. In reality, however, these savings would occur gradually over the planning period.

c. It is assumed that energy and cost savings grow at the statewide base energy forecast growth rate. Likewise, it is assumed that demand savings grow at the statewide base demand forecast growth rate.

d. The sensitivity analysis involves varying the avoided cost of *energy*. The avoided cost of *demand* is not varied because it is assumed that the energy portion of the avoided cost (which accounts for variable costs) is more uncertain than the demand portion (which accounts for fixed costs).

Fuel switching

a. Fuel switching is limited to natural gas measures for customers on current supply mains. Because this analysis does not account for the extending of natural gas service mains over the course of the planning period, it is likely that this assumption understates savings.

b. This analysis does not offset electrical energy savings by the costs associated with increased consumption of natural gas. Natural gas is assumed to have no societal cost. This is because a true avoided societal cost for natural gas was not available, and its development was beyond the scope of this study. *Cost savings* associated with fuel switching measures may be somewhat overstated as a result.

c. Renewable energy sources are considered *conservation* and not *fuel switching*.

Industrial sector

This analysis does not include some of the savings potential available in the industrial sector. This limitation is due to the complexity of estimating the potential for specific industrial processes and to limited information in W-DOD regarding technology saturations. Wisconsin's utilities may not include some of these savings in their individual demand-side plans. This limitation is likely to understate savings.

Inflation

W-DOD's technology cost information was not escalated from W-DOD's base year to the base year of the study. An inflation rate of zero percent was chosen for this cost information because although the capital and maintenance costs of some technologies has risen, the costs for others have fallen. Rather than conduct an extensive review of technology costs, the committee decided to use W-DOD's 1991 costs unaltered.

Innovation

The analysis assumes that the mix of available technologies remains fixed over the planning period at the 1991 level presented by W-DOD. This assumption is likely to understate savings.

Interactive effects

This analysis assumes there are no interactive savings. For instance, reducing the lighting load is likely to lessen the demand for air conditioning. This assumption is likely to understate savings.

Levelized costs

Alternative measures are compared using levelized costs. This method assumes that once a measure is installed, it is continuously replaced for the duration of the planning period.

Load management

This analysis does not limit the savings potential offered by load management options. While the Committee recognizes that such potential might be limited by adverse impacts on system load shapes, it did not want to risk understating the potential by assigning limits.

Persistence

This analysis assumes that once a measure is employed, it remains employed until the end of the planning period. Consequently, all of the energy, demand, and cost savings values associated with a measure reflect continuous replacement and 100% persistence. This assumption is likely to overstate savings.

Replacement measures

For cases where a certain portion of the population is technically unable to install a replacement type measure (where the eligibility of the measure is less than the saturation of the end use), it is assumed that this technically unable population is evenly distributed among the populations employing the other replacement type measures. This assumption will affect each end use differently, overstating savings for some, while understating it for others.

Technical potential

All replacements and add-ons are assumed to occur at the start of the base year of the study. Consequently, the technical potential results reflect the total energy and demand savings available at the start of the planning period.

Transmission and distribution losses

This analysis compares statewide energy consumption and demand at the generator to energy and demand savings at the individual customer meter. This analysis assumes that there are no transmission and distribution losses. This assumption is likely to understate savings.

APPENDIX F: DEFINITIONS

The following definitions were developed for this project. When possible, standard definitions chosen by Wisconsin's DSM Task Force were used.

add-on

An add-on is a demand-side management measure that is applied to (added on to) a replacement type measure to achieve energy savings. For example, a low-flow shower head is an add-on for a standard water heater.

avoided costs

Avoided costs are those costs that a utility can avoid if it is able to procure capacity and energy from a source other than conventional utility-owned and operated facilities, or if the utility does not have to meet an electric demand at all.

base case technology

A base case technology (or conventional technology) is the technology that would be installed in the absence of utility intervention. For this analysis, all base case technologies are replacement type measures.

cost savings (see net benefits)

demand

Demand is the instantaneous peak electrical power requirement of a technology or a group of technologies. Unless noted otherwise, in this study *demand* means the demand coincident with the statewide summer peak electric demand.

economic potential

Economic potential is the electrical energy and demand savings impact that can be obtained if only those economically viable measures, using the *technical cost test*, are adopted. Because this potential is based only on the information contained in W-DOD, it:

