Scoping Study to Evaluate Feasibility of National Databases for EM&V Documents and Measure Savings

Appendices

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Disclaimer

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List of Acronyms

ACEEE	American Council for an Energy-Efficient Economy
AFUE	Annual Fuel Utilization Efficiency
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
Btu	British thermal Unit
CALMAC	California Measurement Advisory Council
CEC	California Energy Commission
CEE	Consortium for Energy Efficiency
CFL	compact fluorescent light bulb
CO_2	carbon dioxide
CPUC	California Public Utilities Commission
DEER	Database for Energy Efficient Resources
DF	demand diversity factor
DOE	U.S. Department of Energy
DSM	demand side management
DWH	domestic water heating
ECM	electronically commutated motor
EFLH	equivalent full load hours
EISA	Energy Independence and Security Act
EM&V	evaluation, measurement, and verification
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act
ESF	energy saving factor
ETO	Energy Trust of Oregon
FTE	full-time equivalence
GPM	gallons per minute
HP	horsepower
HVAC	heating, ventilation, and air conditioning
IECC	International Energy Conservation Code
ISR	in-service rate
kW	kilowatt
kWh	kilowatt hour
LBNL	Lawrence Berkeley National Laboratory
M&V	measurement and verification
MEF	modified energy factor
MMBtu	1 million British thermal units
NEEA	Northwest Energy Efficiency Alliance
NREL	National Renewable Energy Laboratory
NTG	
NYSERDA	New York State Energy Research and Development Authority

PAF	power adjustment factor
PUC	Public Utility Commission
RFP	Request for Proposals
RPM	revolutions per minute
RTF	Regional Technical Forum
therm	100,000 Btu
TRM	technical reference manual
VSD	variable speed drive
W	watt

Definitions

TRM (technical reference manual)* is a resource document that includes information used in program planning and reporting of energy-efficiency programs. It can include savings values for measures, engineering algorithms to calculate savings, impact factors to be applied to calculated savings (e.g., net-to-gross values), source documentation, specified assumptions, and other relevant material to support the calculation of measure and program savings. A TRM may be in the form of a document or an electronic database. TRMs are currently in effect in 21 states.

EM&V documents database is a Web-based repository of information on evaluation, measurement, and verification (EM&V) plans and reports.

Energy efficiency measure* is an installed piece of equipment or system, or modification of equipment, systems, or operations on end-use customer facilities that reduces the total amount of electrical or gas energy and capacity that would otherwise have been needed to deliver an equivalent or improved level of end-use service.

Ex ante* savings values are forecasted savings used for program and portfolio planning purposes.

Ex post* savings values are savings estimates reported by an evaluator after the energy impact evaluation has been completed.

EM&V reports are formal documents describing the methodology, sources of data, and results of energy-efficiency program impact evaluations or project measurement and verification activities. EM&V reports are often prepared by third-party, independent contractors.

EM&V plans establish the general procedures and methods for determining the energy savings and other impacts of energy efficiency measures, projects, programs, and/or portfolios. EM&V plans may be specific to a particular evaluation activity, or come in the form of a general protocol for evaluation of all programs.

Market studies* are analyses that provide an assessment of how and how well a specific market or market segment is functioning with respect to the definition of well-functioning markets or with respect to other specific policy objectives. Common types of such studies are market characterizations, appliance and equipment saturation studies, conservation potential studies, and benchmarking and best-practice studies.

Process evaluation reports* are a systematic assessment of an energy efficiency program for the purposes of documenting program operations at the time of the examination and identifying and recommending improvements to increase the program's efficiency or effectiveness for acquiring energy resources while maintaining high levels of participant satisfaction.

* Adapted from the EM&V Forum Glossary of Terms and Acronyms, Version 2, March 2011.

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Description of Appendix A and Appendix B

Organization of Measure Comparisons

Information on each measure reviewed is presented in the following sequence:

- Measure summary information table (see Table 16).
- Discussion of findings and conclusions
- Discussion of recommended steps required for adoption into a national database
- Detailed table comparing information in databases reviewed (see Table 17).
- Table presenting variable names and definitions used in the detailed table (see Table 18).

The following text and tables provide more information on each of the review components.

Measure Summary Information Table Format

<table>
<tr><td>Measure Name</td><td colspan="5"></td></tr>
<tr><td>Measure Description</td><td colspan="5">Description of applicable technologies and variations in the technology</td></tr>
<tr><td>Weather Sensitive?</td><td>Yes or No</td><td>Sector?</td><td>Residential or Commercial</td><td>Primary Fuel?</td><td>Electric, gas, or both</td></tr>
<tr><td>Prevailing Energy Savings Methodology</td><td colspan="5">Replication of commonly observed algorithm for energy savings.
$\Delta kWh = XYZ$</td></tr>
<tr><td>Prevailing Demand Savings Methodology</td><td colspan="5">Replication of commonly observed algorithm for demand savings.
$\Delta kW = XYZ \times CF$</td></tr>
<tr><td>Variables</td><td colspan="5">Description of each input variable.

ΔkWh = Annual kWh savings per unit
ΔkW = Annual kW savings per unit
X = Input X
Y = Input Y
Z = Input Z
CF = Coincidence factor</td></tr>
</table>

Findings and Conclusions

This subsection indicates which databases are used for this measure comparison and measure assumptions. It includes a discussion of commonly observed methodologies for calculating energy and demand savings. Variations in methodologies and assumptions are also discussed.

This subsection concludes with a discussion of secondary benefits, incremental costs, and measure lifetimes.

Recommendations

This paragraph is used to discuss the suitability of a measure for a national database. If appropriate, steps needed to develop database measure are then presented in the following format:

- Recommended Action #1
- Recommended Action # 2
- Recommended Action # N

Appendix A. Residential Measures

Residential Lighting – Compact Fluorescent Lighting

Measure Name	Residential Lighting				
Measure Description	Replacement of (indoor) incandescent light bulbs with compact fluorescent lighting.				
Weather Sensitive?	No	**Sector?**	Residential	**Primary Fuel?**	Electric
Prevailing Energy Savings Methodology	$\Delta kWh = \frac{(Watt_{base} - Watt_{ee})}{1{,}000} \times HRS \times ISR$				
Prevailing Demand Savings Methodology	$\Delta kW = \frac{(Watt_{base} - Watt_{ee})}{1{,}000} \times CF \times ISR$				
Variables	ΔkWh = Annual kWh savings per unit $Watt_{base}$ = Baseline wattage $Watt_{ee}$ = Efficient condition wattage 1,000 = Watts/kW HRS = Annual operating hours ISR = In-service rate; ratio of lighting purchase that is actually installed ΔkW = Annual kW savings per unit CF = Coincidence factor				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- ENERGY STAR®, Regional Technical Forum (RTF) 2011, Database for Energy Efficient Resources (DEER) 2008, PA TRM 2011, OH TRM 2011
- Replacement of 60 W incandescents with 15 W compact fluorescent light bulbs (CFL).

Energy savings are deemed by the RTF, DEER, and OH TRM. The RTF has many measures, including installation by room type (e.g., living room) or by weighted average of all interior applications; a weighted average of all exterior applications; and a weighted average of all interior/exterior applications.

The RTF also includes three possible scenarios: retail, direct install, and Northwest Energy Efficiency Alliance (NEEA) socket count. The retail method calculates savings from a point-of-purchase perspective, and reduces savings by a storage factor of 33%. Direct install assumes documented installation, and reduces savings by a removal factor of 4%. NEEA socket count savings are based on each lamp being identified through NEEA socket count studies, which assumes each lamp has neither been stored nor removed. All methods account for a 15%reduction in savings due to space cooling interactive effects. For the purpose of comparison, the NEEA method was used, as all other resources considered do not include storage or removal factors.

DEER and the OH TRM both used studies to determine average incandescent and CFL wattage. By dividing incandescent wattage by CFL wattage, a savings ratio was deemed by which the measure wattage could be multiplied. The DEER energy results are gross savings values for installed lamps; they do not include other factors, such as upstream program influences, lamp breakages, storage, and other in-service rates.[1]

The OH TRM accounts for upcoming code changes impacting the baseline. Federal legislation stemming from the Energy Independence and Security Act (EISA) of 2007[2] will require all general-purpose light bulbs between 40 W and 100 W to be approximately 30%more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. In 2012, 100 W incandescent bulbs will no longer be manufactured, followed by restrictions on 75 W in 2013 and 60 W in 2014. The baseline for this measure will therefore become bulbs meeting the new standard (improved incandescent or halogen). To account for these new standards, the first-year annual savings for this measure must be reduced for 100 W equivalent bulbs in 2012 (21 W + CFLs), for 75 W equivalent bulbs in 2013 (16-20 W CFLs), and for 60 W and 40 W equivalent bulbs in 2014 (15 W or less CFLs). To account for this adjustment, the delta watt multiplier is adjusted in the OH TRM.

The remaining sources, ENERGY STAR and the PA TRM, simply use the wattage differential between the baseline and measure when calculating energy savings.

Assumptions provided in the sources reviewed include default hours of operation and waste heat factors for energy and demand (aka HVAC interaction factor). In the case of the OH TRM, the WHF_e, and WHF_d are explicitly given. In the RTF and DEER, a savings reduction is allocated for interactive effects (due to increased heating load), but is not explicitly included in the calculation. The final assumption is the in-service rate (ISR), the ratio of lighting products purchased that are actually installed.[3]

Demand savings calculations include a coincidence factor, in-service rate ratio, and heating/cooling interactive effects. CO_2 reductions (ENERGY STAR and RTF) and O&M savings (RTF) were the only secondary benefits found for residential lighting.

Measure lifetimes range between 5-11 years, due to varying lifetimes of bulbs. The range of rated bulb life is 6,000-12,000 hours. The actual measure life also depends on hours-of-use, which vary between sources. Five to eight years seems to be the major consensus, with the PA TRM setting the lifetime at 6.4 years.

Recommendations

Residential lighting on a single fixture level is a relatively straightforward measure that can be included in a national database with a supporting wattage table. The prevailing algorithm is the most suitable for a national database.

- The prevailing algorithm requires baseline, measure, hours-of-use, and in-service rate. The hours-of-use and in-service rates will need to be deemed by studies, unless actual use is known and installation is ensured.
- A national database will need to include protocols on when to use actual values and when to use default values. Since the purpose of the national database is to help users in states without TRMs and other sources of savings calculations, it will need to balance the degrees of freedom in the

[1] December 2008 DEER Update, Summary of Measure Energy Analysis Revisions, Version 2008.2.05 for 2009-2011 Planning/Reporting: "These factors are expected to reduce and or delay installation credit, and thus gross savings realization by

[2] A provision in EISA 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making CFLs the baseline. Therefore, after 2011 the measure life will have to be reduced each year to account for the number of years remaining until 2020.

[3] Bulbs may not be installed due to various factors, such as leakage of upstream program lamps outside the IOU service areas, breakage of lamps at any point prior to possible installation, delay of installation due to shipment times, or purchaser storage rather than installation.

methodology to maximize user friendliness without introducing excessive errors due to lack of regional-appropriate measurement and verification (M&V) data.

- Regional variations in the HVAC interaction factors and other assumptions will need to be addressed, as with all other measures.
- Multiple lighting calculator tools are currently available to help users determine exact savings, costs, and other impacts of their lighting retrofit. A dynamic database may include a lighting calculator as an additional resource.
- Developing an accepted universal lighting reference table may require significant input and oversight, as well as, at a minimum, annual maintenance of all reference documents to account for technologies updates, code changes, and recent studies.

Residential Lighting	ENERGY STAR	RTF 2011	DEER 2008	PA TRM 2011	OH TRM 2011
Region	National	Pacific Northwest	California	Pennsylvania	Ohio
Measure Name	Light bulbs (CFLs)	ENERGY STAR Lamp/Bulb - Any Interior Application - NEEA Socket Count	Indoor Lighting CFL; 13W lamp; Integral or Modular; Tube, Spiral, or Flood	ENERGY STAR Lighting	Residential ENERGY STAR CFL (Time of Sale)
Units	Per CFL	Per CFL	Per CFL	Per CFL	Per CFL
Approach Commentary	MS Excel® workbook with built in assumptions; input # bulbs, hours used per day (default 3 hrs), and baseline incandescent wattage (default 60 W).	Deemed savings based on MS Excel® workbook with tabulated savings and extensive and detailed calculations. Average energy use per room type is summed and divided by summed average number of lamps per room for entire house.	Deemed savings calculated by program based on calculations with input data from 2005 RLW and KEMA study. Savings are dependent on zone, single family vs. manufactured, and vintage.	Savings based on an algorithm that calculates the difference between existing and new wattage and the average daily hours-of-use for the lighting unit being replaced. An in-service rate is used to reflect the fact that not all lighting products purchased are actually installed.	Deemed calculation based on a ratio of average incandescent wattage removed to average CFL wattage installed. Average wattage of CFL from RLW study was 15.5W, and the replacement incandescent bulb was 61.2W. This is a ratio of 3.95 to 1.*
Calculation Approach Deviations - Energy	$\Delta kWh = kWh_{base} - kWh_{ee}$	Deemed	$\Delta kWh = Watt_{ee} \times 2.53 \div$	$\Delta kWh = \frac{\Delta W}{1{,}000} \times HRS \times ISR$	$\Delta kWh = (Watt_{ee} \times 3.25) \div$ $\Delta MMBTU = \frac{(Watt_{ee} \times 3.25)}{1{,}000 \frac{W}{kW}} \times$
Calculation Approach Deviations - Demand	NA	Deemed	Deemed $\Delta kW = Watt_{ee} \times 2.53 \div 1,$	$\Delta kW = \frac{\Delta W}{1{,}000} \times CF \times ISR$ *	$\Delta kW = Watt_{ee} \times 3.25 \div 1,$ #
Annual Gross Energy Savings	ΔkWh = 49	ΔkWh = 36	ΔkWh = 27 Assumes zone 16, single family, vintage 1978-1992	ΔkWh = 42	ΔkWh = 47
Annual Gross Demand Savings	NA	ΔkW = 0.0110	CF = 0.081 (fixed) ΔkW = 0.0047	CF = 0.05 (fixed) ΔkW = 0.0019	CF = 0.11 (fixed) ΔkW = 0.0056
Baseline	Incandescent bulb	Incandescent average	Incandescent average	Listed in table as “variable” -	Incandescent light bulb

Residential Lighting	ENERGY STAR	RTF 2011	DEER 2008	PA TRM 2011	OH TRM 2011
Condition	$Watt_{base}$ = 60	$Watt_{base}$ = 72	$Watt_{base}$ = 46	Assumes incandescent bulb $Watt_{base}$ = 60	
Efficient Condition	$Watt_{ee}$ = 15	CFL Average $Watt_{ee}$ = 19	CFL; Integral or Modular; Tube, Spiral, or Flood $Watt_{ee}$ = 13	Listed in table as "variable" - ENERGY STAR CFL Bulb (screw-in) $Watt_{ee}$ = 15	Standard ENERGY STAR-qualified CFL ($Watt_{ee}$ = 15)
Assumption 1: Usage	3 hrs/day (default)	2.9 hrs/day (based on weighted average of usage time per fixture per room type)	2.18 hrs/day (fixed)	1.9 hrs/day (fixed)	2.85 hrs/day (fixed)
Assumption 2: In-Service Rate (ISR)	NA	NA	ISR = 90% (fixed)	ISR = 84% (fixed)	ISR = 86% (fixed)
Assumption 3: Interaction Factor	NA	15% reduction in savings due to increased space conditioning. Negative therm savings given due to heating load increase.	Reduction in kWh savings due to increased space conditioning. Negative therm savings given due to heating load increase.	NA	WHF_e = 1.07 Based on cooling loads decreasing by 35% of the lighting savings (average result from REMRate modeling) WHF_d = 1.21 WHF_e and WHF_d are based on typical cooling system operating efficiency of 3.1 COP and 64% of homes having central cooling η= 0.72 HF = 0.45
Lifetime (years)	Varies from 5-11 years depending on bulb type (6,000-12,000 hr lifetimes)	5 years	Varies from 4-8 depending on bulb type (6,000-12,000 hr lifetimes)	6.4 years	8 years; average ENERGY STAR rated life of CFLs of 8,000 hrs
Incremental Costs	$3.40-$0.60 = $2.80	$3.50-$0.75 = $2.75	$2.64	NA	$3.00
Secondary Benefits	Carbon savings: 693 lbs CO_2	O & M Savings: $0.81 CO_2 reduction in tons	NA	NA	NA

Residential Lighting	ENERGY STAR	RTF 2011	DEER 2008	PA TRM 2011	OH TRM 2011
References	LBNL (2007), EPA (2008, 2009)	KEMA (2005), Cost: Lights of America, Sunpark, JKRL	KEMA (2005), Efficiency Vermont TRM (2003)	Nexus Market Research (2004), RLW Analytics (2007), DOE (2010)	RLW Analytics (2004, 2009), Architectural Energy Corporation (2008), EIA (2005), Nexus Market Research
					(2005), Nexus Market Research

* In addition, there is a ΔMMBTUH algorithm included to account for fossil fuel heating load increase.

** Per unit savings estimates are derived primarily from a 2004 Nexus Market Research report evaluating similar retail lighting programs in New England (MA, RI, and VT).

\# The 3.25 constant will be reduced to 2.05 in 2014 for bulbs 15W or less; to 2.00 in 2013 for 16-20W bulbs; and to 2.06 in 2012 for 21W+ bulbs.

Residential Lighting Glossary
ΔkWh = Annual kWh savings per unit
ΔW = Annual watt savings per unit
ΔkW = Annual kW savings per unit
$Watt_{base}$ = Baseline wattage
$Watt_{ee}$ = Efficient condition wattage
HRS = Annual operating hours
CF = Coincidence factor
ISR = In-service rate; ratio of products purchased that are actually installed
1,000 = Watts/kW
2.53 = DEER ratio of average incandescent to CFL wattage
3.25 = OH TRM ratio of average incandescent to CFL wattage
WHF_e = Lighting-HVAC interactive effect for energy
WHF_d = Lighting-HVAC waste heat factor for demand
η = Space heating system efficiency
0.003413 = kWh per MMBtu
HF = Heating factor (% of light savings that must be heated)

Refrigerator Recycling/Retirement

Measure Name	Refrigerator Recycling/Retirement				
Measure Description	This measure involves the removal of an existing inefficient refrigerator from service, prior to its natural end of life (early retirement). Common programs usually target refrigerators with an age greater than 10 years, though it is usually assumed that the average age will be greater than 20 years based on past program performance.				
Weather Sensitive?	No	**Sector?**	Residential	**Primary Fuel?**	Electric
Prevailing Energy Savings Methodology	Deemed savings are applicable for the estimated energy consumption during the remaining life of the existing unit.				
Prevailing Demand Savings Methodology	Deemed savings are applicable for the estimated energy consumption during the remaining life of the existing unit.				
Variables	None, the prevailing methodology is deemed savings.				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- RTF 2011, PA TRM 2011, OH TRM 2011, MA TRM 2011, Mid-Atlantic TRM 2010
- Early replacement of an existing refrigerator.

Energy savings are generally deemed from studies. The most common method to determine existing appliance consumption is to average the energy usage of recycled refrigerators from a list of models provided by JACO Environmental, a recycling corporation.

The RTF and Mid-Atlantic TRM 2010 calculations account for:

- Degradation of efficiency over time
- Lab to in-situ adjustment (to true-up field performance)
- Replacement rate
- Energy usage of replacement
- Partial or non-usage of retired unit.

Other sources use nameplate energy consumption of the retired refrigerator at face value. Demand savings are either deemed or calculated by dividing the kilowatt hour (kWh) savings by the usage hours per year, and multiplying by the summer peak coincidence factor. A majority of the sources also use a net-to-gross factor, which includes adjustments to accounts for a proportion of primary refrigerators replaced, those not used at all or used only parts of the year, and for those that would have been removed and recycled without the program (aka freeriders).

The RTF secondary benefits include CO_2 reduction in tons over expected measure life. The other TRMs did not include secondary benefits for refrigerator recycling/retirement. Measure lifetime, the remaining life of the retired unit, is eight years in four of the five sources.

Recommendations

Refrigerator recycling/retirement can be adapted into a national database with relatively little complication.

- Measure development would be best served by using M&V data and other evaluation studies for accuracy.
- Including adjustment factors would make the net savings result more accurate, but will require use of multiple sources.
- The RTF includes all typical assumptions and an extensive list of retired units (from studies and M&V data), along with the quantity of each model, thus providing the best source for a baseline.