1. excludes potential savings available from measures not in W-DOD (for instance, potential available through industrial process improvements and potential available through technologies not currently in W-DOD but expected to be available by the end of the AP6 planning period)
2. excludes naturally occurring savings resulting from increasing efficiency standards
3. excludes potential for saving fuels and energy resources not provided by the participating public utilities
4. excludes savings due to events for which utilities would not run programs (for instance, changes in population behavior, such as an increase in environmental

awareness that inspires people to use less air conditioning, or savings methods that would involve significant free-ridership rates)

5. excludes rate-related usage modifications such as reductions due to time-of-day or interruptible rates
6. includes some naturally-occurring potential, because this study does not differentiate between savings that result from people who adopt efficient technologies on their own and those who only adopt such technologies when offered special economic incentives.

economic sector

For this analysis, the economy is separated into four sectors: agricultural, commercial, industrial, and residential.

eligible population

The eligible population is the portion of the population that is technically able to install a given replacement or add-on measure.

end-use saturation

The end-use saturation is the percentage of a population that employs a given end use. In this study, the end-use saturation is the sum of the individual technology saturations for the set of technologies within a given end-use grouping.

energy

Unless noted otherwise, this study uses the term *energy* to mean electrical energy only.

levelized cost

A levelized cost represent both initial capital costs and annual operation and maintenance costs as an equal stream of annual cash flows over the life of a measure. Levelized costs allow measures with different lifetimes to be compared.

market segment

A market segment is a subgroup of an economic sector (for instance, single family homes are a market segment within the residential sector.)

net benefits

Benefits are the positive outcomes that may be attributed to a DSM program, such as the avoided use of fuels to generate electricity and the deferment of the construction of power plants by the utility, or such as bill savings incurred by the participating customer. These benefits are offset by costs such as costs of new equipment by the utility or the customer and administrative costs associated with a DSM program. The difference between these benefits and costs are *net benefits.* (See *technical cost test* for a list of costs and benefits considered in this study.)

population

The population is the number of units in the relevant economic sector and market segment. Units can be homes, square feet of floor space, farms, etc.

replacement technology

A replacement technology is a demand-side measure that can take the place of another measure. For instance, a high-efficiency electric water heater is a replacement for a standard water heater.

saturation

The saturation is the percentage of the population that employs the given measure.

technical cost test

According to Figure C1-A1 of Advance Plan 6, the technical cost test generates benefit-cost ratios (B/C) for comparing DSM measures. The method used in this study does not use ratios, but instead uses cost savings (B – C).

The costs and benefits summed in the test are also defined in the source mentioned above. The following list describes each component. Note that not all components of the test are used in this study.

1. Electric utility equipment costs—These costs include the capital investment and fixed O&M costs associated with utility-owned equipment.
2. Non-electric supplier equipment costs—These costs include the capital investment and fixed O&M costs associated with non-electric supplier-owned equipment. (Not used in this study.)
3. Non-electric supplier increased costs—These costs include the additional costs incurred by the non-electric supplier to provide fuel. (These costs may include the costs associated with extending service to customers.) (Not used in this study.)
4. Customer capital and O&M costs—These costs include the incremental costs to customers of installing and maintaining the installed measure. For example, the differential cost between an average appliance and a highly efficient one is considered a customer capital cost.
5. Electric utility fuel savings—These savings include the fuel costs and variable operational and maintenance expenses saved by the electric utility.
6. Electric generation capacity savings—These savings include the reductions in investment in new electric generation facilities.
7. Electric T & D capacity savings—These savings include the reductions in investment in new electric transmission and distribution facilities.
8. Non-combustion savings—These savings include the additional public benefit provided by measures that do not involve combustion. Non-combustion savings quantify the social costs of combustion, such as acid deposition, global climate

change, and human health. These social costs are reflected in the avoided costs for energy and demand.

9. Non-electric supplier cost reduction—These savings include the reductions in demand and sales experienced by the non-electric supplier. These costs can include fuel and variable O&M as well as capital recovery costs associated with fixed investments. (Not used in this study.)

technical potential

Technical potential represents the load impact that can be obtained if (1) the most efficient options are adopted by the entire eligible population (net of current saturation) and (2) the entire eligible population is assumed to adopt the measures in the base year of 1994. Note that the technical potential is limited to the potential offered by the measures in W-DOD. Additional potential may be available from measures not in the database.

ENERGY CENTER
OF WISCONSIN
We show you how

595 Science Drive
Madison, WI 53711
Phone: 608.238.4601
Fax: 608.238.8733
Email: ecw@ecw.org
www.ecw.org

Printed on Plainfield Plus,
a recycled chlorine-free stock
containing 20% post-consumer waste.