Refrigerator Recycling/ Retirement	RTF 2011	PA TRM 2011	OH TRM 2011	MA TRM 2011	Mid-Atlantic TRM 2010
Region	Pacific Northwest	Pennsylvania	Ohio	Massachusett s	Mid-Atlantic
Measure Name	Refrigerator Decommissioning and Recycling	Refrigerator/Freezer Retirement (and Recycling)	Refrigerator and/or Freezer Retirement (Early Retirement)	Refrigerator/Fr eezer Recycling	Refrigerator Early Retirement
Units	Per refrigerator	Per refrigerator/freezer	Per refrigerator/freezer	Per refrigerator/fre eezer	Per refrigerator/fr eezer
Approach Commentary	Deemed savings based on MS Excel® workbook with tabulated savings and extensive and detailed calculations. The energy usage of retired refrigerators comes from an extensive survey of refrigerators found in homes.	The average existing refrigerator kWh consumption is based on data contained in the appliance recycling contractor (JACO) databases* and the ENERGY STAR calculator. The recorded year of manufacture in the JACO databases and the annual kWh consumption data by size, age, and type contained in the ENERGY STAR Refrigerator Retirement Calculator were used.	Calculations with supporting tables.	Unit savings are deemed and were obtained from referenced studies.	Unit savings are deemed and were obtained from various studies. Assumed savings are multiplied by an averaged NTG factor unique to the refrigerator recycling measure.
Calculation Approach Deviations - Energy	$\Delta kWh = [UEC_{Ret}(1 - UR)$ Where: $UEC_{Ret} = (UEC_{New}(1 + Ag$	No deviation	$\Delta kWh = UEC_{Ret} \times ISAF$	No deviation	Includes NTG
Calculation Approach Deviations - Demand	No deviation	No deviation	$\Delta kW = (\Delta kWh \div HRS) \times TAF$	No deviation	No deviation

Refrigerator Recycling/ Retirement	RTF 2011	PA TRM 2011	OH TRM 2011	MA TRM 2011	Mid-Atlantic TRM 2010
Annual Gross Energy Savings	Net $\Delta \mathrm{kWh} = 482$ (using given assumptions) Gross $\Delta \mathrm{kWh} = 1{,}446$ (excludes NTG, replacement, part-use, and *in situ* adjustment factors)	$\Delta \mathrm{kWh} = 1{,}659$	$\Delta \mathrm{kWh} = 1{,}376$ (based on regression savings estimates and incorporating the part-use factors)	$\Delta \mathrm{kWh} = 724$	Net $\Delta \mathrm{kWh} = 950$ (using given assumptions) Gross $\Delta \mathrm{kWh} = 1{,}728$ (excludes NTG)
Annual Gross Demand Savings	$\Delta \mathrm{kW} = 0.03$ deemed using unknown CF (assume this represents net demand savings)	CF = 0.62 $\Delta \mathrm{kW} = 0.2057$	$\Delta \mathrm{kW} = 0.22$	CF = 1.00 $\Delta \mathrm{kW} = 0.08$	CF = 0.62 $\Delta \mathrm{kW} = 0.12$
Baseline Condition	Average retired refrigerator based on AHAM and JACO $\mathrm{UEC_{Ret}}$ = 1,446 kWh	An existing secondary refrigerator or freezer that is no less than 10 years old; 10-30 cubic feet	Existing inefficient unit must be in working order. $\mathrm{UEC_{Ret}} = 1{,}619\ \mathrm{kWh}$	The baseline efficiency case is an old, inefficient secondary working refrigerator or freezer. Estimated average usage is based on combined weight of freezer and refrigerator energy use.	The existing refrigerator baseline efficiency is based on evaluation of a number of existing programs and evaluations $\mathrm{UEC_{Ret}} = 1{,}728\ \mathrm{kWh}$
Efficient Condition	Refrigerator not replaced – 0 kWh	Refrigerator or freezer not replaced – 0 kWh	Refrigerator or freezer not replaced – 0 kWh	Refrigerator or freezer not replaced – 0 kWh	Refrigerator or freezer not replaced – 0 kWh
Assumption 1: Hours-of-use	NA	HRS = 5,000 hrs/yr (fixed)	HRS = 8,760 hrs/yr (fixed)	HRS = 8,760 hrs/yr (fixed)	HRS = 5,000 hrs/yr (fixed)
Assumption 2: Net-to-Gross (NTG) Adjustments**	NTG = 57% (fixed)	NA	NA	NTG = 100% (fixed)	NTG = 55% (fixed)
TRM Specific Assumptions	$\mathrm{UEC_{Rep}}$ = 500 kWh $\mathrm{UEC_{New}}$ = 1,078 kWh UR = 50% Age = 27 yrs $\mathrm{Eff_{inc}}$ = -5% PU = 91% ISAF = 81%	NA	TAF = 1.30 LSAF = 1.074 ISAF = 85% Age > 20 yrs (all fixed)	NA	NA

Refrigerator Recycling/ Retirement	RTF 2011	PA TRM 2011	OH TRM 2011	MA TRM 2011	Mid-Atlantic TRM 2010
	Deg = 1.25% (all fixed)				
Lifetime (years)	9	8	8	8	8
Incremental Costs	$130.00	NA	Actual cost associated with the removal and recycling of retired unit	NA	Actual cost associated with the removal and recycling retired unit
Secondary Benefits	Carbon savings	NA	NA	NA	NA
References	AHAM, JACO Appliance Collection Databases, Summit Blue (2009), Innovologie (2010), ADM Associates (2008), Cadmus Group (2010), NV Energy North (2009)	JACO Appliance Collection Databases received from all EDCs, Vermont Energy Investment Corporation (2010)	Navigant Consulting (2009), Cadmus Group (2010)	KEMA, Inc (2008), Multiyear Evaluation of the MA Home Energy Service Program, Process Evaluation Summary Report (2004)	VT TRM, Fort Collins Utilities (2005), SCE (2001), Pacific Gas and Electric (2007), Quantec (2005), Snohomish PUD (2007), Ontario Energy Board (2006), KEMA (2004)

* Incomplete or erroneous records were removed from the sample prior to use. Because the manufacturer annual kWh consumption was recorded in less than 50% of appliance collections, the JACO data were not used to calculate an average.

** Includes adjustments to account for a proportion of primary refrigerators replaced, those not used at all or for only parts of the year, and those that would have been removed and recycled without the program (known as freeriders).

Refrigerator Recycling/Retirement Glossary

ΔkWh = Annual kWh savings per unit
ΔkW = Annual kW savings per unit
HRS = Annual operating hours
CF = Coincidence factor
UEC_{New} = Average retired unit kWh usage when new
UEC_{Ret} = Average degraded retired unit kWh usage when retired
UEC_{Rep} = Average replacement unit kWh usage
$ISAF$ = Lab to *in situ* adjustment
PU = Partial use factor
Eff_{inc} = Adjustment for increasing unit efficiency from 2009 to 2010-2011
UR = Units replaced rate
Deg = Degradation of unit efficiency per year
Age = Age of retired unit in years
NTG = Net-to-gross factor
TAF = Temperature adjustment factor
LSAF = Load shape adjustment factor

Home Furnace

Measure Name	High-Efficiency Furnace				
Measure Description	High-efficiency, natural gas-fired furnace used for residential space heating, may include an ECM fan motor.				
Weather Sensitive?	Yes	**Sector?**	Residential	**Primary Fuel?**	Gas
Prevailing Energy Savings Methodology	$\Delta \text{MMBtu} = \text{EFLH}_{\text{heat}} \times \text{BTUH} \times \left(1 - \frac{\text{AFUE}_{\text{base}}}{\text{AFUE}_{\text{ee}}}\right) \times 10^{-6}$				
Prevailing Demand Savings Methodology	NA				
Variables	∆MMBtu = Fuel savings for the measure, in MMBtu $\text{EFLH}_{\text{heat}}$ = Annual equivalent full load hours for heating BTUH = HVAC system input capacity in Btu/hr $\text{AFUE}_{\text{base}}$ = Baseline AFUE AFUE_{ee} = Efficient condition AFUE 10^{-6} MMBtu = Btu				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- ENERGY STAR, DEER 2008, OH TRM 2011, NY TRM 2010, MA TRM 2011
- For comparison purposes, furnace 100,000 BtuH input capacity was used.

Energy savings are calculated using the system size and Annual Fuel Utilization Efficiency (AFUE) rating, except for DEER and the MA TRM. DEER deems savings based on DOE-2.2 modeling, using the Heat Input Ratio (HIR), a variable used by DOE-2.2 modeling software. The MA TRM deems savings values based on study results for 92%, 94%, and 96% AFUE. The MA TRM also differs from all other sources considered, in that they include electrical savings for inclusion of an electronically commutated motor (ECM). Inclusion of an ECM is not required in the other resources. Hours of use are generally deemed using study results. Equivalent full load hours (EFLH) for heating is a crucial portion of savings, and a factor leading to differences in savings between resources due to its sensitivity to location. Large variations can be found, even within one state (such as differences found between upstate NY and NYC).

The primary input assumptions are the EFLH (weather-sensitive assumption varying by region), efficiency levels, and furnace outputs. Other than CO_2 reductions provided in the ENERGY STAR calculator, no other secondary benefits were found. Measure lifetimes range between 15 and 18 years, with 18 years being the most frequent lifetime.

Recommendations

Residential furnaces can be adapted into a national database with relatively few complications in the algorithm; the prevailing method would be the most appropriate algorithm for a national database. However, as a weather-sensitive measure, the EFLH would vary by location, making development of national database potentially challenging. The following input considerations may need to be addressed.

- Consensus needs to occur on the best unit to use for savings (therm, MMBtu, or CCF).

- EFLH for each location and building type will need to be provided, either through tables or links to appropriate sources. EFLH could be provided on a higher level through the use of climate zones, or could be more detailed through organization by city, depending on the target area of validity.
- EFLH can be developed by DOE2 modeling. Alternatively, using heating degree days as the basis of the consumption would be easiest to implement nationally, but it does not account for variations of building characteristics.

Furnace	ENERGY STAR	DEER 2008	OH TRM 2011	NY TRM 2010	MA TRM 2011
Region	National	California	Ohio	New York	Massachusetts
Measure Name	ENERGY STAR Qualified Gas Residential Furnace	Higher Efficiency Furnace 96 AFUE (1.03 HIR)	Condensing Furnaces-Residential (Time of Sale)	High Efficiency Gas Furnaces	Furnace (Forced Hot Air) with ECM
Units	Per furnace	Per furnace	Per furnace	Per furnace	Per furnace
Approach Commentary	Calculation worksheet with inputs and lookup tables allowing user to customize to their region and house.*	Savings are deemed based on DOE-2.2 modeling using the Heat Input Ratio (HIR), a variable used by DOE modeling software.	Savings are calculated using the difference in required gas, based upon the efficiency of the furnace and the average annual heating load for Ohio residences. No change in the distribution system efficiency, including fan motor, is assumed. Savings values are given in MMBtu.	Savings are based on an algorithm. Heating equivalent full-load hours for single-family and multifamily residential buildings were calculated from a DOE-2.2 simulation of prototypical residential buildings. The EFLH values as a function of building type, vintage, and city are given in a table. Savings values are given in therms.	Savings are deemed values based on study results given in table for 92%, 94%, and 96% AFUE. A table showing impact factors for calculating adjusted gross savings such as ISR is given. Savings values are given in MMBtu. Reduction of electric use is deemed to be 478 kWh.
Calculation approach deviations - Energy	$\Delta \mathrm{MMBtu} = \frac{A_{heat} \times HL}{1{,}000 \frac{kBtu}{MMBtu}} \times ($	Savings are deemed, based on DOE-2.2 modeling. Savings are calculated in therms.	No deviation.	No deviation, except savings are calculated in therms.	Deemed table based on an impact evaluation report. High-efficiency furnaces equipped with ECM fan motors also save electricity from reduced fan energy requirements.
Calculation approach deviations - Demand	NA	NA	NA	NA	NA
Annual Gross Energy Savings	$\Delta \mathrm{MMBtu} = 8$	$\Delta \mathrm{MMBtu} = 5.54$	$\Delta \mathrm{MMBtu} = 10.83$	$\Delta \mathrm{MMBtu} = 9.59$	$\Delta \mathrm{MMBtu} = 12.7$ $\Delta \mathrm{kWh} = 478$
Annual Gross Demand Savings	NA	NA	NA	NA	NA
Baseline Condition	78% AFUE (assumed new unit)	78% AFUE (assumed federal standard)	78% AFUE (assumed federal standard) OH TRM suggests	78% AFUE (assumed federal standard)	78% AFUE (assumed federal standard)

Furnace	ENERGY STAR	DEER 2008	OH TRM 2011	NY TRM 2010	MA TRM 2011
$AFUE_{base}$			80% AFUE based on study of actual baseline)		
Efficient Condition $AFUE_{ee}$	90% AFUE (Gas) AFUE can be changed by user	67.5 kBtu 96% AFUE	100 kBtu 92% AFUE	100 kBtu 92% AFUE	AFUE = 92% with an ECM installed. Furnace size is not given.
Assumption 1: A_{heat} (SF)	2,500 (fixed)	2,296 (fixed)	NA	NA	NA
Assumption 2: $EFLH_{heat}$	NA	526 hrs (fixed)	712	630 hrs (table, assuming average vintage home NYC)	NA
TRM Specific Assumption: HL (kBtu/ SF/YR)	19.8 (table, assumed house built between 2,000-2,010 in Washington DC)	NA	NA	NA	NA
Lifetime (years)	18	20	15	NA	18
Incremental Costs	$1,400-$1,100 = $300	NA	$310 for 90% AFUE (Table, incremental costs dependant on AFUE)	NA	NA
Secondary Benefits	Carbon savings: 17,820 lbs CO_2	NA	NA	NA	NA
References	LBNL (2008) NOAA (2007) RESNET Mortgage Industry National HERS Standards www.furnacecompare.com (2008)	DOE-2.2 Appliance Magazine	CEE (2010) DEER EERE	US DOE	Nexus (2010) GDS Associates, Inc. (2009) EPA (2009)

*Census region must be selected due to weather sensitivity. A space heating load is calculated using the ratio of heating degree days to regional average heating degree days for select cities, and historical heat loads by construction age and region values based on analysis of residential energy consumption survey data. The user also enters the size of their house; selects the decade their house was built; the decade the existing furnace was installed or indicates "new"; and whether a programmable thermostat will be used. Savings are given for both gas and oil. Savings values are given in units of both MMBtu and therms.

Furnace Glossary

ΔkWh = Annual kWh savings per unit
$\Delta MMBtu$ = Fuel savings for the measure, in MMBtu
$AFUE_{base}$ = Baseline AFUE
$AFUE_{ee}$ = Efficient condition AFUE
kBTUH = HVAC system capacity in kBTU/hr
$EFLH_{heat}$ = Annual equivalent full load hours for heating
HL = Selected City Heat Load by Construction Age (kBtu/ SF/YR)
A_{heat} = Conditioned floor area (SF)
$\Delta therms$ = Fuel savings for the measure, in therms

Low-Flow Showerhead

Measure Name	Low-Flow Showerhead				
Measure Description	Decrease in showerhead flow rate (typically 2.0 gallons per minute or lower).				
Weather Sensitive?	No	**Sector?**	Residential	**Primary Fuel?**	Gas and Electric
Prevailing Energy Savings Methodology	$\Delta kWh = \Delta GPY \times (T_{shower} - T_{main}) \times 8.3 \frac{Btu}{gal \cdot {}^{\circ}F} \div 3414 \frac{Btu}{kWh} \div EF_{elect}$ $\Delta therms = \Delta GPY \times (T_{shower} - T_{main}) \times 8.3 \frac{Btu}{gal \cdot {}^{\circ}F} \div 100{,}000 \frac{Btu}{therm} EF_{gas}$ $\Delta GPY = (GPM_{base} - GPM_{low}) \times 0.75 \times t_{shower} \times N^{shower} \times 365$				
Prevailing Demand Savings Methodology	$\Delta kW = \Delta kWh \div HRS \times CF$				
Variables	ΔkWh = Annual kWh savings per unit ΔkW = Annual kW savings per unit HRS = Annual operating hours CF = Coincidence factor Δtherms = Fuel savings for the measure, in therms ΔGPY = Water savings per year (gal/yr) T_{main} = Temperature of water from main (°F) T_{shower} = Temperature of water to shower (°F) t_{shower} = Length of time per shower (in minutes) EF_{elect} = Electric water heater efficiency EF_{gas} = Gas water heater efficiency GPM_{base} = Gallons Per Minute of baseline showerhead (GPM) GPM_{low} = Gallons Per Minute of low flow showerhead (GPM) N^{shower} = Number of showers per day 365 = Days per year 0.75 = throttle factor (NY TRM)				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- RTF 2011, OH TRM 2011, NY TRM 2010, PA TRM 2011, and MEMD 2009
- 2 gallons per minute or lower showerhead flow rate.

Energy savings for showerheads are calculated with an algorithm or deemed. Savings arise from reduced hot water consumption, which can be calculated in many different ways. At the most general level, the prevailing algorithm breaks down into two parts: the water savings and the heat required to heat that amount of water.

Assumptions involved in calculating energy savings of low-flow showerheads primarily address water savings in gallons per year. The temperature of the water main varies by city. The NY TRM has a table of locations and corresponding water main temperatures. There is a throttle factor used in NY TRM calculation from a Lawrence Berkeley National Laboratory (LBNL) study to adjust for occupant reduction in full flow rate. RTF uses the temperature differential between the water heater entrance and exit, but the NY TRM finds the differential between the water heater entrance and shower. Hours of use are calculated based on studies, and are used in both energy and demand savings algorithms.

The RTF uses the largest number of assumptions in its calculation. Since the baseline and efficient condition are given in units of gallons/minute, assumptions must be made to reach the end result of gallons per year usage for each condition. Savings vary, depending on whether the showerhead is self-installed or is “direct installed,” meaning rebates are only provided for confirmed installations. The RTF also calculates savings due to reduced pre-use water treatment, pumping, and wastewater treatment by assuming an energy intensity of water (WW). In contrast, the OH TRM assumes a kWh savings per reduced gallons per minute (GPM); this multiplier approach provides a very simple method for calculating savings.

Demand savings are found by dividing kWh savings by the hours of use, and multiplying by the coincidence factor.

Measure lifetimes vary from 9 to 12 years, with 9 years being the most common. Secondary benefits are present in many of the sources as water savings. Incremental costs range between $6 to $24.

Recommendation

It is recommended showerheads be included in a standardized national database:

- The average temperature rise of water and baseline consumption can vary with region. Reference tables or default values should be developed, possibly based on references used in the sources reviewed.
- The efficiency of the water heater will need to be assumed for gas and electric type heaters.

Showerhead	RTF 2011	OH TRM 2011	NY TRM 2010	PA TRM 2011	MEMD 2009
Region	Pacific Northwest	Ohio	New York	Pennsylvania	Michigan
Measure Name	Residential Showerhead Replacement, 2.00 GPM, Primary Shower	Low-Flow Showerhead (Time of Sale or Early Replacement)	Low-Flow Showerheads	Low-Flow Showerheads	Low-Flow Showerheads
Units	Per showerhead	Per showerhead	Per showerhead	Per showerhead	Per showerhead
Approach Commentary	Savings are deemed based on Excel workbooks with built in assumptions. Equations are built in and not explicitly given; reproduced here.	Calculation with default values. User provides actual flow rate of low-flow showerheads.	Calculation with default values. Water savings in gal/yr are calculated using the throttle factor, minutes/shower, and #showers/day (365 days/yr). Water savings are used to calculate energy savings using equations and reference tables. This methodology is derived from the 2008 CL&P and UI Program Savings Documentation.	Partially deemed (for 1.5 GPM showerhead); savings algorithm provided with default values.	Deemed savings are given in an Excel table. No calculations are given. The measure efficiency is set at 1.75 GPM without equations allowing the user to vary the measure efficiency.
Calculation approach deviations - Energy	$\Delta kWh = \text{Uptake}\left[(GPY_{Bas}\right.$ $\Delta therms = \text{Uptake} \times (GF$	$\Delta kWh = ISR \times (GPM_{base}$ $\Delta MMBTU = ISR \times (GPM_{b}$	$\Delta kWh = \Delta GPY \times (T_{shower}$ $\Delta therms = \Delta GPY \times (T_{show}$ $\Delta GPY = (GPM_{base} - GPM$	$\Delta kWh = \frac{GPM_{base} - GPM_{low}}{GPM_{base}} \times$	Deemed tables. Calculations are not publicly available.
Calculation approach deviations - Demand	Deemed. Calculations are unknown.	$\Delta kW = \Delta kWh \div HRS \times C$	NA	$\Delta kW = \Delta kWh \times EDF$	$\Delta kW = \Delta kW_{actual} \times CF$
Annual Gross Energy Savings	$\Delta kWh = 148$ $\Delta therms = 6.3$	$\Delta kWh = 130$ $\Delta MMBtu = 0.57$	$\Delta kWh = 583$ $\Delta therms = 26$	$\Delta kWh = 231$	$\Delta kWh = 518$ $\Delta therms = 27$
Annual Gross Demand Savings	CF = 0.33 $\Delta kW = 0.02$	CF = 0.00371 $\Delta kW = 0.17$	NA	$\Delta kW = 0.02$	CF = 0.7 $\Delta kW = 0.058$
Baseline Condition	2.2 GPM Showerhead	Average flow rate of	Average flow rate of	Federal standard 2.50 GPM	Federal standard 2.50 GPM

Showerhead	RTF 2011	OH TRM 2011	NY TRM 2010	PA TRM 2011	MEMD 2009
GPM_{base}		replaced showerhead 2.87 GPM Enbridge Gas (2010)	replaced showerhead 3.25 GPM	showerhead	showerhead
Efficient Condition GPM_{low}	2.0 GPM Showerhead (fixed)	2.0 GPM Showerhead	2.0 GPM Showerhead	2.0 GPM Showerhead	1.75 GPM Showerhead
Assumption 1: T_{main} (°F)	53 (fixed)	NA	62.5 (table, NYC)	55 (fixed)	NA
Assumption 2: T_{heater} (°F)	128 (fixed)	NA	NA	120 (fixed)	NA
Assumption 3: Annual Occupancy (days/year)	350 (fixed)	365 (fixed)	365 (fixed)	365 (fixed)	NA
Assumption 4: Persons/Showerhead	2.51(fixed)	1.17 (fixed)	NA	2.48/1.6 = 1.55 (calculated, fixed)	NA
Assumption 5: Average Shower Length (minutes)	7.84	NA	8	NA	NA
Assumption 6: HRS	63 (fixed)	29 (fixed)	NA	NA	100 (fixed)
TRM Specific Assumptions	$HW\%_{Base}$ = 73.1% $HW\%_{Eff}$ = 75.5% GPY_{Base} = 8333.8 GPY_{Eff} = 6818.6 WHE_{elect} = 0.00249 WHE_{gas} = 0.00011 Uptake = 80% WW = 5.3 Daily showers per person = 0.55 (all are fixed)	NA ISR = 1.0 (retrofit/direct install) $kWh/GPM_{reduced}$ = 149 $MMBtu/GPM_{reduced}$ = 0.66 Gal/person/day = 11.6 (all are fixed)	Throttle Factor = 0.75 T_{shower} (°F) = 105 EF_{elect} = 0.97 EF_{gas} = 0.75 N^{shower} = 2 (all are fixed)	EDF = 0.00009172 W/kWh GPY_{Base} = 11.6 X 365 = 4234 gal/yr EF_{elect} = 0.90 (all are fixed)	NA
Lifetime (years)	10	9	NA	9	12
Incremental Costs	$24	$6	NA	NA	$15
Secondary Benefits	Water Savings = 1,212 gal/yr CO_2 reduction	Water Savings = 1,504 gal/yr	NA	Water Savings = 5,475 gal/yr	NA
References	SBW Metering Study (1994), US EPA (2005), Burton, Franklin L. (1996),	EPA "water sense" documents, EIA	LBNL study	EPA (1992), Pennsylvania Census (2000), U.S. EPA (2010), PNNL, PJM (2007),	DEER (2008)

Showerhead	RTF 2011	OH TRM 2011	NY TRM 2010	PA TRM 2011	MEMD 2009
	Seattle End-use Study (2000)			Efficiency Vermont (2008)	

Showerhead Glossary
ΔkWh = Annual kWh savings per unit
ΔkW = Annual kW savings per unit
HRS = Annual operating hours
CF = Coincidence factor
Δtherms = Fuel savings for the measure, in therms
ΔGPY = Water savings per year (gal/yr)
$HW\%_{Base}$ = Shower Water from Hot Tap – baseline condition (%)
$HW\%_{Eff}$ = Shower Water from Hot Tap – efficient condition (%)
GPY_{Base} = Total Gallons per Year – baseline condition (gal/yr)
GPY_{Eff} = Total Gallons per Year – efficient condition(gal/yr)
WHE_{elect} = Electric Water Heater Heating Energy (kWh per °F per gallon)
WHE_{gas} = Gas Water Heater Heating Energy (therm per °F per gallon)
Uptake = This factor is not defined by the user, the RTF. It may be similar to an in service rate.
WW = Energy intensity of water, including treatment, pumping, and wastewater treatment (kWh/1,000gal)
GPM_{base} = Gallons Per Minute of baseline showerhead (GPM)
GPM_{low} = Gallons Per Minute of low flow showerhead (GPM)
$kWh/GPM_{reduced}$ = Assumed kWh savings per GPM reduction (kWh/GPM)
T_{main} = Temperature of water from main (°F)
T_{shower} = Temperature of water to shower (°F)
T_{heater} = Temperature of water at water heater outlet or supplied to faucet (°F)
EF_{elect} = Electric water heater efficiency
EF_{gas} = Gas water heater efficiency
EDF = Summer Peak Energy to Demand Factor (kW/kWh)
t_{shower} = Length of time per shower (in minutes)
N^{shower} = Number of showers per day
365 = Days per year
0.75 = Throttle factor (NY TRM)

Attic/Ceiling Insulation

Measure Name	Attic/Ceiling insulation				
Measure Description	Improvements to ceiling insulation in residential buildings by increasing the R-value.				
Weather Sensitive?	Yes	**Sector?**	Residential	**Primary Fuel?**	Gas and Electric
Prevailing Energy Savings Methodology	Varies by HVAC system type and heating or cooling savings. Air Conditioning Savings $\Delta kWh_{CAC} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times \frac{CDD \times 24\frac{hr}{day} \times DUA \times A}{1{,}000\frac{W}{kW} \times SEER_{part}}$				
Prevailing Demand Savings Methodology	Air Conditioning Savings $\Delta kW_{summer} = \frac{\Delta kWh_{CAC}}{EFLH_{cool}} \times CF_{CAC}$				
Variables	ΔkW_{summer} = Summer kW savings per unit $EFLH_{cool}$ = Annual equivalent full load hours for cooling CF = Coincidence factor $SEER_{part}$ = SEER of cooling systems within participant population A = Effective area of increased insulation (sq ft) DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F ΔkWh_{CAC} = Annual kWh cooling savings with central A/C CF_{CAC} = Summer peak coincidence factor for central AC systems CDD = Cooling degree days (65°F default) R_{base} = Baseline condition effective thermal resistance value (hr-SF-°F/Btu) R_{ee} = Efficient condition effective thermal resistance value (hr-SF-°F/Btu)				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- RTF 2011, PA TRM 2011, MA TRM 2011, OH TRM 2011, and NY TRM 2010
- Increase ceiling insulation R-value, comparison applicable to cooling systems.

Energy savings from various HVAC systems are calculated on a per square foot basis, either through use of simulation software or algorithms. These per square foot savings are then scaled up by the effective area of increased insulation. Multiple algorithms were found depending on the system type (AC, heat pump, furnace, etc.) or fuel type.

Demand savings are generally calculated using the energy savings, hours of cooling, and a coincident factor, which varies by region and heating or cooling systems. The MA TRM uses a kW/kWh factor to convert energy savings into demand savings.

Secondary benefits were observed in the MA TRM, which has a table (for low-income programs) with algorithms to calculate the annual discounted rate cost reduction, annual fire, illness, and moving avoidance benefits, and the one-time property value benefit. In addition, the RTF secondary benefits include $C0_2$ reduction in tons over expected measure life.

Measure lifetimes, available in four of the five sources, vary from 25 to 45 years, with 25 years the most commonly found value. Incremental costs are available in only one of the five sources on a per installation basis for the RTF.

In general, incremental costs depend on residence size and measure. Climate zone, building type, vintage, HVAC system, and other characteristics must be considered when using simulation software or equations.

Recommendation

Due to the very high sensitivity to climate variation and other characteristics that vary by location, this measure would be challenging to standardize, based on simulation software. Modeling residential roof insulation would not be recommended (initially) to be included as part of the national database as it could require a significant effort. The models would need to be developed for regions, requiring significant data on regional building characteristics. The engineering calculation methodology of using the basic heat transfer equation could initially be the easiest to incorporate into a national database.

- Professional modeling has the highest accuracy, if existing building stock data are available, and would provide this measure (and other shell measures) with tabulated results.
- DEER prototypical building simulation is a good starting point for the national prototypical models, as DEER has been thoroughly vetted by California's efficiency programs.
- An engineering calculation method, though less accurate than modeling, would provide a quick and reasonable result if proper bounds to inputs are provided. Therefore, Heating Degree Days and Cooling Degree Days will need to be supplied by location or region, which is readily available through various sources, such as the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

In either scenario, a national database would need to adequately support all inputs with user guidance on how to make the most appropriate choices.

Insulation	RTF 2011	PA TRM 2011	MA TRM 2011	OH TRM 2011	NY TRM 2010
Region	Pacific Northwest	Pennsylvania	Massachusetts	Ohio	New York
Measure Name	Single-Family Weatherization—Insulate Attic	Ceiling/Attic and Wall Insulation	Multifamily—Insulation (Walls, Roof, Floor)	Attic-Roof-Ceiling Insulation (Retrofit)	Opaque Shell Insulation
Units	Per square foot installed	Per square foot installed	Per square foot installed	Per square foot installed	Per square foot installed
Approach Commentary	Savings are deemed, based on an assumed area and SEEM simulation software. Only heating system savings are considered.	Savings algorithms for gas and electric heating and electric cooling. Specific systems included are: central AC, room AC, ASHP (heating and cooling), and baseboard and electric furnace heating. The measure assumes an auditor, contractor, or utility staff member is on location, and will measure and record: the existing and new insulation depth and type (to calculate R-values), the surface area of insulation added, and the efficiency of the HVAC system.	Algorithm based on deemed savings. Average annual kWh reduction per sq ft of insulation is given in a table for attic (ceiling), basement, and walls. This value is scaled by the difference of the inverse of the R-values.	Savings algorithms are given for gas and electric heating and electric cooling. The measure assumes an auditor, contractor, or utility staff member is on location, and will measure and record: the existing and new insulation depth and type (to calculate R-values), the surface area of insulation added, and the efficiency of the cooling or heating system used in the home.	Parameters for the energy and demand savings calculations are based on DOE-2.2 simulations of a set of prototypical residential buildings, derived from the DEER study, with adjustments made for local building practices and climate. Energy savings are listed in tables as ΔkWh/kSF by city, building category, HVAC system and fuel type, and R-value. The calculation includes correction factors for differences between modeling assumptions of efficiency values.*

Insulation	RTF 2011	PA TRM 2011	MA TRM 2011	OH TRM 2011	NY TRM 2010
Calculation approach deviations - Energy	Savings are deemed, based on an assumed area and kWh/SF savings generated from use of the SEEM simulation software. HVAC systems considered are: “average” heating systems, zonal heating systems, electric furnaces and heat pump heating systems.	Central AC Savings $\Delta kWh_{CAC} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right)$ ΔkWh_{RAC}: Same as ΔkWh_{CAC} except EER replaces SEER and savings are multiplied by F_{RAC}. $\Delta kWh_{ASHP\ cool}$: Same as ΔkWh_{CAC} $\Delta kWh_{ASHP\ heat} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right.$ $\Delta kWh_{elec\ heat} = \left(\frac{1}{R_{base}} - \frac{1}{R}\right.$	$\Delta kWh = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times A$	AC Savings $\Delta kWh_{Cool} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right)$ Space Heating Savings Fossil Fuel $\Delta MMBtu = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times$ Electric $\Delta kWh_{heat} = \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right)$	$\Delta kWh = \frac{A}{1{,}000} \times \frac{\Delta kWh}{kSF} \times \frac{SEE}{SEE}$ $\Delta therm = \frac{A}{1{,}000} \times \frac{\Delta therm}{kSF} \times$ ΔkWh/kSF savings are deemed, based on simulation software results. Software unknown.
Calculation approach deviations - Demand	NA	Central AC $\Delta kW_{summer} = \frac{\Delta kWh_{CAC}}{EFLH_{cool}} \times CF_{CA}$	$\Delta kW_{summer} = \Delta kWh \times \frac{kW}{kWh}$	Central AC $\Delta kW_{summer} = \frac{\Delta kWh_{cool}}{EFLH_{cool}} \times 0$	$\Delta kW_{summer} = \frac{A}{1{,}000} \times \frac{\Delta kW}{kSF} \times$
Annual Gross Energy Savings	Varies by R-values, heating system type, and climate zone.	Varies by system and R-values.	Varies by R-values.	Varies by system and R-values.	Table with electricity and gas savings per 1,000 SF by building type, city, R-values.

Insulation	RTF 2011	PA TRM 2011	MA TRM 2011	OH TRM 2011	NY TRM 2010
Annual Gross Demand Savings	ΔkW for all heating systems is deemed to be 0 since they are unlikely to operate during summer.	CF varies by cooling/heating and HVAC system type. CF_{CAC} = 0.70 CF_{RAC} = 0.58 ΔkW for all heating systems is deemed to be 0 since they are unlikely to operate during summer.	Varies by R-values	CF = 0.5	CF = 0.8
Baseline Condition	Variable	Variable, table of R-values according to thickness of existing attic insulation. R-5 is for uninsulated attic.	Existing insulation	Actual recorded. If uninsulated assembly assume R-5	Actual recorded.
Efficient Condition	Variable	Variable	Variable	Variable	Variable
Assumption 1: $AFUE_{part}$	NA	NA	NA	Varies by system	Varies by system
Assumption 2: $SEER_{part}$	NA	Varies by system (default is 13)	NA	Varies by system	Varies by system
Assumption 3: EER_{part}	NA	Varies by system (default is 9.8)	NA	NA	Varies by system
Assumption 4: $HSPF_{part}$	NA	Varies by system (default is 7.7)	NA	NA	NA
Assumption 6: Discretionary Use Adjustment Factor	NA	DUA = 0.75 (fixed)	NA	DUA = 0.75 (fixed)	NA
Assumption 10: A (ft^2)	1,414 (fixed weighted average)	Varies	Varies	Varies	Varies
TRM Specific Assumptions	NA	F_{RAC} = 0.38 (fixed) Reference table by location for: cooling degree days $EFLH_{cool}$ (CAC and RAC) heating degree days	ΔkWh_{sqft} = 38.803 $\frac{kW}{kWh}$ = 0.000125	Provides tables by location for: cooling degree hours $EFLH_{cool}$ heating degree days (60 °F base temperature)	$\eta_{dist,base}$ = 0.956 $\eta_{dist,pk,base}$ = 0.956 $AFUE_{base}$ = 78% $SEER_{base}$ = 13 EER_{base} = 11.1 $\eta_{dist,part}$ Varies by location $\eta_{dist,pk,part}$ Varies by location

Insulation	RTF 2011	PA TRM 2011	MA TRM 2011	OH TRM 2011	NY TRM 2010
Lifetime (years)	45	25	25	25	NA
Incremental Costs	Varies by measure.	NA	NA	The actual installation cost should be used.	NA
Secondary Benefits	CO_2 reduction	NA	Algorithms to calculate annual discounted rate cost reduction; annual fire, illness, and moving avoidance benefits; and one-time property value benefit.	NA	NA
References	SEEM simulation software	Ohio TRM (2010), eQuest, ENERGY STAR, PECO, PA TRM (2010), NOAA, MA TRM (2010)	Quantec LLC (2000), GDS Associates, Inc. (2007), Oppenheim, Jerry (2000), Cadmus Group (2010)	NREL, Energy Center of Wisconsin (2008) GDS Associates (2007)	Electric Power Research Institute (1993)

*In cases where the exact R-value (either pre or post) falls between the values on these tables, linear extrapolation can be used to approximate the savings.

Insulation Glossary
ΔkW_{summer} = Summer kW savings per unit ΔkWh = Annual kWh savings per unit $EFLH_{cool}$ = Annual equivalent full load hours for cooling CF = Coincidence factor EER_{base} = EER used in the simulations EER_{part} = EER of cooling systems within participant population $SEER_{base}$ = SEER used in the simulations $SEER_{part}$ = SEER of cooling systems within participant population $AFUE_{base}$ = AFUE used in the simulations $AFUE_{part}$ = AFUE of heating systems within participant population $HSPF_{part}$ = HSPF of ASHP within participant population $\eta_{dist,base}$ = Distribution system seasonal efficiency used in the simulations $\eta_{dist,part}$ = Distribution system seasonal efficiency within participant population $\eta_{dist,pk,base}$ = Distribution system efficiency under peak conditions used in the simulations $\eta_{dist,pk,part}$ = Distribution system efficiency under peak conditions of cooling systems within participant population A = Effective area of increased insulation (sq ft) CDH = Cooling Degree Hours DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F ΔkWh_{CAC} = Annual kWh cooling savings with central A/C ΔkWh_{RAC} = Annual kWh cooling savings with room A/C $\Delta kWh_{ASHP\ cool}$ = Annual kWh cooling savings with electric air-to-air heat pump $\Delta kWh_{ASHP\ heat}$ = Annual kWh heating savings with electric air-to-air heat pump $\Delta kWh_{elec\ heat}$ = Annual kWh heating savings with electric baseboard or electric furnace heat CF_{CAC} = Summer peak coincidence factor for central AC systems CF_{RAC} = Summer peak coincidence factor for room AC systems CF_{ASHP} = Summer peak coincidence factor for ASHP systems F_{RAC} = Adjustment factor to relate insulated area to area served by Room AC units HDD = Heating degree days (65°F default) CDD = Cooling degree days (65°F default) ΔkWh_{sqft} = Average annual kWh reduction per sq ft of insulation $kW\ /kWh$ = Average kW reduction per kWh reduction R_{base} = Baseline effective thermal resistance value (hr-SF-°F/Btu) R_{ee} = Efficient effective thermal resistance value (hr-SF-°F/Btu)

Unitary Air Source Heat Pump

Measure Name	Unitary Air Source Heat Pump				
Measure Description	Installation of high-efficiency air cooled heat pump system. Some TRMs also include water source or ground source type systems.				
Weather Sensitive?	Yes	**Sector?**	Residential	**Primary Fuel?**	Electric
Prevailing Energy Savings Methodology	$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$ $\Delta kWh_{cool} = \frac{BTUH_{cool}}{1{,}000} \times \left[\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right] \times EFLH_{cool}$ $\Delta kWh_{heat} = \frac{BTUH_{heat}}{1{,}000} \times \left[\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right] \times EFLH_{heat}$				
Prevailing Demand Savings Methodology	$\Delta kW_{summer} = \frac{BTUH_{cool}}{1{,}000} \times \left[\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right] \times CF$				
Variables	ΔkWh = Annual kWh savings per unit ΔkWh_{cool} = Annual cooling kWh savings per unit ΔkW_{summer} = Summer kW savings per unit ΔkWh_{heat} = Annual heating kWh savings per unit $SEER_{base}$ = Baseline seasonal energy-efficiency ratio $SEER_{ee}$ = Efficient condition seasonal energy-efficiency ratio $BTUH_{cool}$ = HVAC system cooling capacity in BTU/hr $BTUH_{heat}$ = HVAC system cooling capacity in BTU/hr $EFLH_{cool}$ = Annual equivalent full load hours for cooling $EFLH_{heat}$ = Annual equivalent full load hours for heating EER_{base} = Baseline energy-efficiency ratio EER_{ee} = Efficient condition energy-efficiency ratio CF = coincidence factor for demand 1,000 = watts per kW				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- ENERGY STAR, RTF 2011, DEER 2005, PA TRM 2011, and OH TRM 2011
- 3 ton (36,000 BTUH) sized system

Residential air source heat pumps (ASHP) are more likely to be rated in SEER/HSPF units while commercial units tend to be EER/COP. Energy savings are calculated per system on a retrofit basis, and PA TRM, ENERGY STAR calculator, and OH TRM use the prevailing algorithm. Baseline conditions are typically defined based on International Energy Conservation Code (IECC) requirements (13 SEER/7.7 HSPF). The efficient condition is usually the nameplate efficiency. DEER utilizes modeling to determine energy savings. Tables of $EFLH_{cool}$ and $EFLH_{heat}$ values are generally provided with the algorithm for various cities and building types. Demand savings are calculated using the EER value with a coincidence factor, when available.

Secondary benefits are available through the ENERGY STAR calculator and RTF, which converts energy savings into CO_2 reductions. Measure lifetimes range from 12 to 20 years. Incremental costs are available in three of the five sources (ENERGY STAR, PA TRM, and OH TRM) as $/ton and in the RTF as $/unit.

Recommendation

Although weather sensitive, this measure may be appropriate for a national database once the usage or EFLH is tabulated by climate zone/building type/location, given the relatively small deviation in the savings algorithm and well-defined baseline and efficient conditions. The biggest challenge is determining the correct values for $EFLH_{cool}$ and $EFLH_{heat}$. Database recommendations, similar to commercial ASHP, are presented below:

- The primary challenge will be to develop weather-sensitive usage or EFLH by climate zone and building type. This can be achieved through DOE2 building simulations, but, as with shell measures, this poses a significant undertaking to develop models nationally.
- DEER prototypical building simulations provide a good starting point for national prototypical models as DEER has been thoroughly vetted by California's efficiency programs.
- As with most measures, a national database would require adequate technical support to address state and federal codes updates.
- Coincidence factors are location/climate dependent, and a table should be provided with default values.

Air Source Heat Pump	ENERGY STAR	RTF 2011	DEER 2005	PA TRM 2011	OH TRM 2011
Region	National	Pacific Northwest	California	Pennsylvania	Ohio
Measure Name	ENERGY STAR Qualified Air Source Heat Pump	Existing Single-Family Home HVAC Upgrade - Heat Pump	A/C Heat Pump 8.8 HSPF, 15 SEER	Heat Pump (includes air-to-air HP, packaged terminal HP, water source HP, and groundwater source HP).	Air Source Heat Pump (Time of Sale)
Units	Per air source heat pump	Per air source heat pump	Per ton (cooling)	Per air source heat pump	Per air source heat pump
Approach Commentary	Interactive calculator with user supplied variables, such as electric rates, number of units, SEER and HSPF, cost, and capacity. Option exists for use with programmable thermostat. Default is 3 ton size.	Deemed savings based on SEEM simulation software.	Use DOE2.2 modeling for various building types/climate zones. Convert EER and COP into DOE2.2 inputs.	Calculation with baseline efficiency values from a table; uses actual installed and efficient condition values. Table of $EFLH_{cool}$ and $EFLH_{heat}$ values provided for various cities and building types.	Calculation with deemed baseline efficiency values; uses actual installed and efficient condition values. Table of $EFLH_{cool}$ and $EFLH_{heat}$ values provided for various cities and building types.
Calculation approach deviations - Energy	Trivial deviation; combines the cooling and heating equations.	Tabulated by climate zone, building type.	Tabulated by climate zone, vintage, building type.	No deviation.	Trivial deviation; combines the cooling and heating equations.
Calculation approach deviations - Demand	NA	Tabulated by climate zone, building type	Tabulated	No deviation	No deviation
Annual Gross Energy Savings	ΔkWh = 909 (not used with programmable thermostat)	ΔkWh = 169	ΔkWh/ton = 164	ΔkWh = 951	ΔkWh = 643
Annual Gross Demand Savings	NA	ΔkW = 0.050 CF = 0.36 (fixed)	ΔkW/ton= 0.101	ΔkW = 0.246 CF = 0.70 (fixed)	ΔkW = 0.219 CF = 0.50 (fixed)
Baseline Condition	36,000 BTUH 7.7 HSPF 13 SEER (Above are default, but can be changed)	size varied based on SEEM software 8.5 HSPF 13 SEER (Fixed)	Depends on vintage 8.1 HSPF 13 SEER 11.07 EER (Fixed)	36,000 BTUH 7.7 HSPF 13 SEER 11.3 EER (Fixed; Cadmus size based on value from ENERGY STAR)	36,000 BTUH 7.7 HSPF 13 SEER 11.3 EER (Fixed; Cadmus size based on value from ENERGY STAR)
Air Source Heat Pump	ENERGY STAR	RTF 2011	DEER 2005	PA TRM 2011	OH TRM 2011

Air Source Heat Pump	ENERGY STAR	RTF 2011	DEER 2005	PA TRM 2011	OH TRM 2011
Efficient Condition	36,000 BTUH 8.2 HSPF 15 SEER (Default but can be changed)	size varied based on SEEM software 9.0 HSPF 14 SEER (fixed)	units: per/ton 8.8 HSPF 15 SEER 12.70 EER (fixed)	36,000 BTUH 8.8 HSPF 15 SEER 12.70 EER (Cadmus defined based on DEER and ENERGY STAR)	36,000 BTUH 8.8 HSPF 15 SEER 12.70 EER (Cadmus defined based on DEER and ENERGY STAR)
Assumption 1: Hours of use	EFLHcool = 947 EFLHheat = 2,238 (table, Dayton, OH)	Heating Zone 1	Climate Zone 16 – Mt. Shasta	EFLHcool=737 EFLHheat=2380 (table, Pittsburgh, PA)	EFLHcool=631 EFLHheat=1438 (table, Dayton, OH)
TRM Specific Assumptions: Building Type	NA	Single-Family	Single-Family	NA	NA
Lifetime (years)	12	20	15	NA	18
Incremental Costs	$333/ton	$63	$196/ton	NA	$274/ton
Secondary Benefits	lbs of CO2 reduced = 16804	tons of CO2 reduced = 0.1	NA	NA	NA
References	Industry data, NAECA, LBNL (2007), EPA (2002), EIA AEO (2009)	SEEM simulation modeling software	CALMAC, CEE	Federal Register Vol. 66, No. 14 (2001), ENERGY STAR (2009), Proctor Engineering	ENERGY STAR, Neme, Proctor, Nadal, (1999), Federal Register, Vol. 66, No. 14 (2001), Duke Energy, OH Joint Utility TRM (2009), Energy Center of Wisconsin Metering Study (2008), GDS Associates (2007), DEER (2008)

Air Source Heat Pump Glossary
ΔkWh_{cool} = Annual cooling kWh savings per unit
ΔkW_{summer} = Summer kW savings per unit
ΔkWh_{heat} = Annual heating kWh savings per unit
$SEER_{base}$ = Baseline seasonal energy-efficiency ratio
$SEER_{ee}$ = Efficient condition seasonal energy-efficiency ratio
$BTUH_{cool}$ = HVAC system cooling capacity in Btu/hr
$BTUH_{heat}$ = HVAC system cooling capacity in Btu/hr
$EFLH_{cool}$ = Annual equivalent full load hours for cooling
$EFLH_{heat}$ = Annual equivalent full load hours for heating
EER_{base} = Baseline energy-efficiency ratio
EER_{ee} = Efficient condition energy-efficiency ratio
CF = Coincidence factor for demand
1,000 = Watts per kW

Storage Water Heater

Measure Name	High-Efficiency Storage Water Heater				
Measure Description	A high-efficiency tank-type water heater with either an electric or gas-based heat source. Does not include solar thermal or heat pump water heaters.				
Weather Sensitive?	No	**Sector?**	Residential	**Primary Fuel?**	Gas and Electric
Prevailing Energy Savings Methodology	$\Delta \mathrm{kWh} = \left(\frac{1}{EF_{base}} - \frac{1}{EF_{ee}}\right) \times \frac{GPD \times 365 \times 8.33\frac{lb}{gal} \times (T_{out} - T_{main})}{3{,}413\frac{Btu}{kWh}}$ $\Delta \mathrm{therms} = \left(\frac{1}{EF_{base}} - \frac{1}{EF_{ee}}\right) \times \frac{GPD \times 365 \times 8.33\frac{lb}{gal} \times (T_{out} - T_{main})}{100{,}000\frac{Btu}{therms}}$				
Prevailing Demand Savings Methodology	$\Delta \mathrm{kW}_{summer} = (UA_{base} - UA_{ee}) \times (T_{amb} - T_{main}) \div 3{,}413\,\frac{\mathrm{Btu}}{\mathrm{kWh}} \times CF$ where: $\Delta UA = \frac{\left(\frac{1}{EF} - \frac{1}{RE}\right)}{\left(67.5 \times \frac{24}{41{,}904} - \frac{1}{RE \times Cap}\right)}$				
Variables	$\Delta \mathrm{kWh}$ = Annual kWh savings per unit Δtherms = Fuel savings for the measure, in therms $\Delta \mathrm{kW}$ = Annual kW savings per unit GPD = Water usage (gal/day) EF_{base} = Baseline water heater efficiency EF_{ee} = Efficient condition water heater efficiency RE = Recovery efficiency T_{out} = Water temperature exiting the water heater T_{main} = Water main temperature T_{amb} = Ambient temperature (°F) UA_{ee} = Overall heat loss coefficient of efficient water heater [Btu/(hr °F)] UA_{base} = Overall heat loss coefficient of base water heater [Btu/(hr °F)] 67.5 = Temperature difference between storage set point and ambient air temperature at the DOE test condition (°F) 41,094 = Standard daily recovery load at DOE test condition (Btu/day). Cap = Water heater capacity (Btu/hr) CF = Coincidence factor				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- RTF 2011, DEER 2008, PA TRM 2011, OH TRM 2011, NY TRM 2010
- A high-efficiency, tank-type water heater with either an electric or gas-based heat source.
- Does not include solar thermal or heat pump water heaters.

Energy savings are generally calculated using some variation of the prevailing methodology, using the volume of hot water consumed (gallons per day), the temperature differential of the water into and out of the water heater, and the equipment efficiency. GPD accounts for the variation in water heater size.

Demand savings are calculated using ambient room temperatures, the water main temperature differential, and the UA-value.[4] The NY TRM includes a variable called the demand diversity factor (DF). DF is not defined in the TRM, however, and users will have difficulty using this TRM due to the undefined variable. Other assumptions include the recovery efficiency and capacity in Btu/hr.

The only assumptions for this measure that may be regional are the water main temperature, which varies by city, and the ambient room temperature. The baseline and efficient EF values depend on fuel type. Gas water heaters have a much lower efficiency than electric water heaters at both the baseline and efficient conditions.

Measure lifetimes are included in the NY TRM, PA TRM, and RTF with values of 13, 14, and 15 years, respectively. Incremental costs in the RTF and DEER are $51.06 and $25.16, respectively, with DEER only considering costs of electric water heaters for this particular size and efficiency. The OH TRM has gas only incremental costs of $400. The other two sources do not consider costs.

Recommendation

Considering the minimal weather sensitivity of water heaters (except for potential HVAC interaction and water main temperatures) and the algorithm's ease of use, efficient water heaters are a good candidate for inclusion in a measures database.

- The prevailing algorithm is recommended, with separate algorithms for electric and gas-type heaters.
- National or regional averaged water usage values will need to be developed.
- Determine whether baseline EF should be based on the federal minimum or the market average.
- Determine how to define efficient condition EF.

[4] The U-value is a commonly used term for the overall heat loss coefficient; it has units of Btu/(hr °F sq ft). Although the U-value is not used, in the case of DEER and the NY TRM, UA incorporates surface area, and has the units of Btu/(hr °F).

Storage Hot Water Heater	RTF 2011	DEER 2008	PA TRM 2011	OH TRM 2011	NY TRM 2010
Region	Pacific Northwest	California	Pennsylvania	Ohio	New York
Measure Name	Residential-type Water Heater (>= 35 gallons, <45 gallons)	High-Efficiency Small Electric Storage Water Heater – 40 Gal, 0.94 EF High-Efficiency Small Gas Storage Water Heater – 40 Gal, 0.67 EF	Efficient Electric Water Heaters	Water Heaters (Time of Sale)	Water Heater
Units	Per water heater	Per water heater	Per water heater	Per water heater	Per water heater
Approach Commentary	Deemed savings based on calculations in Excel spreadsheet, using real product data. Includes HVAC interaction effects.	DOE-2 modeling using the Heat Input Ratio (HIR) – a variable used by DOE modeling software.	Savings based on calculation. Electric only savings.	Savings based on calculation. Gas only savings. Calculation based on deemed therms/yr value.	Savings based on calculation.
Calculation approach deviations - Energy	Deemed savings based on calculations in Excel spreadsheet.	DOE-2 inputs are HIR and Tank UA, and part-load performance. where: $UA = \frac{\left(\frac{1}{EF}-\frac{1}{RE}\right)}{\left(67.5\times\frac{24}{41094}-\frac{1}{RE\times Cap}\right)}$ $HIR = \frac{1}{RE}$	No deviation	$\Delta kWh = BtuHW_{USAGE} \times ($	No deviation
Calculation approach deviations - Demand	Deemed savings based on calculations in Excel spreadsheet.	DOE-2 inputs are HIR and Tank UA, and part load performance. where: $UA = \frac{\left(\frac{1}{EF}-\frac{1}{RE}\right)}{\left(67.5\times\frac{24}{41094}-\frac{1}{RE\times Cap}\right)}$ $HIR = \frac{1}{RE}$	$\Delta kW = EDF \times \Delta kWh$	NA	No deviation, except inclusion of a variable called demand diversity factor. DF is not given a value in TRM. Users will have difficulty using this TRM due to the undefined variable.
Annual Gross Energy Savings	ΔkWh = 99	ΔkWh = 347 Δtherms = 39	ΔkWh = 175	Δtherms = 24	ΔkWh = 339 Δtherms = 57
Annual Gross Demand Savings	CF = 0.60 ΔkW = 0.01	ΔkW = 0.033	ΔkW = 0.016 EDF = 0.000092	NA	CF = 0.80 ΔkW = 0.033

Storage Hot Water Heater	RTF 2011	DEER 2008	PA TRM 2011	OH TRM 2011	NY TRM 2010
Baseline Condition	35-45 gallons EF_{base} = 0.93 (fixed)	40 gallon Electric: EF_{base} = 0.88 Gas: EF_{base} = 0.59 (calculated)	50 gallon Electric: EF_{base} = 0.90 (fixed)	50 gallon Gas: EF_{base} = 0.58 (fixed - federal minimum)	40 gallon Electric: EF_{base} = 0.88 Gas: EF_{base} = 0.54 (calculated) NAECA standards
Efficient Condition	35-45 gallons EF_{ee} = 0.95 (fixed)	40 gallon (fixed) Electric: EF_{ee} = 0.94 Gas: EF_{ee} = 0.67 (table, code baseline)	50 gallon Electric: EF_{ee} = 0.94 (fixed)	50 gallon (fixed) Gas: EF_{ee} = 0.67 (table, ENERGY STAR gas storage)	40 gallon Electric: EF_{ee} = 0.94 Gas: EF_{ee} = 0.67 (Cadmus defined based on value from OH TRM)
Assumption 1: Hot Water Usage	NA	NA	GPD = 64.3 (fixed)	$BtuHW_{USAGE}$ = 180 therms/yr (fixed)	78 GPD (default for single family)
Assumption 2: Water Temperature T_{main} & T_{out}	NA	NA	T_{main} = 55 T_{out} = 120 (fixed)	NA	T_{main} = 62.5 (table, NYC, NY) T_{out} = 130 (fixed)
TRM Specific Assumptions:	NA	RE = 0.81 (fixed)	NA	NA	T_{amb} = 65 (fixed) DF = 1 (Cadmus assumed value) UA_{ee} = 0.943 (calculated) UA_{base} =3.021 (calculated) RE_{elec} = 0.97 (table, electric) Cap = 15,400 Btu/hr (table, electric)
Lifetime (years)	15	NA	14	NA	13
Incremental Costs	$51.06	Electric: $25.16 Gas: No cost values for selected measure.	NA	Gas: $400	NA
Secondary Benefits	Lbs of carbon = 0	NA	NA	NA	NA
References	6th Power Plan, US DOE, ACEEE (2007), NAHB (2007)	CLASS CEE DOE (2007)	DOE (2006), Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 25996, Mid-Atlantic TRM	ENERGY STAR, Residential Energy Consumption Survey (2001)	Rev. Lawrence Berkeley Laboratory (1996), NREL, DOE 2.2.

Storage Hot Water Heater Glossary
ΔkWh = Annual kWh savings per unit Δtherms = Fuel savings for the measure, in therms ΔkW = Annual kW savings per unit GPD = water usage (gal/day) EF_{base} = Baseline water heater efficiency EF_{ee} = Efficient condition water heater efficiency T_{out} = Water temperature exiting the water heater (°F) T_{main} = Water main temperature (°F) T_{amb} = Ambient temperature (°F) UA_{ee} = Overall heat loss coefficient of efficient water heater [Btu/(hr °F)] UA_{base} = Overall heat loss coefficient of base water heater [Btu/(hr °F)] 67.5 = Temperature difference between storage set point and ambient air temperature at the DOE test condition (°F) 41,094 = Standard daily recovery load at DOE test condition (Btu/day). $BtuHW_{USAGE}$ = Gas usage per year (therms) *This is the variable used in the OH TRM. Variable name is misleading DF = Demand diversity factor RE_{elec} = Electric water heater recovery efficiency Cap = Water heater capacity (Btu/hr)

ECM Furnace Fan Motor

Measure Name	ECM Furnace Fan Motor				
Measure Description	An ECM (electronically commutated motor) consumes less power than a standard motor used in a ventilation and circulation system (residential furnace fan).				
Weather Sensitive?	Yes	**Sector?**	Residential	**Primary Fuel**?	Electric
Prevailing Energy Savings Methodology	Deemed, usually through adjustment of deemed savings from other studies for local differences in equipment, climate (hours of use), or other characteristics.				
Prevailing Demand Savings Methodology	Deemed				
Variables	None because savings are typically deemed.				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- Mid-Atlantic TRM 2010, MA TRM 2011, MEMD 2010, NY TRM 2010, VT TRM 2010
- ECM used to drive the home furnace fan.

Energy savings are deemed on a per-furnace basis, ranging from 419 to 733 kWh. The general methodology uses claimed savings reported from a technical study. The VT and Mid-Atlantic TRM both use the same 2003 Wisconsin study as the basis for the kWh savings; the Mid-Atlantic TRM uses a heating degree-day adjustment factor, while the VT TRM does not explain explicitly how it was adapted. The New York TRM uses a different Wisconsin study from 2009 for their deemed electric savings. The MA TRM uses a study conducted in Massachusetts for their electric and natural gas savings but adapted natural gas savings with an AFUE and heating load hour adjustment factor.

The Mid-Atlantic and Massachusetts methods for adjusting reported savings differ. The Mid-Atlantic TRM uses heating degree-days to adjust kWh savings from motor usage during heating season and cooling load hours for kWh cooling season savings. The Massachusetts TRM uses heating load hours to adjust natural gas impacts. None of the other three technical manuals indicate if and what factors were used to adjust their reported savings.

The Massachusetts TRM is the only technical manual that claims natural gas heating impacts due to efficiency improvements. The Vermont TRM and Michigan database claim zero natural gas impacts, while the Mid-Atlantic and New York TRM do not mention gas savings. While each TRM had documented deemed savings, only the Vermont TRM provided the input values used to calculate their deemed savings. This added level of detail could allow the user to calculate more accurate site savings where only either the baseline or measure consumption is known. Both the Mid-Atlantic and Massachusetts TRMs provide sourced assumptions for weather adjustment factors applied to their reported savings.

Demand savings are deemed in all five technical manuals, with only the New York TRM claiming zero savings. The Mid-Atlantic TRM and Michigan database use coincidence factors to adjust reported demand savings. It is unknown if a coincidence factor has been built into the other TRMs' deemed savings.

Measure lives range between 10 to 18 years, with 18 years most commonly observed. This lifetime is consistent with lifetime estimates of residential furnace. No secondary benefits were reported in any of the TRMs.

Recommendation

Adapting the residential ECM furnace fan measure into a national database could be intensive, like other weather-sensitive measures. The difficultly in adapting reported state savings for use in a national database is in accommodating differences in building configuration and weather impacts.

- While a portion of these differences can be captured in load hour or degree-day adjustments, for a national database, reliable studies with M&V data would be preferred that ideally represent regional differences.
- Savings by state or climate zone regions for both electric and gas furnaces and with or without a central air conditioner would be preferable.

ECM Furnace Fan	Mid-Atlantic TRM 2010	MA TRM 2011	MEMD 2010	NY TRM 2010	VT TRM 2010
Region	Mid-Atlantic	Massachusetts	Michigan	New York	Vermont
Measure Name	Central Furnace Efficient Fan Motor	HVAC – Warm Air Furnace Electronically Commutated Motor (ECM)	ECM Furnace	EC Motors on Furnace Fans	Efficient Furnace Fan Motor
Units	Per furnace	Per furnace	Per furnace	Per furnace	Per furnace (retrofit)
Approach Commentary	Deemed savings derived from an Energy Center of Wisconsin Study (2003). A heating degree day ratio of Baltimore compared to Wisconsin (4704 / 7800) adjustment was applied to the WI study claimed savings of 400kWh. The average cooling savings WI Study (2003) is 70 to 95kWh. An estimate for Mid-Atlantic is provided by multiplying by the ratio of full load cooling hours in Baltimore compared to Southern Wisconsin (1050/487). Demand savings, also deemed, includes the coincidence factor.	Deemed kWh savings from a paper by Harvey Sachs (2003) and demand savings estimated using a methodology described in evaluation report by Quantec (2000). An adjustment is made to the natural increased heating load of 2.3 MMBtu given in Sachs' study. The original savings value is multiplied by 420 heating hours divided by 600 total running hours (420/600 = 0.70). An AFUE adjustment of 90/92 is also multiplied to the original value to create a more realistic final value.	Deemed energy savings calculated by Morgan Marketing Partners (2009). Methodology not posted on Website. Demand savings, also deemed, includes the coincidence factor.	The deemed kWh impact is estimated by PA Consulting for the Wisconsin Focus on Energy Program (2009). This value is considered to be representative of EC motor savings in New York, and accounts for the fraction of homeowners who operate their new furnaces in continuous fan mode. kW savings during cooling mode not considered.	Deemed kWh savings from Wisconsin Field Study (2003). kWh savings calculated for heating only and heating and cooling systems. Takes into account heating, cooling, indirect AC and standby kWh consumption under baseline and efficient conditions. kW savings were calculated using the RER Load shape research from the VT Power to Save Report (2002).
Calculation approach deviations - Energy	Deemed	Deemed	Deemed	Deemed	Deemed
Calculation approach deviations - Demand	Deemed	Deemed	Deemed	Deemed	Deemed
Annual Gross Energy Savings	ΔkWhheat = 241 ΔkWhcool = 178	ΔkWh = 600 ΔMMBTU = -1.575	ΔkWh = 730	ΔkWh = 733	ΔkWh = 462 (table, heating only) ΔkWh = 553 (table, heating and cooling)
Annual Gross	CF = 0.65 (fixed)	ΔkW = 0.116	CF = 0.9 (fixed)	ΔkW = 0	ΔkW = 0.3035

ECM Furnace Fan	Mid-Atlantic TRM 2010	MA TRM 2011	MEMD 2010	NY TRM 2010	VT TRM 2010
Demand Savings	ΔkWsummer = 0.106		ΔkW = 0.066		(table, heating) ΔkW = 0.3035 (table, heating and cooling)
Baseline Condition	A standard low-efficiency permanent split capacitor (PSC) fan motor.	Furnace with a standard efficiency steady-state motor.	Non-ECM furnace	Non-EC Motor furnace	A furnace meeting minimum federal efficiency standards using a low-efficiency permanent split capacitor (PSC) fan motor.
Efficient Condition	A high-efficiency brushless permanent magnet fan motor (BPM or ECM).	Furnace with an electronically commutated motor.	ECM furnace	EC Motor furnace	High-efficiency brushless permanent magnet fan motor (e.g., ECM, ICM).
Assumption 1: Hours of Use	EFLHcool = 1,050 (fixed)	NA	HRS = 8,760 (fixed)	NA	EFLHcool = 375 (fixed)
TRM Specific Assumptions	NA	NA	Reduction in power consumption kWACTUAL = 0.073 (fixed)	NA	NA
Lifetime (years)	18	18	10	NA	18
Incremental Costs	$200	NA	$11 per kBTUH	NA	$200
Secondary Benefits	NA	NA	NA	NA	NA
References	Electricity Use by New Furnaces: A Wisconsin Field Study (2003), Sachs and Smith (2003), Saving Energy with Efficient Furnace Air Handlers: A Status Update and Program Recommendations, Development of Residential Load Profiler for HVAC systems	Sachs, Harvey (2003), Quantec (2000)	DEER (2008), Morgan Marketing Partners (2009)	PA Consulting Study (2009)	Electricity Use by New Furnaces: A Wisconsin Field Study (2003), Sachs and Smith (2003), VT Power to Save (2002)

ECM Glossary
$EFLH_{cool}$ = Annual equivalent full load hours for cooling ΔkWh_{cool} = Annual cooling kWh savings per unit ΔkWh_{heat} = Annual heating kWh savings per unit HRS = Annual operating hours $EFLH_{cool}$ = Annual equivalent full load hours for cooling ΔkWh = Annual kWh savings per unit ΔkW = kW savings per unit CF = Coincidence factor $\Delta MMBtu$ = Fuel savings for the measure, in MMBtu

ENERGY STAR Refrigerator

Measure Name	ENERGY STAR Refrigerator – Full-size with freezer on top				
Measure Description	A residential refrigerator that meets or exceeds ENERGY STAR requirements; includes different configurations, and those with or without a through-the-door ice machine.				
Weather Sensitive?	No	**Sector**?	Residential	**Primary Fuel**?	Electric
Prevailing Energy Savings Methodology	Deemed based on appliance characteristics, such as ice through door option, freezer configuration (top, side, bottom), and efficiency level (CEE, ENERGY STAR).				
Prevailing Demand Savings Methodology	Deemed based on appliance characteristics, such as ice through door option, freezer configuration (top, side, bottom), and efficiency level (CEE, ENERGY STAR).				
Variables	None since prevailing methodology is deemed.				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- ENERGY STAR, RTF 2011, DEER 2008, PA TRM 2011, and OH TRM 2011
- ENERGY STAR Refrigerator – Full-size with freezer on top.

None of the sources reviewed require user-defined input assumptions to calculate energy savings. These savings range from 41 to 106 kWh, and are deemed per refrigerator. There are two main methodologies used to claim refrigerator savings: savings based on defined maximum consumption limits for baseline and efficient appliances; or using region-specific data to calculate or model expected savings. The PA TRM, OH TRM, and ENERGY STAR calculator use the equations for baseline and measure consumption, based on NAECA and ENERGY STAR specifications. These equations calculate maximum allowed annual consumptions, based on the refrigerator's fresh and freezer volume. The RTF and DEER use region-specific data to determine energy savings.

The ENERGY STAR savings calculator was the tool used to derive the PA and OH TRM savings. While the ENERGY STAR calculator and OH TRM savings are roughly the same
(106 and 100 kWh, respectively), the PA TRM has a lower savings estimate of 80 kWh because it cites a prior version of the ENERGY STAR savings calculator. The ENERGY STAR refrigerator specification changed in 2008, from a 15%improvement over NAECA definitions to 20%, and this update has yet to be captured by the PA TRM and the DEER database.

The RTF and DEER databases start with NAECA definitions, but use secondary data to adjust savings to expected results. RTF uses regional data, such as sales volumes, to derive appropriate fresh and freezer volumes and to include HVAC effects into the savings. The DEER database also accounts for HVAC effects by modeling expected savings using DOE2 simulations. To pick a savings estimate from the DEER database, a climate zone, vintage of home, and baseline type was chosen. These HVAC impacts cause the savings to be about half of claimed savings from the ENERGY STAR calculator.

Of the five sources reviewed, only three (ENERGY STAR, RTF, and DEER) explicitly indicate the volumes used to calculate consumption, and all three volumes are different, ranging from 19.71 to 25.77 ft^3. The transparency of the input assumptions used to calculate savings are not as well documented in the PA or OH TRM because they cite the ENERGY STAR calculator, but not its assumptions at that time. Because the ENERGY STAR savings calculator is updated as needed, the input assumptions used to calculate the PA or OH TRM may no longer be applicable. The ENERGY STAR calculator, DEER, and RTF all provide documented input assumptions and methodology.

Demand savings are only provided in four of the five technical manuals, because the ENERGY STAR savings calculator only provides kWh savings. No input assumptions are needed to calculate refrigerator demand savings, which range from 0.0057 to 0.018 kW.

Measure lives range between 12 to 20 years, with all five sources containing to different values. The average of these five years is 15.2. The only secondary benefits found were claimed through the ENERGY STAR calculator, which converts energy savings into CO_2 reductions.

Recommendation

This measure is ideal for inclusion in a national standardized savings database as a set of deemed savings by appliance configuration and efficiency level, which is done in the RTF. This provides deemed savings based on easily observable attributes (for both homeowners and program administrators).

- If the refrigerator is kept in a conditioned space, which is most likely, an HVAC equipment adjustment factor can be included in the deemed savings methodology. Multiple HVAC adjustment factors may need to be created using computer modeling to account for natural gas and electric furnaces, and whether the home has a central air conditioner.
- This recommendation is in contrast to the large and complex output tables found in DEER. The DEER database may be considered overly complicated,5 with too many combinations of location, vintage, and other attributes.

[5] DEER requires the use of the MISER tool and there may be a learning curve to use this MISER tool.

ENERGY STAR Refrigerator	ENERGY STAR	RTF 2011	DEER 2008	PA TRM 2011	OH TRM 2011
Region	National	Northwest	California	Pennsylvania	Ohio
Measure Name	ENERGY STAR Refrigerator: Configuration # 3-Top Mount Freezer without through-the-door ice	ENERGY STAR Refrigerator - Top Freezer without through-the-door ice	ENERGY STAR Refrigerator: Top Mount Freezer without through-the-door ice	Top mount freezer without door ice	Efficient Refrigerator – ENERGY STAR and CEE TIER 2 (Time of Sale)
Units	Per refrigerator, floating adjusted volume	Per refrigerator	Per refrigerator	Per refrigerator	Per refrigerator
Approach Commentary	Excel workbook with built-in assumptions; user can input refrigerator type, fresh volume and freezer volume (in ft^3).	Excel workbook with tabulated savings and calculation sheets. ProCost is used to determine system-level benefits, including demand reductions. Region-specific data and regression analysis are used to determine consumption. The baseline and measure consumptions have been adjusted to account for HVAC interaction.	Building energy simulation, refrigerator energy use is a function of the temperature of the space it is in; a refrigerator in a warm space uses more energy than a similar refrigerator in a cooler space. The energy use of the refrigerator ends up warming the space it is in. Refrigerator measures are divided into several configuration categories. Savings are based on improvements between the customer average appliance and the measure. Above-code savings are based on improvements between minimum code required and the measure.	Deemed savings derived from the ENERGY STAR refrigerator calculator.	Deemed savings based on 20% reduction in energy usage of the average federal standard for the range of efficient units purchased through the Efficiency Vermont's Residential Refrigerator program during 2009.
Calculation approach deviations - Energy	$\Delta kWh = (9.8 \times AV + 276)$ $AV = Vol_{fresh} + 1.63Vol_{free}$	Tabulated by efficiency tier (CEE and ENERGY STAR) and configuration (bottom, top, side-by-side freezer; option for ice through the door).	Deemed savings, where savings vary by climate zone (20 types), vintage (11 types), baseline (two types), HVAC equipment (two configurations).	Tabulated savings based on refrigerator configuration.	$\Delta kWh = kWh_{base} - kWh_{ee}$

ENERGY STAR Refrigerator	ENERGY STAR	RTF 2011	DEER 2008	PA TRM 2011	OH TRM 2011
Calculation approach deviations - Demand	NA	Tabulated by efficiency tier (CEE and ENERGY STAR) and configuration (bottom, top, side-by-side freezer; option for ice through the door).	Deemed savings, where savings vary by climate zone (20 types), vintage (11 types), baseline (2 types), HVAC equipment (2 configurations).	Deemed	ΔkW = (ΔkWh/8760) x TAF x LSAF
Annual Gross Energy Savings	ΔkWh = 106	ΔkWh = 45	Small Volume: ΔkWh = 41 ΔTherm = -1.77 Medium Volume: ΔkWh = 46 ΔTherm = -1.97 Large Volume: ΔkWh = 52 ΔTherm = -2.25	ΔkWh = 80	ΔkWh = 100 (table, ENERGY STAR top freezer)
Annual Gross Demand Savings	NA	ΔkW = 0.01	Small Volume: ΔkW = 0.0057 Medium Volume: ΔkW = 0.0063 Large Volume: ΔkW = 0.0073	CF = 1 ΔkW = 0.0125	ΔkW = 0.018 (table, ENERGY STAR top freezer)
Baseline Condition	529 kWh/yr	368 kWh/yr	Small Volume: 420 kWh/yr Medium Volume: 469 kWh/yr Large Volume: 532 kWh/yr	NA	497 kWh/yr
Efficient Condition	423 kWh/yr	323 kWh/yr	Small Volume: 357 kWh/yr Medium Volume: 399 kWh/yr Large Volume: 452 kWh/yr	NA	397 kWh/yr
Assumption 1: Fresh and Freezer Volume	Vol_{fresh} = 14.75 $Vol_{freezer}$ = 6.76 AV = 25.77	AV = 20.98	Small AV = 12.50 Medium AV = 17.50 Large AV = 23.00	NA	NA

ENERGY STAR Refrigerator	ENERGY STAR	RTF 2011	DEER 2008	PA TRM 2011	OH TRM 2011
Assumption 2: TRM Specific Assumptions	NA	NA	Gas Furnace with Central AC, Climate Zone 16, Existing Vintage, Code Baseline, Automatic Defrost	NA	LSAF = 1.18 TAF = 1.30 (fixed)
Lifetime (years)	12	20	14	13	17
Incremental Costs	$30	$14	Small Volume: $114 Med Volume: $117 Large Volume: $134	NA	$30
Secondary Benefits	CO_2 Reductions	NA	NA	NA	NA
References	NAECA, EIA AEO (2009), EPA (2009), Appliance Magazine (2008), Average volume of all active refrigerator models (2009)	AHAM appliance report, NAECA, California Energy Commission Appliances Database (accessed on 07/09/2010), ENERGYSTAR, CEE	DEER (2005), SDGE, PG&E, and SCE residential programs, Appliance Magazine, ENERGY STAR Refrigerator Savings Calculator, CEC appliance database	ENERGY STAR Refrigerator Savings Calculator (Calculator updated: 2/15/05, Constants updated 05/07)	Efficiency Vermont TRM, New Jersey TRM, ENERGY STAR, Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use" (2004)

ENERGY STAR Refrigerator Glossary
AV = Adjusted volume (ft3) Volfreezer = Freezer volume (ft3) Volfresh = Refrigerator fresh volume (ft3) TAF = Temperature Adjustment Factor LSAF = Load Shape Adjustment Factor ΔkWh = Annual kWh savings per unit ΔkW = kW savings per unit

Residential Clothes Washer

<table>
<tr><td>Measure Name</td><td colspan="5">ENERGY STAR Clothes Washer</td></tr>
<tr><td>Measure Description</td><td colspan="5">ENERGY STAR or CEE-rated, full-capacity residential clothes washer with front or top load configuration. May include savings from reduced dryer energy consumption.</td></tr>
<tr><td>Weather Sensitive?</td><td>No</td><td>Sector?</td><td>Residential</td><td>Primary Fuel?</td><td>Electric and Gas</td></tr>
<tr><td>Prevailing Energy Savings Methodology</td><td colspan="5">Deemed savings by domestic water heating (DWH) and dryer fuel, and efficiency level (CEE vs. ENERGY STAR).</td></tr>
<tr><td>Prevailing Demand Savings Methodology</td><td colspan="5">Deemed savings by DWH and dryer fuel and efficiency level (CEE vs. ENERGY STAR).</td></tr>
<tr><td>Variables</td><td colspan="5">None, because prevailing methodology is through deemed savings.</td></tr>
</table>

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- ENERGY STAR, RTF 2011, PA TRM 2011, OH TRM 2011, and Mid-Atlantic TRM 2010
- Residential ENERGY STAR clothes washer, any configuration, all domestic water heating (DWH) and dryer fuels
- Where applicable, the energy savings comparison is for: (1) electric water heat and electric dryer and (2) gas water heat and gas dryer.

The clothes washer is not a standalone measure. Savings from DWH and dryer savings (due to less moisture in the clothes) are usually implicit.

Deemed energy savings are tabulated on a per-appliance basis, for a combination of DWH/dryer options (gas, electric, no dryer) or as a program average over all possible DWH and dryer fuel combinations. The average number of uses per year is multiplied by the average savings per use in the ENERGY STAR calculator. The PA TRM bases deemed savings values on the ENERGY STAR calculator. All deemed savings consider or weight by DWH and dryer fuel. The RFT also specifies if the measure applies to single-family or multifamily.

The number of loads/cycles per year range from 282 to 392. This spread is relatively small, considering the variation in the commercial clothes washer measure; however, it still illustrates uncertainty on usage.

Measure lives range between 11 to 14 years. The secondary benefits found were primarily water savings claimed. The ENERGY STAR calculator also claimed pounds of CO_2 reductions. The RTF included waste water treatment savings and dollars saved from detergent savings.

Recommendation

Residential clothes washers are ideal for inclusion in a national standardized savings database as a set of deemed savings by DWH and dryer fuel, and efficiency level.

- This provides deemed savings based on easily observable attributes (for both homeowners and program administrators).

- Alternatively, average savings (electric and gas) over all types of fuel combinations would be even more user-friendly, but requires comprehensive data for weighting purposes.
- Measure development will need to account for differences in usage in each region or adopt a nationally averaged value.
- Clothes washers in multifamily settings may require separate calculations to account for in-unit washers and washers in a laundry center.

Clothes Washer	ENERGY STAR	RTF 2011	PA TRM 2010	OH TRM 2011	Mid-Atlantic TRM 2010
Region	National	Northwest	Pennsylvania	Ohio	Mid-Atlantic
Measure Name	ENERGY STAR Qualified Residential Clothes Washer	Single Family ENERGY STAR Clothes Washer – Electric DWH, Electric Dryer Gas DWH, Gas Dryer	ENERGY STAR Appliances - ENERGY STAR Clothes Washers	Clothes Washer – ENERGY STAR (Time of Sale)	Clothes Washer
Units	Per washer or per user defined number	Per washer	Per clothes washer	Per washer	Per washer
Approach Commentary	Calculator allows user to choose residential or commercial; number of units, utility rates, number loads per week, water heat, and dryer fuel. Based on average energy consumption, and based on all qualified models (July 2009)	Excel workbook with tabulated savings and supporting calculation sheets. ProCost used to determine system-level benefits, including demand reductions. Calculate savings in parts: water heating, washer electricity, dryer, detergent, water treatment. Use of real data and regression to determine consumption for each component.	Deemed Savings from ENERGY STAR calculator. Demand savings derived using NEEP screening clothes washer load shape. Does not include dryer savings. Does not include gas savings, even for systems using gas water heating.	The clothes washer savings value is derived from a weighted distribution of water heating fuel types, dryer heating fuel types, and the percentage of the MEF associated to the washer's, dryer's, and water heater's consumption. Using these three distributions and making assumptions about washer volumes and cycles per year as a savings value, the OH TRM calculates weighted savings values for electric, natural gas, fuel oil, and propane customers. Since a weighted average is used, all fuel savings should be claimed by the customer, regardless of their fuel type usage.	The clothes washer savings value is derived from a weighted distribution of water heating fuel types, dryer heating fuel types, and the percentage of the MEF associated to the washer's, dryer's, and water heater's consumption. Using these three distributions and making assumptions about washer volumes and cycles per year as a savings value, the Mid-Atlantic TRM calculates weighted savings values for electric, natural gas, fuel oil, and propane customers. Since a weighted average is used, all fuel savings should be claimed by the customer, regardless of their fuel type usage.
Calculation approach deviations – Energy	$\Delta \mathrm{kWh} = \mathrm{N}^{\mathrm{cycle}} \times$ $\Delta \mathrm{kWh}_{\mathrm{cycle}} =$	Table of deemed savings.	Deemed kWh savings by gas or electric hot water heater.	Deemed savings by efficiency criteria (ENERGY STAR or CEE Tier 3).	Deemed savings by efficiency criteria (ENERGY STAR or CEE Tier 3).
Calculation approach	NA	Table of deemed savings.	Deemed kWh savings by gas or electric water heater.	$\Delta \mathrm{kW} = \frac{\Delta \mathrm{kWh}}{\mathrm{Hours}} \times \mathrm{CF}$	$\Delta \mathrm{kW} = \frac{\Delta \mathrm{kWh}}{\mathrm{Hours}} \times \mathrm{CF}$

Clothes Washer	ENERGY STAR	RTF 2011	PA TRM 2010	OH TRM 2011	Mid-Atlantic TRM 2010
deviations - Demand					
Annual Gross Energy Savings	Elec DWH and dryer: ΔkWh = 224 Gas DWH and dryer: Δtherm = 9.0 ΔkWh = 24	Elec DWH and dryer: ΔkWh = 144 Gas DWH and dryer: Δtherm = 6 ΔkWh = 1	Electric DWH: ΔkWh = 258 Gas DWH: Δtherm = NA ΔkWh = 26	ΔkWh = 202 $\Delta MMBtu_{GAS}$ = 0.447 $\Delta MMBtu_{OIL}$ = 0.02 $\Delta MMBtu_{LP}$ = 0.013	ΔkWh = 127 $\Delta MMBtu_{GAS}$ = 0.342 $\Delta MMBtuU_{OIL}$ = 0.041 $\Delta MMBtu_{LP}$ = 0.008
Annual Gross Demand Savings	NA	Elec DWH and dryer: ΔkW = 0.084 Gas DWH and dryer: ΔkW = 0.003	CF = 1 ΔkW = 0.015	CF = 0.033 ΔkW = 0.028	CF = 0.033 ΔkW = 0.015
Baseline Condition	MEF >= 1.26 WF <= 9.5 Average non qualified models: Electric DWH and dryer: 787 kWh/yr Gas DWH and dryer: 81 kWh/yr 29.8 therms/yr	MEF = 1.94 WF = 7.02	Unknown ENERGY STAR calculator defined; does not indicate when calculator was accessed.	The baseline condition is a clothes washer at the minimum federal baseline efficiency. MEF ≥ 1.26	The baseline condition is a clothes washer at the minimum federal baseline efficiency. MEF ≥ 1.26
Efficient Condition	MEF ≥ 2.0 WF ≤ 6.0 Average ENERGY STAR Qualified Electric DWH and dryer: 563 kWh/yr Gas DWH and dryer: 57 kWh/yr 20.8 therms/yr	ENERGY STAR (2011) MEF = 2.36 WF = 4.12	ENERGY STAR Clothes Washer	The efficient condition is a clothes washer meeting either the ENERGY STAR efficiency criteria MEF ≥ 2.0 WF ≤ 60.	The efficient condition is a clothes washer meeting the ENERGY STAR efficiency criteria MEF ≥ 1.80 WF ≤ 7.5
Assumption 1: Loads per year	N^{cycle} = 392	N^{cycle} = 352	NA	The number of cycles per year is based on a weighted average calculated using RECS data specific to the East North Central Census division. N^{cycle} = 320	The number of cycles per year is based on a weighted average calculated using RECS data specific to the Middle Atlantic Northeast Census division. N^{cycle} = 282

Clothes Washer	ENERGY STAR	RTF 2011	PA TRM 2010	OH TRM 2011	Mid-Atlantic TRM 2010
Assumption 2: TRM Specific Assumptions	NA	Table of fuel shares	Fuel shares, balance is electric: 75% gas water heat 60% gas dryer	Vol = 3.23 ft^3 Energy consumption breakout: $\%_{DWH}$ = 26.0% $\%_{WASHER}$ = 7.0% $\%_{DRYER}$ = 67.0% DWH fuel share: $DWH_{ELECTRIC}$ = 27% DWH_{GAS} = 63% DWH_{OIL} = 6% DWH_{LP} = 4% Dryer fuel share: $Dryer_{ELECTRIC}$ = 66% $Dryer_{GAS}$ = 34% WF_{EE} = 6.0	Vol = 3.23 ft^3 Energy consumption breakout: $\%_{DWH}$ = 26.0% $\%_{WASHER}$ = 7.0% $\%_{DRYER}$ = 67.0% DWH fuel share: $DWH_{ELECTRIC}$ = 18.5% DWH_{GAS} = 61.0% DWH_{OIL} = 17.1% DWH_{LP} = 3.4% Dryer fuel share: $Dryer_{ELECTRIC}$ = 60.8% $Dryer_{GAS}$ = 39.2% WF_{EE} = 7.5
Lifetime (years)	11	14	11	11	14
Incremental Costs	$258/appliance	$80/appliance	NA	$258/appliance	$250/appliance
Secondary Benefits	Lbs of CO_2; water savings	Waste Water Energy = 15 kWh Non-Energy Benefit Cost Savings = $31	NA	Water savings and water pump savings included in total kWh	Water savings and water pump savings included in total kWh
References	National retail pricing (2009), Appliance Magazine (2008), DOE, EIA AEO (2009), EPA (2007, 2009)	AHAM, CEC Database, ENERGY STAR (2007, 2011), BLS CPI, 6th Power Plan, LBNL	ENERGY STAR (2008), NEEP	ENERGY STAR residential clothes washer savings calculator, Efficiency Vermont, RECS (2005), DOE-EERE TSD Clothes Washers	RECS (2005), Efficiency Vermont, DOE-EERE TSD Clothes Washers, ENERGY STAR savings calculator

Clothes Washer Glossary
N^{cycle} = Number of cycles/uses per year MEF = Modified energy factor WF = Water factor

Appendix B. Commercial Measures

Commercial Indoor Lighting Fixtures - Linear Fluorescent

Measure Name	Indoor Lighting Fixtures – specifically linear fluorescent fixtures in offices				
Measure Description	Improvements to lighting equipment efficiency; linear fluorescent lamps and fixtures (lamps and ballasts). Some sources also include delamping and controls.				
Weather Sensitive?	No	**Sector?**	Commercial	**Primary Fuel?**	Electric
Prevailing Energy Savings Methodology	$\Delta kWh = \frac{(Watt_{base} - Watt_{ee})}{1{,}000} \times HRS \times (1 + WHF_e)$				
Prevailing Demand Savings Methodology	$\Delta kW = \frac{(Watt_{base} - Watt_{ee})}{1{,}000} \times CF \times (1 + WHF_d)$				
Variables	$Watt_{base}$ = Baseline wattage $Watt_{ee}$ = Efficient condition wattage 1,000= conversion from watts to kW HRS = Annual operating hours WHF_d = lighting-HVAC waste heat factor for demand WHF_e = lighting-HVAC waste heat factor for energy CF = Coincidence factor				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions.

- Mid-Atlantic TRM 2010, PA TRM 2011, AR TRM 2007, DEER 2008, OH TRM 2011
- Baseline: one T12 lamp with magnetic ballast (based on the lighting tables).
- Energy-efficient condition: one T8 lamp with electronic ballast (based on the lighting tables).
- The Mid-Atlantic TRM does not include a wattage table, and the example within the TRM used a three-lamp, T12 fixture with magnetic ballast. The retrofit measure was a three-lamp, high-performance T8 with an electronic ballast.

Even with the similar fixture configurations, variations were observed in the default wattages provided in the reference tables. Energy savings are commonly calculated for retrofit of a single lighting fixture (lamp + ballast). If actual wattages are not available, the user can refer to a table of default wattages for various combinations of lamps and ballasts, provided in the appendix of the TRMs reviewed. These wattage tables are not identical, and differences in wattages of similar fixture configurations are common. For example, the OH TRM wattage table does not include standard 32 watt T8 lamp fixtures, only low wattage and high-performance lamp configurations. Only high-efficiency lighting fixtures are included in the table, and have a set baseline to compute fixture savings. The other TRMs include a wider range of lighting fixtures and require the user to pick both the baseline and efficient fixture separately from the wattage tables.

Assumptions provided in the sources include default hours of operation, and the waste heat factors for energy and demand (i.e., HVAC interaction factor). For example, in the AR TRM, an additional percentage of savings is allocated for interactive effects (due to reduced cooling load), but is not explicitly included in the calculation. There are several variations of the prevailing calculation that include multipliers for the number of lights retrofitted, in-service rate, and an adjustment factor for lighting controls.

Default lighting hours of operation vary by TRM, creating a universal inconsistency between documents. Also, there is inconsistency in how variables are defined, even when represented by the same name. In some algorithms, the waste heat factor is less than one and incorporated into the equation as ($1+WHF_e$); in other calculations, it is greater than one and included directly as WHF_e. The two expressions are valid, but using a WHF_e from one TRM in a different calculation can lead to large errors, even if the variable name is identical. Demand savings calculations include a coincidence factor and waste heat factor.

One noteworthy observation from the lighting measure, although not confined to lighting, was the mixed use of actual and deemed values in the calculation methodology. The OH TRM encourages use of actual wattages and hours, but provides default values where those are unknown. In the PA TRM, the baseline and efficient wattages are defined by the wattage table, while actual hours of use are recommended.

Measure lifetimes range between 0.9-20 years, with 15 years most commonly observed. These lifetimes are over a large variety of lighting fixtures. The large difference in lifetimes is based on the rated lamp hours and application hours of operation, as well as if the lifetime is based on the life of the lamp or the entire fixture, including the ballast. The fixture and ballast lifetime is typically longer, lasting 10-20 years. No secondary benefits were found for commercial lighting.

Recommendations

Commercial indoor lighting could be recommended as part of the national database primarily for the significance lighting has on utility programs. The database recommendations are presented below:

- Commercial lighting, on a single fixture level, is a relatively straightforward measure that can be included in the database once a universal wattage table is developed. Creating a consensus in appropriate fixtures and wattage configurations will pose a challenge.
- For each lighting application, using actual hours would be preferable to using default values. However, this may require reliable M&V data to appropriately determine lighting operating hours. Using averaged deemed values per building type can greatly simplify the determination of savings, but will require consensus to develop a reference lighting hours of operation by building type table.
- Maintenance of the lighting table will require, at a minimum, an annual review and upkeep.
- Regional variations in the HVAC interaction factors will need to be addressed. It is worth noting in certain jurisdictions that utilities do not claim savings associated with HVAC interactive affects for deemed measures. For those cases, the interaction factor would be one.
- A national database will need to include protocols on when to use actual values and when to use default values.
- Since one purpose of the national database is to help users in states without TRMs and other sources of savings calculations, it will need to balance the degrees of freedom in the methodology to maximize user friendliness without introducing excessive errors due to lack of region-appropriate M&V data.
- Scaling savings up to the project level can become problematic as the prevailing methodology does not allow for certain lighting improvements, such as delamping or controls. The ability to calculate savings on a project level may be attractive to facility owners as well as program planning personnel. Lighting calculator tools, of which many are in existence today, can be developed to help users determine the exact savings, costs, and other impacts of their lighting retrofit.

Indoor Lighting	Mid-Atlantic TRM 2010	PA TRM 2011	AR TRM 2007	DEER 2008	OH TRM 2011
Region	Mid-Atlantic	Pennsylvania	Arkansas	California	Ohio
Measure Name	High Performance T8 Lighting	Lighting Equipment Improvements	Lighting Efficiency	Linear Fluorescent Indoor Lighting	Lighting Systems (Non-Controls) (Early Replacement, Retrofit)
Units	Per fixture	Per project	Per project	Per fixture	Per fixture
Approach Commentary	Calculation with supporting tables and default values.	Algorithms are for lighting improvements with and without controls. Calculation method varies by project type, program year, and level of project kW savings. Retrofit projects should refer to a standard wattage table. Lighting controls reference table provided. Projects with savings greater than a certain threshold should be split into various “usage groups” to determine EFLH.	Calculation with supporting tables	Lighting profiles and LPDs were determined from commercial end use survey data. Full load hours were aligned with recent M&V lighting research.	Uses actual wattages, if known, else user can use reference tables. Actual hours of use can be used or default values.
Calculation approach deviations - Energy	$\Delta kWh = \frac{[(Watt]_{base} - Watt_{ee})}{1{,}000}$	$\Delta kWh = \frac{(Watt_{base} - (Watt_{ee} \times [1 - ESF]))}{1{,}000} \times$	$\Delta kWh = \Delta kWh \times HRS$	Tabulated for single light fixture replacement.	No Deviation
Calculation approach deviations - Demand	$\Delta kW = \frac{(Watt_{base} - Watt_{ee})}{1{,}000} \times ($	$\Delta kW = \frac{(Watt_{base} - Watt_{ee})}{1{,}000} \times ($	$\Delta kW = \sum_i \left(\left[N^0_{base(i)} \times \frac{Watt}{1,} \right. \right.$	Tabulated for single light fixture replacement.	No Deviation
Annual Gross Energy Savings	ΔkWh = 239 (3-lamp fixture)	ΔkWh = 38	ΔkWh = 54 (calculated correctly, without CF)	ΔkWh = 34	ΔkWh = 69
Annual Gross Demand Savings	CF = 0.694 (fixed) ΔkW_{summer} = 0.053	CF = 0.84 (table, office) ΔkW = 0.014	CF = 0.78 (table, office) ΔkW= 0.011	ΔkW = 0.012	CF = 0.76 (table, office) ΔkW= 0.018

Indoor Lighting	Mid-Atlantic TRM 2010	PA TRM 2011	AR TRM 2007	DEER 2008	OH TRM 2011
Baseline Condition	Existing lighting fixture (retrofit application) or code/standard (lost opportunity) Default retrofit: 3 lamp F34T12 fixture with magnetic ballast $Watt_{base}$ = 136	Find in wattage table: Fluorescent, (1) 48", ES lamp, Magnetic-ES Ballast F40T12/ES $Watt_{base}$ = 43	IECC 2003 LPD table and standard wattage table T-12 48" one lamp Magnetic -ES F40T12/ES $Watt_{base}$ = 43	FL; (1) 48"; ES lamp; ES Mag; Lumens=2228; $Watt_{base}$ = 43	T12 48" one lamp, Magnetic – ES $Watt_{base}$ = 43
Efficient Condition	High performance 3 lamp T8 fixtures and lamp/ballast combinations (retrofit and lost opportunity) $Watt_{ee}$ = 72	Fluorescent, (1) 48", T8 lamp, Instant Start Ballast, NLO (BF: .85-.95) F32T8 with Electronic Ballast $Watt_{ee}$ = 31 (wattage table)	Fluorescent (1) 48" reduced wattage T8 lamp, IS - NLO (BF: .85-.95) F32T8/WM $Watt_{ee}$ = 29 (Standard wattage table)	FL; (1) 48"; T8 lamp; IS EB, NLO (BF:.85-.95); Lumens=2673; (replace, code references) $Watt_{ee}$ = 31 (wattage table)	T8 48" one lamp (high performance lamp), electronic - IS $Watt_{ee}$ = 25 (wattage table)
Assumption 1: Hours of use	HRS = 3,435 (table, office)	Actual hours should be used where stated and verified. HRS = 2,808 (table, large or small office)	HRS = 3,850 (table, office)	NA	HRS = 3,526 (table, office)
Assumption 2: HVAC interaction adjustment factors	WHF_e = 1.11 WHF_d = 1.21 (fixed)	WHF_e = 0.12 WHF_d = 0.34 (table, cooled space)	Interactive effects for reduced cooling load. +10% savings for demand +5% savings for energy	NA	WHF_e = 0.095 WHF_d = 0.200 (table, interior fixtures)
TRM Specific Assumptions	ISR = 0.98 (fixed)	Lighting controls are included in the general lighting improvement measure. ESF=30% for an occupancy sensor*	NA	Large Office building type Mt. Shasta Area (CZ 16) Existing building	NA
Lifetime (years)	15	15	0.9 - 16	15	15
Incremental Costs	$60	NA	NA	$3.49/fixture	NA
Secondary Benefits	Change in O&M costs	NA	NA	NA	NA

Indoor Lighting	Mid-Atlantic TRM 2010	PA TRM 2011	AR TRM 2007	DEER 2008	OH TRM 2011
References	ASHRAE (1993), VT TRM (2009), GDS Associates (2007), ctsavesenergy.org (2007), CEE	CBECS (2003), NYSERDA (2009), ACEEE (1992), PA and VT TRM, KEMA (2009), RLW Analytics (2007), Quantum Consulting (1999), DEER (2005 and 2008), NJ Clean Energy Protocols (2009), SCE (2007), ASHRAE 90.1 (2007), various others	Xcel Energy (2006), DEER, Texas Standard Offer Programs, ENERGY STAR, RTF, KEMA (2006), Quantec (2005), Ecotope (2003), others	CEUS	VT TRM (2010), KEMA (2009), SCE (2010), ACEEE (2003), tecMarket Works (2007), NE Clean Energy Program (2007), others

*Cadmus assumes 0% for this measure because none of the other lighting has controls embedded.

Indoor Lighting Glossary
$Watt_{base}$ = Baseline wattage
$Watt_{ee}$ = Efficient condition wattage
1,000= Conversion from watts to kW
HRS = Annual operating hours
WHF_d = Lighting-HVAC waste heat factor for demand
WHF_e = Lighting-HVAC interactive effect for energy
CF = Coincidence factor
kWh_{base} = Annual baseline electricity consumption
kWh_{ee} = Annual efficient condition electricity consumption
ESF = Equipment energy saving factor
ISR = In service rate
$N^0_{base(i)}$ = Number of baseline units
$N^0_{ee(i)}$ = Number of efficient units

Furnace

Measure Name	Furnace				
Measure Description	Gas-fired equipment used for space heating, may include an ECM fan motor.				
Weather Sensitive?	Yes	**Sector**?	Commercial	**Primary Fuel**?	Gas
Prevailing Energy Savings Methodology	$\Delta \text{Therms} = \text{kBTUH}_{\text{heat}} \times \frac{\text{EFLH}_{\text{heat}}}{100} \times \left(1 - \frac{\text{AFUE}_{\text{base}}}{\text{AFUE}_{\text{ee}}}\right)$				
Prevailing Demand Savings Methodology	NA				
Variables	$\text{kBTUH}_{\text{heat}}$ = HVAC system input capacity for heating in kBtu/hr $\text{EFLH}_{\text{heat}}$ = Annual equivalent full load hours for heating 100 = kBtu per therm $\text{AFUE}_{\text{base}}$ = Baseline AFUE AFUE_{ee} = Efficient condition AFUE				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- OH TRM 2011, AR TRM 2007, NY TRM 2010, WI TRM 2010, MA TRM 2011
- For comparison purposes, furnace 100,000 BTUH input capacity was used.

The prevailing energy savings calculation methodology is adapted from the AR TRM. This methodology is the most general version of the algorithms reviewed for this measure. The first two elements are the heat rate and full load hours, the last element of the algorithm is the resulting difference in consumption between the baseline and an efficient unit. This measure is subject to federal standards, and a uniform baseline AFUE is in place for new construction and burnout replacement scenarios.

Formulaically, this prevailing algorithm is very straightforward, but does not allow the user to account for interactions with the ECM (if there are any), and requires reference tables for the effective full-load hours. Variations of this algorithm include calculations, which assume a system equipped with an ECM.

The WI TRM includes an oversizing factor of 80%, where furnace burners are assumed to often be oversized for the building heating load when packaged with air handlers typically sized for building cooling loads. In addition, the TRM bases consumption on heating degree days versus EFLH. These variations are not included in the other TRMs.

Recommendations

This measure, although weather sensitive, is ideal for inclusion in a national database of energy savings. This is because of the relatively small variations in calculation algorithms and the small number of inputs.

- Reference tables of EFLH need to be developed across all industries (building types) and locations, which may be expensive and time consuming, since this is typically calculated with DOE2 modeling. Alternatively, using heating degree days as the basis of the consumption would be easiest to implement nationally but does not account for variations of building characteristics.
- Validation of the algorithm(s) for a national database is recommended.

Furnace	OH TRM 2011	AR TRM 2007	NY TRM 2010	WI TRM 2010	MA TRM 2011
Region	Ohio	Arkansas	New York	Wisconsin	Massachusetts
Measure Name	Energy-Efficient Furnace (Time of Sale, Retrofit – Early Replacement)	Commercial Furnaces	Furnaces and Boilers	Furnace	HVAC – High Efficiency Natural Gas Warm Air Furnace
Units	Per furnace	Per furnace	Per furnace	Per furnace	Per furnace
Approach Commentary	Calculation based on presence of ECM fan motors. If there is no ECM equipped, then electric energy savings are zero. Default values provided for baseline efficiency and full load heating hours.	Calculation with various user inputs and reference tables. No electric savings from this measure.	Calculation based on the difference in efficiencies, heating capacity, and hours-of-use. DOE 2.2 simulations of prototypical small commercial buildings was used to determine $EFLH_{heat}$.	Assumes there is an ECM fan motor, space heating application. Table of deemed savings broken out by heating capacity ranges with supporting calculation and assumptions.	Since there are significant savings, Cadmus believes it is a good measure for deemed calculation rather than a deemed savings value. Deemed savings based on efficiency and presence of ECM.
Calculation Approach Deviations - Energy	Furnace with ECM fan motor: $\Delta kWh = 5 \times \frac{kBTUH_{heat}}{1,000} \times$ $\Delta MMBTU = \frac{kBTUH_{heat}}{1,000} \times$ $MMBtu_{ECM} = 0.019 \times kB$ Furnace without ECM fan motor – No deviation (reported in MMBTU)	$\Delta Therms = \frac{kBTUH_{heat}}{100} \times E$	$\Delta Therms = N^0 \times kBTUH$	$\Delta Therms = \left(\frac{80\% \times kBTUH}{\Delta T}\right)$ $\Delta kWh = 0.5 \times \left(\frac{80\% \times kBTU}{\Delta T}\right.$	Deemed savings in MMBtu from table. Additional kWh savings if furnace ECM installed.

Furnace	OH TRM 2011	AR TRM 2007	NY TRM 2010	WI TRM 2010	MA TRM 2011
Calculation Approach Deviations - Demand	NA	NA	NA	NA	NA
Annual Energy Savings	ΔMMBtu = 30 ΔkWh = 1,035 (with ECM)	ΔMMBtu = 4.8 ΔTherms = 48*	ΔMMBtu = 1.1 ΔTherms = 114	ΔMMBtu = 3.3 ΔTherms = 331 ΔkWh = 1,076	ΔMMBtu = 19.6 (table, 0.92 AFUE with ECM) ΔkWh = 478
Annual Gross Demand Savings	NA	NA	NA	NA	NA
Baseline Condition	The equivalent baseline equipment is a natural gas-fired furnace with an AFUE of 80%. $AFUE_{base}$ = 0.80 (fixed)	$AFUE_{base}$ = 0.78 (table, 100 kBTUH)	$AFUE_{base}$ = 0.78 (fixed, NAECA requirement)	$AFUE_{base}$ = 0.78 (fixed, code)	$AFUE_{base}$ = 0.78 (fixed, IECC 2006)
Efficient Condition	The efficient equipment is a natural gas-fired furnace with a minimum AFUE rating of 93%. $AFUE_{ee}$ = 0.93 (Cadmus used default)	New furnace nameplate efficiency. $AFUE_{ee}$ = 0.93 (Cadmus used same as OH TRM)	$AFUE_{ee}$ = 0.92 (Cadmus chose lowest efficiency requirement: ACEEE tier one)	$AFUE_{ee}$ = 0.90 (fixed, conservative estimate)	$AFUE_{ee}$ = 0.92 (table, conservative value)
Assumption 1: Hours-of-use	$EFLH_{heat}$ = 2,408 (fixed)	$EFLH_{heat}$ = 233 (table, business hours 8:00 a.m. to 5:00 p.m., Little Rock)	$EFLH_{heat}$ = 747 (table, small office in Albany NY)	NA	NA
Assumption 2: Heating Capacity	$kBTUH_{heat}$ = 100,000 (input capacity)	$kBTUH_{heat}$ = 100,000 (input capacity)	$kBTUH_{heat}$ = 100,000 (input capacity)	$kBTUH_{heat}$ = 100,000 (input capacity)	$kBTUH_{heat}$ = 100,000 (input capacity)
TRM Specific Assumptions	NA	NA	N^0=1 (Cadmus defined for single furnace)	ΔT = 80 °F (fixed) HDD = 7,699 (fixed, population-weighted statewide average)	NA
Lifetime (years)	20 years	18 years	NA	NA	18 years
Incremental Costs	$900	NA	NA	NA	NA

Furnace	OH TRM 2011	AR TRM 2007	NY TRM 2010	WI TRM 2010	MA TRM 2011
Secondary Benefits	NA	NA	If applicable, electronically commutated motors (ECM) electric savings; high-efficiency furnaces may be packaged with ECMs. Also, draft fans, when present, will increase electricity consumption.	NA	NA
References	M. Blasnik & Associates and KEMA (2008), Energy Center of Wisconsin (2003), IECC (2006), GuelphHydro Inc	DEER (2005), ENERGY STAR, CEE, Texas LoanS Program Guidebook, IECC (2003), ASHRAE	DOE 2.2, NAECA, ACEEE, National Grid	Wisconsin Perspective (2004)	GDS Associates, Inc. (2009), NYSERDA Deemed Savings Database, IECC (2006), ASHRAE Applications Handbook (2003)

* The AR TRM does not clearly state whether the capacity in the equation is referring to the input capacity or output capacity. The input capacity may overstate the savings.

Furnace Glossary
5 = kWh savings per MMBtu of heating fuel consumption
0.5 = kWh per therm
$kBTUH_{heat}$ = HVAC system capacity for heating in kBtu/hr
$EFLH_{heat}$ = Annual equivalent full load hours for heating
1,000 = kBTUH per MMBtuH or BTUH per kBtuH
100 = kBtu per therm
N^0 = Number of units in affected area
$AFUE_{base}$ = Baseline AFUE
$AFUE_{ee}$ = Efficient condition AFUE
ΔT = Heating design temperature difference
24 = Hours per day
80% = Percent of furnace output capacity assumed to represent building heating load
HDD = Heating degree days (65°F default)

Storage Water Heater

Measure Name	Storage Water Heater				
Measure Description	A tank-type water heater with either an electric or gas based heat source.				
Weather Sensitive?	No	**Sector?**	Commercial	**Primary Fuel?**	Electric and Gas
Prevailing Energy Savings Methodology	$\Delta MMBtu = \left[G_{yr} \times 8.33 \times (T_{setpoint} - T_{supply}) \times \left(\frac{1}{N_{base}} - \frac{1}{N_{ee}}\right) + (STBY_{base} - STBY_{ee}) \times 8{,}760\right] \div 1$ For small water heaters (40 gallon residential sized), equation reduces to: $\Delta MMBtu = \left[G_{yr} \times 8.33 \times (T_{setpoint} - T_{supply}) \times \left(\frac{1}{EF_{base}} - \frac{1}{EF_{ee}}\right)\right] \div 1{,}000{,}000$				
Prevailing Demand Savings Methodology	None				
Variables	G_{yr} = Average annual hot water consumption, in gallons 8.33 = Density of water in lbs/gal or Btu required to raise one gallon of water by 1°F $T_{setpoint}$ = Water heater set point T_{supply}= Supply water temperature of water heater N_{base} = Efficiency of baseline equipment N_{ee} = Efficiency of efficient equipment $STBY_{base}$ = Standby losses/hr of baseline water heater(Btu/hr) $STBY_{ee}$ = Standby losses/hr of efficient water heater (Btu/hr) EF_{base} = Energy factor of baseline water heater EF_{ee} = Energy factor of energy-efficient water heater 1,000,000 = Btu per MMBtu 8,760 = Hours per year				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- RTF 2011, OH TRM 2011, AR TRM 2007, NY TRM 2010, VT TRM 2010
- For comparison purposes, a 40-gallon storage tank was assumed.

Energy savings are commonly calculated based on the difference in efficiencies of equipment in all the TRMs, multiplied by annual hot water consumption. The RTF provides a deemed value per water heater. Most baseline efficiencies are provided based on tank size and Btu output; reference tables are provided in the TRMs. The OH TRM includes standby losses, which account for the increased insulation of the new high-efficiency water heaters; none of the other TRMs account for savings associated with standby losses. This measure also has an enormous number of variables across the different TRMs, and not all variables were adequately documented. This makes it challenging for novice users to use these sources.

The user provides most inputs when possible; otherwise the reference table is used. Baseline assumptions vary by the source used. The OH TRM uses IECC 2006 standards for water heating equipment; this provides standards for efficiencies and standby losses. The AR TRM provides two algorithms based on performance requirements; the smaller units (≤ 75,000 BTUH) are rated using the energy factor (EF) and the larger units (> 75,000 BTUH) are rated by thermal efficiency (E_t).

The OH TRM equation is used only for natural gas fired, tank-type water heaters; it does not account for electric storage water heaters. Other TRMs had algorithms for both electric and gas water heaters. Measure lifetimes were found to range from 10-15 years, with the majority being 15 years. No secondary benefits were provided in any of the TRMs.

Recommendations

This measure can be accommodated in a national database of energy savings. To standardize this measure:

- Provide separate calculations for gas and electric water heaters.
- Provide separate calculations for units rated by energy factor and those rated by thermal efficiency (ET).
- Decide if hot water consumption should be calculated based on facility, square footage, or something else.
- Minimize the number of inputs for each calculation and provide reference tables scalable to size and facility type, with consideration for multiple hot water systems.
- Provide adequate support for each variable described in the calculation.
- As with most measures, a national database would require adequate technical support to address code changes.

Water Heater	RTF 2011	OH TRM 2011	AR TRM 2007	NY TRM 2010	VT TRM 2010
Region	Pacific Northwest	Ohio	Arkansas	New York	Vermont
Measure Name	Commercial-type Water Heater (≥ 35 gallons, < 45 gallons)	High Efficiency Storage Tank Water Heater (Time of Sale, Retrofit – Early Replacement)	Commercial Water Heaters	Water Heater	Hot Water End Use Efficient Hot Water Heater
Units	Per water heater	Per gas water heater	Per water heater	Per water heater	Per water heater
Approach Commentary	Deemed savings based on size of water heater. MS Excel® workbook with supporting calculation sheets based on industry data.	Calculation based on formula for gas only. User inputs actual values if known; if unknown use reference tables.	Calculation based on formulas by fuel and efficiency rating of unit. User inputs actual values if known; if unknown use reference tables. Provides formula for determining the baseline EF based on tank size.*	Program level calculation based on user inputs, reference tables provided. Ambient water temperature provided for different cities, and gallons per day table provided based on building type.	Calculation based on building type and water heater size. Reference tables provided.
Calculation Approach Deviations – Energy	Tabulated in workbook. Based on calculations from AHRI commercial data.	$\Delta MMBtu = [G_{yr} \times 8.33 \times ($ Small water heaters: $\Delta MMBtu = [G_{yr} \times 8.33 \times ($	(Electric, small water heater)**: $\Delta kWh = 8.33 \times 1 \times G_{day} \times$ (Gas, small water heater): $\Delta therms = 8.33 \times 1 \times G_{day}$	$\Delta kWh = N^0 \times \frac{G_{day} \times 365 \times 8.3}{3413}$ $\Delta Therms = N^0 \times \frac{G_{day} \times 365 \times}{100,000}$	$\Delta MMBTU = kBTU_{sqft} \times SF$
Calculation Approach Deviations – Demand	Spreadsheet with tabulated savings based on number of gallon capacity for the unit.	NA	NA	$\Delta kW_{summer} = N^0 \times \frac{(UA_{base}}{341}$	NA
Annual Gross Energy Savings	ΔkWh = 51	ΔMMBtu = 2.8	Δtherm = 15 (ΔMMBtu = 1.5)	ΔkWh = NA ΔTherms = NA[++]	ΔMMBtu = 7.6
Annual Gross Demand Savings	ΔkW = 0.01	NA	NA	CF = not defined ΔkW = NA	NA

Water Heater	RTF 2011	OH TRM 2011	AR TRM 2007	NY TRM 2010	VT TRM 2010
Baseline Condition	205 Btu/hr average standby loss	The baseline condition is a gas-fired, tank-type water heater meeting the requirements of IECC 2006. EF_{base} = 0.67 – 0.0019*V = 0.594 (Cadmus calculated for 40 gallon tank, gas)	IECC 2003 commercial water heater minimum efficiencies for natural gas water heaters. EF_{base} = 0.93 – 0.00132 *V = 0.8772 (Cadmus calculated for 40 gallon tank, electric) EF_{base} = 0.61 – 0.0019*V = 0.534 (Cadmus calculated for 40 gallon tank, gas)	Larger water heaters used in commercial applications are rated by thermal efficiency instead of EF. ET_{base} = 0.8 (gas) ET_{base} = 1 (electric)#	No electric DWH; residential tank style unit. EF_{base} = 0.67 – 0.0019*V = 0.594 (Cadmus calculated for 40 gallon tank, gas)
Efficient Condition	185 Btu/hr standby loss or lower	Exceeds IECC 2006 water heater efficiency EF_{ee} = 0.67 (Cadmus assumed, equal to ENERGY STAR)	Exceeds IECC 2003 water heater efficiency EF_{ee} = 0.67 (Cadmus assumed, equal to ENERGY STAR)	Exceeds baseline	Exceeds efficiency required by VT Guidelines for Energy Efficient Commercial Construction EF_{ee} = 0.67 (Cadmus assumed, equal to ENERGY STAR)
Assumption 1: Water Consumption	NA	G_{yr} = actual usage or 21,900 (fixed)	G_{day} = 2.3 * 10 = 23 Days = 250 (table and calculation, large office 10,000 sq. ft.)	G_{day}= 500 (table, large office)	NA
Assumption 2: Water Temperature Rise	$T_{setpoint}$ = 135°F T_{supply} = 67.5°F (fixed)	$T_{setpoint}$ = actual or 130°F T_{supply} = actual or 50°F (fixed)	$T_{setpoint}$= Water heater set point; if unavailable, use 140°F (fixed) T_{supply}= Supply water temperature of water heater (DOE), 58°F (fixed)	For NYC (from table) ΔT_s = 93.5°F (table, NYC) $T_{setpoint}$ = 150°F (Range, lower limit) T_{supply} = 62. °F (table, NYC)	NA

Water Heater	RTF 2011	OH TRM 2011	AR TRM 2007	NY TRM 2010	VT TRM 2010
TRM Specific Assumptions	NA	NA	NA	Tank overall heat loss coefficient: $UA = SL/70$ Large electric type: $SL = 20 + 35\sqrt{V}$ Large gas type: $SL = Q/800 + 110\sqrt{V}$	Hot water energy use (per sq. ft.) by building type $kBtu_{sqft}$ = 6.7 (table, office) SF = 10,000 (Cadmus defined)
Lifetime (years)	15 years	12 years	15 years for gas, 10 years for HPWH	NA	13 years (table, gas type)
Incremental Costs	= $23.48/(0.01*$EF_{ee}$)	Deemed cost: $300	NA	NA	NA
Secondary Benefits	NA	NA	NA	NA	NA
References	DOE EERE, AHRI, federal standards, NAHB (2007), ACEEE (2007), 6th Power Plan	NAHB Research Center (2002), IECC 2006	IECC 2003, DEER, Texas Gas Service, CEE, LBNL (1995)	Lawrence Berkeley Laboratory (1996), NREL	2005 Vermont Guidelines for Energy Efficient Commercial Construction, NAECA

*This TRM uses the variable name "V" to refer to two separate inputs: in one instance, V refers to the water heater tank volume, in another instance V refers to the average daily hot water use in gallons. Cadmus has interpreted the use of V and renamed one of the variables to correct the inconsistency.

**EF_{base} = 0.93 – 0.00132 *V

+EF_{base} = 0.61 – 0.0019 *V

++Not applicable to 40 gallon tanks with less than 75,000 BTUH.

#ET_{ee} will not exceed 1 for electric systems, rather the standby losses improve. This input causes the kWh savings to be zero.

Hot Water Heater Glossary
SF = Facility square footage
$kBTU_{sqft}$ = Annual building water heating energy use in kBtu per building square foot
V = Water heater tank volume
3,412 or 3,413 = Number of Btu per kWh
8.33 = Density of water in lbs/gal or Btu required to raise one gallon of water by 1°F
G_{ksf} = Average daily hot water use in gallons, per 1,000 square feet of building
G_{yr} = Average annual hot water consumption, in gallons
G_{day} = Average daily water consumption, in gallons
1 = Specific heat of water [1 Btu/(lb °F)]
$T_{setpoint}$ = Water heater set point
T_{supply}= Supply water temperature of water heater
EF_{base} = Energy factor of baseline water heater
EF_{ee} = Energy factor of energy-efficient water heater
Days = Annual days of operation
100,000 = Btu per therm
1,000,000 = Btu per MMBtu
1,000 = kBtu per MMBtu
$STBY_{base}$ = Standby losses/hr of baseline water heater(Btu/hr)
$STBY_{ee}$ = Standby losses/hr of efficient water heater (Btu/hr)
8,760 = Hours per year
DF = Demand diversity factor
365 = Days/year
ΔT_s = Temperature difference between stored hot water and surrounding air (°F)
UA_{base} = Baseline equipment standby loss (Btu hr^{-1} $°F^{-1}$)
UA_{ee} = Efficient equipment standby loss (Btu hr^{-1} $°F^{-1}$)
SL = Standby loss (Btu hr^{-1})
70 = Temperature difference associated with standby loss specification
Q = Input capacity (Btu hr^{-1})
ET_{base} = Baseline water heater thermal efficiency
ET_{ee} = Efficient water heater thermal efficiency
N_{base} = Efficiency of baseline equipment
N_{ee} = Efficiency of efficient equipment

Lighting Controls

Measure Name	Lighting Controls				
Measure Description	Refers to the installation of a lighting control system, which includes occupancy sensors, daylight dimming sensors, timeclocks, and multilevel lighting.				
Weather Sensitive?	No	**Sector**?	Commercial	**Primary Fuel**?	Electric
Prevailing Energy Savings Methodology	$\Delta kWh = kW_{connect} \times HRS \times (1 + WHF_e) \times ESF$				
Prevailing Demand Savings Methodology	$\Delta kW = kW_{connect} \times (1 + WHF_d) \times ESF \times CF$				
Variables	$kW_{connect}$ = System connected kW HRS = Annual operating hours WHF_e = lighting-HVAC interactive effect for energy ESF = Equipment energy saving factor WHF_d = lighting-HVAC waste heat factor for demand CF = Coincidence factor				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- PA TRM 2011, OH TRM 2011, AR TRM 2007, Mid-Atlantic TRM 2010, WI TRM 2010
- Ceiling-mounted under 200 W; occupancy sensor.

Energy savings are calculated on a per controlled load basis. The calculation methodology is closely related to the indoor lighting savings approach; the PA TRM combines savings from lighting fixture retrofits and additions of lighting controls into one calculation. Mathematically, the PA TRM formula reduces to the prevailing savings formula if pre- and post-retrofit wattages are equal. Variations of the prevailing calculation methodology are minor and include: use of a power adjustment factor (PAF) rather than an energy savings factor (PAF seems to be related to the energy saving factor (ESF), with the relationship PAF = 1-ESF); inclusion of the in-service rate adjustment factor; and omission of the waste heat factor.

Assumptions must be made by the user when selecting appropriate values from the reference tables for the ESF and HRS. ISR, WHF_e, and WHF_d are given as default values (one TRM gives a set of waste heat factors for indoor lighting and another set for outdoor lighting). The actual connected load is used in most algorithms, except in WI where the load is deemed for various kW “bins.”

Demand savings algorithms are provided in three of the five TRMs. Two TRMs provide CFs, but do not provide an algorithm for demand savings. In the AR TRM, the energy savings algorithm actually uses the CF as an input. The PA TRM uses the same formula to calculate demand for controls and lighting retrofits. It does not include the ESF in the demand calculation, resulting in no demand savings when the pre- and post-wattages are equal. In this case, we conclude that three of the TRMs assume demand savings for lighting controls that are too variable to occur during coincidence peak and thus are assumed to be zero.

Measure lifetimes range from 8-10 years for occupancy sensors (where specified). No secondary benefits were reported.

Recommendations

This measure is ideal for inclusion in a national database because all methodologies follow mathematically similar formulas.

- We recommend either a savings calculation approach with user reference tables (more flexible for a range of control types), or deemed values for one specific type of control equipment covering a range of connected wattages.
- The main hurdle facing integration of this measure is its dependence on reference tables and values fixed in the TRM. Some values, such as the energy savings factor, are similar and vary by control type. Other values, such as operating hours, are commonly tabulated by building types, with one TRM weighting hours across all building types from the commercial sector.
- A policy for breaking this measure out needs to be determined to create reference tables.

Lighting Controls	PA TRM 2011	OH TRM 2011	AR TRM 2007	Mid-Atlantic TRM 2010	WI TRM 2010
Region	Pennsylvania	Ohio	Arkansas	Mid-Atlantic	Wisconsin
Measure Name	Lighting Equipment Improvements	C&I Lighting Controls (Time of Sale, Retrofit)	Lighting Controls	Occupancy Sensor - Wall Box	Occupancy Sensors – Wall or Ceiling Mount
Units	Per controlled lighting system	Per controlled lighting system	Per controlled lighting system	Per controlled lighting system	Per controlled lighting system
Approach Commentary	Algorithms are for lighting improvements with and without controls. This is a part of the indoor lighting measure.	Algorithm with default tables. Hours-of-use given by building type; ESF and CF given by control type. Uses actual connected kW. This measure is for the installation of a new lighting control on a new or existing lighting system.	Algorithm with default tables. Hours-of-use and coincidence factor tabulated by building type; PAF given by control type. Uses actual connected kW. This measure is for the installation of automatic lighting controls.	Algorithm with default tables and values. Hours-of-use tabulated by building type. Uses actual connected kW. This measure is for the installation of occupancy sensors.	Applicable to installation of wall- or ceiling-mounted occupancy sensors to control non-high bay lighting. Table of deemed savings provided by controlled wattage and sector. Supporting calculations provided.
Calculation Approach Deviations - Energy	$\Delta kWh = \frac{(Watt_{base} - (Watt_{ee} \times [\ldots}{1{,}000}$ Assuming $Watt_{base} = Watt_{ee}$ No deviation, mathematically equivalent	No deviation	$\Delta kWh = \left(\sum_k \left[N^0_{(k)} \times \frac{Watt_{b\ldots}}{1{,}00\ldots}\right.\right.$ Where k = fixture type	$\Delta kWh = kW_{connect} \times HRS \ldots$	$\Delta kWh = kW_{connect} \times HRS$
Calculation Approach Deviations - Demand	$\Delta kW = \frac{(Watt_{base} - Watt_{ee})}{1{,}000} \times \ldots$ Assuming $Watt_{base} = Watt_{ee}$	No deviation	NA	$\Delta kW = kW_{connect} \times (1 + W\ldots$	NA
Annual Energy Savings	ΔkWh = 189	ΔkWh = 232	ΔkWh = 180	ΔkWh = 224	ΔkWh = 535 (table, deemed value for commercial sector ceiling mount ≤500W)
Annual Gross Demand Savings	CF = 0.84 (table, office) ΔkW = 0	CF = 0.15 (table, ceiling occupancy sensor) ΔkW = 0.011	CF = 0.78 (table, office) ΔkW = 0	CF = 0.694 ΔkW = 0.049	CF = 0.77 ΔkW = 0
Baseline Condition	No controls	Uncontrolled lighting system; manual switch	As required by IECC 2003	Uncontrolled lighting system; manual switch	No controls

Lighting Controls	PA TRM 2011	OH TRM 2011	AR TRM 2007	Mid-Atlantic TRM 2010	WI TRM 2010
Efficient Condition	Controlled with occupancy sensor	Measure includes wall-, ceiling-, and fixture-mounted occupancy sensors; remote or fixture-mounted daylight dimming sensors; switching controls for multilevel lighting; and time clocks.	Measure includes wall- or ceiling-mounted occupancy sensors; photocells; switching controls for multilevel lighting; and time clocks.	Controlled with occupancy sensor	Ultrasonic or passive IR sensors, not socket based or fixture mounted.
Assumption 1: Energy Savings Adjustment Factor	ESF=0.30 (table, occupancy sensor)	ESF = 0.30 (table, ceiling occupancy sensor)	PAF = 0.70 (table, occupancy sensor)	ESF = 0.30 (fixed)	ESF = 0.41 (fixed, averaged over all building types)
Assumption 2: Annual Hours-of-use	HRS = 2,808 (table, large office) Actual hours should be used where stated and verified	HRS = 3,526 (table, office)	HRS = 3,850 (table, office)	HRS = 3,435 (table, office)	HRS = 3,730 (table, commercial)
Assumption 3: HVAC Interaction Factor	WHF_e = 0.12 WHF_d = 0.34 (table, cooled space)	WHF_e = 0.095 WHF_d = 0.200 (fixed)	NA	WHF_e = 0.11 WHF_d = 0.21 (fixed)	NA
Assumption 4: Connected Load	$kW_{connect}$ = 0.200 (Cadmus defined based on measure definition)	$kW_{connect}$ = 0.200 (Cadmus defined based on measure definition)	$kW_{connect}$ = 0.200 (Cadmus defined based on measure definition)	$kW_{connect}$ = 0.200 (Cadmus defined based on measure definition)	$kW_{connect}$ = 0.350 (table, ≤ 500 W)
TRM Specific Assumptions	NA	NA	NA	ISR = 0.98	NA
Lifetime (years)	15 (table, lighting program)	8	8 (table, occupancy sensor)	10	NA
Incremental Costs	NA	$66 (table, wall mounted occupancy)	NA	$55	NA
Secondary Benefits	NA	NA	NA	NA	NA
References	CBECS (2003), NYSERDA (2009), ACEEE (1992), PA and VT TRM, KEMA (2009), RLW Analytics (2007),	DEEF (2008), KEMA (2009 and 2010), VT TRM (2010), United Illuminating (2009), RLW Analytics (2007)	Ecotope (2003), PG&E (2003), Stellar Processes (2006), Xcel Energy (2006), Quantec (2005), KEMA	Quantum Consulting (1999), VT DPS, CBECS (2003), Orange & Rockland (1993), ASHRAE (1993), VT TRM	ESource

Lighting Controls	PA TRM 2011	OH TRM 2011	AR TRM 2007	Mid-Atlantic TRM 2010	WI TRM 2010
	Quantum Consulting (1999), DEER (2005 and 2008), NJ Clean Energy Protocols (2009), SCE (2007), ASHRAE 90.1 (2007), various others		(2006), CEE, ENERGY STAR, RTF, NPCC (2005), Nexant (2005), CEC (2005)	(2008), GDS (2007)	

Lighting Controls Glossary
HRS = Annual operating hours
WHF_e = lighting-HVAC interactive effect for energy
WHF_d = lighting-HVAC waste heat factor for demand
ESF = Equipment energy saving factor
CF = Coincidence factor
$kW_{connect}$ = System connected kW
ISR = In-service rate
$Watt_{base}$ = Baseline wattage
$Watt_{ee}$ = Efficient condition wattage
N^0 = Number of units in affected area
PAF = Power adjustment factor (1-ESF)
1,000 = watts per kW

Motors

Measure Name	Motors				
Measure Description	Applicable to high-efficiency electric motors (OPD or TEFC) between 1 to 200 HP used in single motor systems.				
Weather Sensitive?	No	**Sector?**	Commercial	**Primary Fuel?**	Electric
Prevailing Energy Savings Methodology	$\Delta kWh = HP \times RLF \times 0.746 \times \left[\frac{1}{N_{base}} - \frac{1}{N_{ee}}\right] \times HRS$				
Prevailing Demand Savings Methodology	$\Delta kW = HP \times RLF \times 0.746 \times \left[\frac{1}{N_{base}} - \frac{1}{N_{ee}}\right] \times CF$				
Variables	RLF = Rated load factor of motor HP = Nameplate horsepower of equipment motor 0.746 kW/HP = conversion factor from horsepower to kW HRS = operating hours (actual or based on use scenario) N_{base} = Efficiency of baseline motor (EPACT table) N_{ee} = Efficiency of efficient motor (NEMA table) CF = coincidence factor				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- WI TRM 2010, PA TRM 2011, Mid-Atlantic TRM 2010, AR TRM 2007, OH TRM 2011
- 10 HP Open Drip Proof; 1,800 revolutions per minute (RPM) (4 Pole); single motor system.

Energy savings are calculated per motor on a retrofit basis. All baselines were found to be the same (EPACT), and the efficient condition is defined as meeting or exceeding National Electrical Manufacturers Association (NEMA) premium efficiency requirements. Calculations reviewed were all technically correct, with some approaches relying on more default assumptions than others. Typically, greater than 200 HP to 500 HP motors were not included as part of TRMs, and some refer these motor sizes to be included as part of a custom protocol.

Users are expected to provide the HP and hours of operation. Some TRMs provide a lookup table to determine hours of use. N_{base} and N_{ee} can be based on actual or tabulated values. N_{ee} must equal or exceed the NEMA requirements. The WI TRM contains gross energy savings algorithm where the deemed demand savings are multiplied by the hours of use. For a given HP, a single deemed demand savings value is provided, which has been weighted by motor type and RPMs. Coincidence factors vary greatly; some TRMs do not consider it while others provide default values ranging from 0.38 to 0.74. The rated load factor (RLF) varies from 0.5 to 0.75, with 0.75 being the most commonly found RLF.

The 2007 EISA standards required the general purpose electric motors (subtype I) to meet “NEMA Premium” levels.[6] At the time of this comparison, only the PA TRM includes the change in baseline efficiencies to account for the new EISA standards. This measure illustrates the importance of regular updates to the database due to regulatory changes. Code updates have the potential to significantly alter the savings methodology; in this case, the baseline efficiency has been updated to the efficient levels requiring all reference tables in the TRMs be revised. As of the date of this report, NEMA has not proposed the next tier in motor-efficiency specifications. CEE has developed a

[6] NEMA Premium Efficiency motors became the federal minimum efficiency levels effective on December 19, 2010.

product list for enhanced premium efficiency motors that are more efficient than the new standard for motor efficiency. This would require TRM users to define the efficient condition. Code changes also impact the ability for utilities to continue to offer incentives either by not making the measure cost-effective or having the resources to update the program.[7] Under the same rational, TRM administrators may have similar constraints and measures may be removed. A national database would require adequate technical support to address these code impacts.

Motors often appear in TRMs multiple times, usually as a general measure and as an ECM for use in HVAC or refrigeration applications. No secondary benefits were reported in any of the TRMs. Measure lifetimes range from 15-20 years.

Recommendations

Commercial high efficiency motors could be recommended as part of the national database. There is low variation in energy savings calculation methodologies for motors, making it ideal for inclusion in a national database of energy-efficiency measures. Database recommendations are presented below:

- It is preferable to follow a calculation based methodology that considers the specific motor type, size, and RPM versus deeming savings by HP. An engineering algorithm provides flexibility, ease of updating measure inputs, and greater transparency.
- Provide a reference table of operating hours by use scenario and a corresponding table of RLF.
- As with most measures, a national database would require adequate technical support to address code changes.

[7] For example, Duke Energy announced motor rebates will expire in the first quarter of 2011 due the changes in motor efficiency standards.

Motors	WI TRM 2010	PA TRM 2011	Mid-Atlantic TRM 2010	AR TRM 2007	OH TRM 2011
Region	Wisconsin	Pennsylvania	Mid-Atlantic	Arkansas	Ohio
Measure Name	NEMA Premium Motors	Premium Efficiency Motors	Premium Efficiency Motors	Motors	Motors (Time of Sale)
Units	Per motor 1-200HP	Per motor	Per motor ≤ 200HP	Per motor	Per motor
Approach Commentary	Two approaches, one is deemed and is weighted average by type to get deemed savings by size. Other is based on calculation for particular motor (type, size, RPMs).	Applicable to replacement with same rated horsepower. Replacement with new motor with different HP rating considered custom measure. Calculation with lookup tables. Lookup tables from EPACT and NEMA by HP broken out by ODP and TEFC type motors. Baseline varies by early replacement or burnout scenarios. CF and HRS are for single motor systems; multiplex systems are considered custom.	Applicable to replacement with same rated horsepower. Calculation with lookup tables. Lookup tables from EPACT and NEMA by HP broken out by ODP and TEFC type motors.	Calculation based on actual or tabulated motor efficiencies. Table of hours, load factor and efficiency by motor size. Does not differentiate between ODP or TEFC type motors. The efficiencies are not totally consistent with the NEMA/EPACT tables.	Calculation, but allows different HP and RLF factors between baseline and efficient condition. Lookup tables from EPACT and NEMA by HP broken out by ODP and TEFC type motors.
Calculation approach deviations - Energy	No deviation Deemed formula: $\Delta kWh = 0.1075 \times HRS$	No deviation	No deviation	No deviation	$\Delta kWh = 0.746 \times EFLH \times [$
Calculation approach deviations - Demand	No CF Deemed	No deviation	No deviation	No CF	$\Delta kW = 0.746 \times CF \times [HP_{bas}$
Annual Gross Energy Savings	$\Delta kWh = 475$	$\Delta kWh = 662$	$\Delta kWh = 562$	$\Delta kWh = 387$	$\Delta kWh = 662$
Annual Gross Demand Savings	CF = NA $\Delta kW = 0.108$	CF = 0.74 $\Delta kW = .111$	CF = 0.555 $\Delta kW = .083$	CF = NA $\Delta kW = 0\ .138$	CF = 0.38 $\Delta kW = 0.057$
Baseline Condition	$N_{base} = 89.5\%$ (EPACT table, motor type	$N_{base} = 89.5\%$ (EPACT table, motor type	$N_{base} = 89.5\%$ (EPACT table, motor type	$N_{base} = 89.45\%$ (EPACT table, motor size)	$N_{base} = 89.5\%$ (EPACT table, motor type

Motors	WI TRM 2010	PA TRM 2011	Mid-Atlantic TRM 2010	AR TRM 2007	OH TRM 2011
	and size)	and size)	and size)		and size)
Efficient Condition	Nee = 91.70% (NEMA table, motor type and size)	Nee = 91.70% (NEMA table, motor type and size)	Nee = 91.70% (NEMA table, motor type and size)	Nee = 92.52% (NEMA table, motor size)	Nee = 91.70% (NEMA table, motor type and size)
Assumption 1:Annual hours of use	HRS = provided by user = 4,414 (Cadmus defined based on PA TRM)	HRS = 4,414 (table, large office, HVAC fan)	HRS = 3,748 (table, general office HVAC fan)	HRS = 2,797 (table, motor size)	HRS = provided by user = 4,414 (Cadmus defined based on PA TRM)
Assumption 2: Rated load factor	RLF = 0.62 (fixed)	RLF = 0.75 (fixed)	RLF = 0.75 (fixed)	RLF = 0.5 (table, motor size)	RLFbase = 0.75 RLFee = 0.75*
Lifetime (years)	NA	20	20	15	16
Incremental Costs	NA	NA	$116 (table, 10 HP ODP or TEFC)	NA	$116
Secondary Benefits	NA	NA	NA	NA	NA
References	Motor studies, EPACT, NEMA, New England Motor Baseline Study, CEE	EPACT, NEMA, DEER (2005), Primary data collection, ENERGY STAR, others	EPACT, DEER, NEMA, GDS	EPACT (1992), DEER (2005), NEMA (2002), Ecotope (2003), PG&E (2003), Quantec (2005), RTF, NPCC (2005), CEE, MotorMaster+, others	EPACT, NEMA (2008), VT TRM (2010), PA Consulting (2009), Xenergy (2001)

*Cadmus assumes the same load factor for both the efficient and baseline conditions.

Motors Glossary
RLF = Rated load factor of motor
HP = Nameplate horsepower of equipment motor
0.746 kW/HP = conversion factor from horsepower to kW
HRS = operating hours (actual or based on use scenario)
N_{base} = Efficiency of baseline motor (EPACT table)
N_{ee} = Efficiency of efficient motor (NEMA table)
CF = coincidence factor
HP_{base} = Nameplate horsepower of baseline motor
HP_{ee} = Nameplate horsepower of efficient condition motor
RLF_{base} = Rated load factor of baseline motor
RLF_{ee} = Rated load factor of efficient motor

Unitary Air Source Heat Pump

Measure Name	Unitary Air Source Heat Pump				
Measure Description	Installation of high-efficiency air cooled heat pump system. Some TRMs also include water source or ground source type systems.				
Weather Sensitive?	Yes	**Sector?**	Commercial	**Primary Fuel?**	Electric
Prevailing Energy Savings Methodology	$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$ $$\Delta kWh_{cool} = kBTUH_{cool} \times \left[\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right] \times EFLH_{cool}$$ $$\Delta kWh_{heat} = kBTUH_{heat} \times \frac{1}{3.412}\left[\frac{1}{COP_{base}} - \frac{1}{COP_{ee}}\right] \times EFLH_{heat}$$				
Prevailing Demand Savings Methodology	$$\Delta kW_{summer} = kBTUH_{cool} \times \left[\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right] \times CF$$				
Variables	$kBTUH_{cool}$ = HVAC system cooling capacity in kBTU/hr $kBTUH_{heat}$ = HVAC system cooling capacity in kBTU/hr $EFLH_{cool}$ = Annual equivalent full load hours for cooling $EFLH_{heat}$ = Annual equivalent full load hours for heating EER_{base} = Baseline energy-efficiency ratio EER_{ee} = Efficient condition energy-efficiency ratio CF = Coincidence factor for demand COP_{base} = Coefficient of performance of baseline unit COP_{ee} = Coefficient of performance of efficient condition 3.412 = Conversion factor between EER and COP				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- ENERGY STAR, AR TRM 2007, DEER 2005, PA TRM 2011, OH TRM 2011
- 10-ton size (120 kBTUH) and, where applicable, Cadmus defined the efficiency rating of 11.5 EER and 3.4 COP according to CEE Tier 1.

Energy savings are calculated per HVAC system on a retrofit basis. Baseline conditions are typically defined based on the state's adopted code and/or federal requirements, for example IECC 2009 and ASHRAE 90.7-2007. The efficient condition is either the nameplate efficiency or the values defined by the CEE (typically Tier 1: 11.5 EER/3.4 COP). Calculations provided by ENERGY STAR and AR TRM appear to be more appropriate for residential-sized systems, based on use of SEER/HSPF units. DEER uses energy modeling to determine energy savings. The PA TRM and OH TRM use the prevailing algorithm. Residential units are more likely to be rated in units of SEER/HSPF (used for systems <5.4 tons) while commercial units tend to be EER/COP based (used for systems >= 5.4 tons). Demand savings are calculated with a coincidence factor, when available. Secondary benefits are found only through the ENERGY STAR calculator, which converts energy savings into CO_2 reductions. Measure lifetimes range from 12-15 years, with 15 years being the most commonly found value, primarily due to cross-referencing within the examined sources. Incremental costs are available in three of the five sources, ranging from $100/ton (OH TRM) to $333/ton (ENERGY STAR). However, as noted, the ENERGY STAR calculator is aimed towards the residential sector (even though it was downloaded from the business section). Commercial systems may have greater economies of scale, which is why the other two sources found an incremental cost between $100/ton-$182/ton.

Recommendations

A unitary air source heat pump could be recommended as part of the national database due to the importance HVAC equipment has on utility programs. Database recommendations are presented below:

- The primary challenge will be to develop weather-sensitive usage or EFLH by climate zone and building type. This can be achieved through DOE2 building simulations, but, as with shell measures, this poses a significant undertaking to develop models nationally.
- DEER prototypical building simulations is a good starting point for the national prototypical models since DEER has been thoroughly vetted by California's efficiency programs.
- Like most measures, a national database would require adequate technical support to address code changes.
- Coincidence factors are location/climate dependent, and a table should be provided with default values.

Air Source Heat Pump	ENERGY STAR	AR TRM 2007	DEER 2005	PA TRM 2011	OH TRM 2011
Region	National	Arkansas	California	Pennsylvania	Ohio
Measure Name	ENERGY STAR Qualified Air Source Heat Pump	Unitary ac and hp equipment	High eff. packaged unitary system HP (65-134k)	Heat Pump (includes air-to-air HP, packaged terminal HP, water source HP, and groundwater source HP).	Heat Pump Systems (Time of Sale, New Construction)
Units	Per heat pump	Per heat pump	Per system ton	Per heat pump	Per heat pump
Approach Commentary	Interactive calculator with user supplied variables such as electric rates, number of units, SEER and HSPF, cost and capacity. Option exists for use with programmable thermostat. Default is 3 ton size (residential).	Have formulas for peak demand, energy savings, and EFLH (cooling and heating). Provides tables of baseline and efficient conditions; table of $EFLH_{cool}$ and coefficients for $EFLH_{heating}$.	Use DOE-2.2 modeling for various building types/climate zones. Convert EER and COP into DOE-2.2 inputs.	Calculation with baseline efficiency values from a table; uses actual installed and efficient condition values. Table of $EFLH_{cool}$ and $EFLH_{heat}$ values provided for various cities and building types.	Calculation with baseline efficiency values from a table; uses actual installed and efficient condition values. Table of $EFLH_{cool}$ and $EFLH_{heat}$ values provided for various cities from DOE2 modeling.
Calculation approach deviations - Energy	$\Delta kWh = kBTUH \times \left(\left[\frac{EFLH_c}{SEER_b} \right. \right.$	$\Delta kWh = kBTUH \times \left(\left[\frac{EFLH_c}{SEER_b} \right. \right.$ *	Tabulated by climate zone, vintage, building type	No deviation; alternate calculation uses SEER or HSPF in place of EER or COP, respectively. This is to account for units <65 kBTUH.	No deviation for cooling savings. $\Delta kWh_{heat} = kBTUH_{heat} \times$
Calculation approach deviations - Demand	NA	$\Delta kW = kBTUH \times \left[\frac{1}{EER_{base}} \right.$	Tabulated	No deviation	No deviation
Annual Gross Energy Savings	ΔkWh = 3,031	ΔkWh = 1,370	ΔkWh = 109	ΔkWh = 568	ΔkWh = 1,362 (cool) + 1,171 (heat) = 2,534
Annual Gross Demand Savings	NA	CF = NA ΔkW = 0.972	ΔkW = 0.042	CF = 0.67 ΔkW_{summer} = 0.318	CF = 0.74 ΔkW_{summer} = 1.070

Air Source Heat Pump	ENERGY STAR	AR TRM 2007	DEER 2005	PA TRM 2011	OH TRM 2011
Baseline Condition	7.7 HSPF 13 SEER (fixed)	IECC 2003 10.1 EER ** 3.2 COP (table, system size) This may be a typo in the TRM, EER and COP are typically reported together, not SEER and COP.	Depends on vintage 10.1 EER 3.2 COP (Cadmus defined based on OH TRM)	11 EER 3.3 COP (table, system size and type)	IECC 2006 10.1 EER 3.2 COP (table, system size and type)
Efficient Condition	8.2 HSPF 14.5 SEER (12 EER) (fixed)	CEE tier 1-3 11 EER 3.4 COP (table, CEE tier 1)	11 EER 3.4 COP (fixed)	Nameplate efficiency. 11.5 EER and 3.4 COP (Cadmus defined at CEE T1)	Exceeds IECC 2006 11.5 EER and 3.4 COP (Cadmus defined at CEE T1)
Assumption 1: Annual hours of use	$EFLH_{cool}$=947 $EFLH_{heat}$=2,238 (table, Dayton OH)	$EFLH_{cool}$= 1,177 $EFLH_{heat}$= 233 (table, Little Rock, AR 5 days a week)	NA	$EFLH_{cool}$ = 718 $EFLH_{heat}$ = 725 (table, Pittsburgh Office)	$EFLH_{cool}$ = 942 $EFLH_{heat}$ = 810 (table, Dayton OH)
TRM Specific Assumptions	NA	/47°F db/43°F wb outdoor air	Health/Medical building type Climate Zone 16 – Mt. Shasta	NA	/47°F db/43°F wb outdoor air
Lifetime (years)	12 (LBNL)	15 (DEER)	15	NA	15
Incremental Costs	$333/ton	NA	$182.43/ton	NA	$100/ton
Secondary Benefits	Lbs of CO_2 reduced	NA	NA	NA	NA
References	Industry data (2008), NAECA, LBNL (2007), EPA (2002, 2004 and 2009), EIA AEO (2009)	IECC (2003), KEMA (2006), DEER, Quantec (2005), CEE, ENERGY STAR, Xcel Energy (2006), NPCC (2005), Ecotope (2003), PG&E (2003)	CALMAC, CEE	ENERGY STAR, ASHRAE 90.1, IECC (2009)	IECC (2006), DEER, Duke Energy, GDS (2007), TRMs from VT, WI and CA

*This formula contains a typo. Inputs in [brackets] should be additive.

**This may be a typo in the TRM, it originally stated SEER instead of EER.

Air Source Heat Pump Glossary
$kBTUH_{cool}$ = HVAC system cooling capacity in kBtu/hr $kBTUH_{heat}$ = HVAC system cooling capacity in kBtu/hr $EFLH_{cool}$ = Annual equivalent full load hours for cooling $EFLH_{heat}$ = Annual equivalent full load hours for heating EER_{base} = Baseline energy-efficiency ratio EER_{ee} = Efficient condition energy-efficiency ratio CF = coincidence factor for demand COP_{base} = Coefficient of performance of baseline unit COP_{ee} = Coefficient of performance of efficient condition 3.412 = conversion factor between EER and COP $SEER_{base}$ = Baseline seasonal energy-efficiency ratio $SEER_{ee}$ = Efficient condition seasonal energy-efficiency ratio $HSPF_{base}$ = Baseline heating seasonal performance factor $HSPF_{ee}$ = Efficient condition heating seasonal performance factor

Commercial Ceiling/Roof Insulation

Measure Name	Ceiling/Roof Insulation				
Measure Description	Improvements to roof insulation in commercial buildings, typically through increasing the roof assembly R-value.				
Weather Sensitive?	Yes	**Sector**?	Commercial	**Primary Fuel**?	Electric and Gas
Prevailing Energy Savings Methodology	Tabulated savings by climate zone or location, building type, vintage, HVAC system, or other characteristics developed by building energy simulation software. Usually in units of 1,000 sq ft, with the user scaling up the value appropriately.				
Prevailing Demand Savings Methodology	Tabulated savings by climate zone or location, by building type, vintage, HVAC system, and other characteristics developed by building energy simulation software.				
Variables	NA; because the methodology relies primarily on modeling and results are tabulated.				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- DEER 2005, NY TRM 2010, VT TRM 2010, OH TRM 2011, PA TRM 2011
- Prevailing methodology uses DOE-2.2 to simulate energy savings for various buildings.
- Comparable savings estimates were not determined for this measure because of weather dependence of savings.

The prevailing methodology to determine energy savings is based on building simulations of prototypical buildings in the region where the TRM was written. DEER uses DOE-2.2 to simulate energy savings for various buildings, and tabulates the results in a database. Following DEER's methodology, New York and Ohio start with the DEER building prototypes, and adapt them to local building practices and climate. Energy modeling requires many assumptions around developing prototypical buildings, including basic characteristics such as: building size, geometry, glazing, operating hours and HVAC setpoints, lighting power density, and HVAC system type and size. The resulting energy and demand savings are then tabulated by building type per one or 1,000 square feet of affected roof area.

Alternative methodologies include a derivative of the basic heat transfer equation to estimate energy savings through an assembly. In this engineering calculation approach, the user must refer to various tables to calculate the energy savings. The methodology uses cooling degree days and heating degree days as a way to incorporate climate differences. This method does not account for variations in commercial building type characteristics, only efficiencies of the heating and cooling equipment and baseline R-values. However, this method is faster and cheaper to develop than modeling multiple buildings for various climate zones, making it an attractive option for TRM developers.

As with any TRM, there are errors and assumptions that cannot be found in reference tables, and the user is left to estimate the appropriate input. For example, the user may not have the space heating system efficiency, including distribution losses. There may be no indication on how to determine this system efficiency, nor are default values provided.

Demand savings follow the same methodology as the energy savings, except for the OH TRM, which is a hybrid approach with an overarching formula that scales per square foot savings up to the project or roof assembly level. The demand savings for calculated or hybrid approaches can then be calculated by applying a coincidence factor.

Measure lifetimes range from 15-30 years. No secondary benefits were reported.

Recommendations

Modeling commercial roof insulation would not be recommended (initially) to be included as part of the national database since it would be difficult to standardize this measure. The models would need to be developed for regions, requiring significant data on regional building characteristics. The engineering calculation methodology of using basic heat transfer equation could initially be the easiest to incorporate into a national database.

- Professional modeling has the highest accuracy, if existing building stock data are available, and would provide this measure (and other shell measures) with tabulated results.
- DEER prototypical building simulation is a good starting point for the national prototypical models since DEER has been thoroughly vetted by California's efficiency programs.
- An engineering calculation method, though less accurate then modeling, would provide a quick and reasonable result, if proper bounds to the inputs are given.

In either scenario, a national database would need to adequately support all inputs with user guidance on how to make the most appropriate choices.

Ceiling/Roof Insulation	DEER 2005	NY TRM 2010	VT TRM 2010	OH TRM 2011	PA TRM 2011
Region	California	New York	Vermont	Ohio	Pennsylvania
Measure Name	Older building ceiling/roof insulation up to current standards	Commercial Roof Insulation Upgrade	Envelope (space heating end use)	Roof Insulation (Retrofit – New Equipment)	Wall and Ceiling Insulation
Units	1,000 sq ft of roof	1,000 sq ft of roof*	Per affected roof	Per affected roof	Per affected roof
Approach Commentary	eQuest modeling (DOE 2.2)	DOE 2.2 modeling; adapted from DEER prototypes. Adjustments made for local building practices and climate.	Savings algorithm is for roof assemblies; also can be applied to wall assemblies and windows and glass door assemblies. Provides reference tables.	DOE 2.2 modeling; adapted from DEER, reference tables	Heated and cooled with electricity. This algorithm is specific to central AC and ASHP. Insulations are fixed for new construction/unknown and variable for existing.
Calculation approach deviations - Energy	No deviation	No deviation	$\Delta MMBTU = HDD \times 24 \times$	$\Delta kWh = A \times \Delta kWh_{sqft}$	$\Delta kWh = \Delta kWh_{cool} + \Delta kW$ $\Delta kWh_{cool} = \frac{A \times CDD \times 24}{EER \times 1{,}000} \times ($ $\Delta kWh_{heat} = \frac{A \times HDD \times 24}{COP \times 3413} \times ($
Calculation approach deviations - Demand	No deviation	No deviation	NA (VT does not include cooling savings)	$\Delta kWh = A \times \Delta kWh_{sqft} \times ($	$\Delta kW = \frac{\Delta kWh_{cool}}{EFLH_{cool}} \times CF$
Annual gross energy savings	Database with electricity and gas savings, costs, measure life, other factors	Tables with kWh/unit savings, summer kW/unit savings, therm savings/unit. Tables broken out by city, building type, and HVAC system type.	Varies by HVAC system type	Table with electricity and gas savings per 1,000 sq ft by building type and city.	Varies by HVAC system type
Annual Gross Demand Savings	Tabulated	Tabulated	ΔkW = NA	CF = 0.74 ΔkW = NA	CF = 0.67 ΔkW = NA

Ceiling/Roof Insulation	DEER 2005	NY TRM 2010	VT TRM 2010	OH TRM 2011	PA TRM 2011
Baseline Condition	Depends on vintage and climate zone	Varies by building type	Provides guidelines in a summary table for baseline assembly R-value, depends on type of roof assembly	Varies by building type, table	R-value varies by building type and vintage. HVAC baseline efficiencies vary by system type, size, and vintage.
Efficient Condition	NA	NA	Guidelines in summary table, minimum increase in R-value depends on type of roof assembly	R-18 is efficient condition (fixed)	(User defined)
TRM Specific Assumptions	NA	NA	NA	NA	A = (User defined) (Table, Pittsburgh) HDD = 5429 CDD = 726 EFLH reference table varies by location and space type.
Lifetime (years)	20	NA	30	20	15
Incremental Costs	Tabulated	NA	NA	$1.36/sq ft	NA
Secondary Benefits	NA	NA	NA	NA	NA
References	DEER (1994), NCC (James J. Hirsch & Associates), HPCBS (2002)	DEER (2005)	ASHRAE 90.1 (2004), Vermont Guidelines for Energy Efficient Commercial Construction (2005)	DEER (2008), Duke Energy	US Dept of Commerce, IECC (2009), eQuest, PA TRM (2010), ASHRAE 90.1 (2004)

*Definition of units not included in the measure tables; assume 1,000 sq ft of roof based on building model characteristics.

Ceiling/Roof Insulation Glossary

$\Delta MMBtu$ = Fuel savings for the measure, in MMBtu
ΔkWh_{sqft} = Annual kWh savings per square foot
24 = Hours per day
A = Effective area of increased insulation (SQFT)
R_{base} = Baseline effective thermal resistance value (hr-ft^2-°F/Btu)
R_{ee} = Efficient effective thermal resistance value (hr-ft^2-°F/Btu)
η = Space heating system efficiency including distribution losses
10^6 = Conversion from BTU to MMBtu
ΔkWh_{cool} = Annual cooling kWh savings per unit
ΔkWh_{heat} = Annual heating kWh savings per unit
HDD = Heating degree days (65°F default)
CDD = Cooling degree days (65°F default)
EER = HVAC system energy-efficiency ratio
COP = HVAC system coefficient of performance
1,000 = Number of W per kW
3413 = Btu per kWh
$EFLH_{cool}$ = Annual equivalent full load hours for cooling
CF = Coincidence factor

Commercial Clothes Washer

Measure Name	Clothes Washer – commercial-sized electric water heat and dry; gas water heat and dry				
Measure Description	A commercial-sized clothes washer for use in a multifamily building, Laundromat, or institution setting. May include savings from reduced dryer energy consumption.				
Weather Sensitive?	No	**Sector**?	Commercial	**Primary Fuel**?	Electric and Gas
Prevailing Energy Savings Methodology	$\Delta\mathrm{kWh} = \mathrm{N}^{\mathrm{cycle}} \times \Delta\mathrm{kWh}_{\mathrm{cycle}}$ ΔkWh_{cycle} tabulated by washer/dryer combination.				
Prevailing Demand Savings Methodology	NA				
Variables	ΔkWh_{cycle} = kWh savings per unit per use cycle N^{cycle} = Number of cycles/uses per year				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- ENERGY STAR, RTF 2011, OH TRM 2011, MEMD 2009, VT TRM 2010
- Two scenarios were chosen for the comparison table: (1) electric water heat and electric dryer; and (2) gas water heat and gas dryer.

The measure databases calculate energy savings on a per appliance basis for a combination of domestic water heater (DWH) and dryer options (gas, electric, no dryer). The average number of uses per year is multiplied by the average savings per use. The main variation on these methodologies is the calculation of savings per cycle. There are three main approaches to defining the baseline Modified Energy Factor (MEF):

- Average the baseline MEF over only non-ENERGY STAR-qualified models.
- Average the baseline MEF that includes ENERGY STAR-qualified models in the market baseline (RTF).
- Define the baseline MEF as federal code (1.26 MEF).

The second scenario will yield lower savings per cycle; however, the RTF assumes a much higher number of cycles per year, resulting in the highest RTF energy savings out of the resources compared.

Most sources examined also included water savings as a non-energy benefit. The RTF includes detergent savings, and the ENERGY STAR calculator includes CO_2 reduced.

Measure lifetimes were found to range from 7-14 years; note that the RTF's estimate of a 7-year lifetime is the shortest; however, the RTF also assumes the highest use scenario (in a Laundromat). The VT TRM assumes 14 years, but has the fewest cycles per year (in low-income, multifamily facilities).

Recommendations

Commercial clothes washers could be recommended as part of the national database. Database recommendations are presented below:

- There are three areas of savings: clothes washer, water heater, and dryer. Transparency in how savings are derived for each savings area would be needed.

- Consistency in wash loads per year, per application would be needed.
- The savings and measure life should vary by DWH/dryer fuel and by use scenario (multifamily facility, Laundromat, etc.).
- A policy needs to be developed regarding how natural adoption of the energy-efficient models should be calculated into the baseline. For example, for the RTF, where energy efficiency has a long history, it is appropriate to include all models currently in the market as part of the baseline. In areas with little demand side management (DSM) activity, it may be more appropriate to have the baseline represent federal code.
- As with most measures, a national database would require adequate technical support to address code changes.

Clothes Washer	ENERGY STAR	RTF 2011	OH TRM 2011	MEMD 2009	VT TRM 2010
Region	National	Pacific Northwest	Ohio	Michigan	Vermont
Measure Name	ENERGY STAR-Qualified Commercial Clothes Washer	Energy Star [sic] Commercial Clothes Washer in Laundromat w/ MEF 1.80 and higher - Electric DWH & Dryer or Gas DWH & Dryer	Commercial Clothes Washer (Time of Sale)	Clothes Washer CEE Tier1, Gas Water Heater, Gas Dryer –OR– Electric Water Heater, Electric Dryer	ENERGY STAR Commercial Clothes Washer
Units	Per appliance or per user-defined number of appliances	Per washer	Per washer	Per washer	Per washer
Approach Commentary	Calculator allows user to choose residential or commercial, number of units, utility rates, number of loads per week, water heat type, and dryer fuel. Based on average energy consumption based on all qualified models (July 2009).	MS Excel® workbook with tabulated savings and supporting calculation sheets. ProCost used to determine system level benefits, including demand reductions. Calculate savings in parts: water heating, washing electricity, dryer, detergent, water treatment. Use of real data and regression to determine consumption for each component. Use in Laundromat application.	Calculates annual energy savings by multiplying the savings per load by the number of loads per year. A reference table of savings per load is provided for electric and gas hot water with electric dryer. Reference table based on ENERGY STAR calculator (July 2009). For installation in Laundromats, MF buildings and, institutions.	MS Excel® worksheet with measures in the rows and measure information in the columns. Each unique combination of washer/dryer fuel is considered a separate measure. No publicly available calculation methodology.	Savings are based on weighted average MEF factor, which is based on residential models rebated during previous calendar year. This is a conservative estimate because commercial grade washers on the market have higher average MEF than residential washers. Use in low-income multifamily facility.
Calculation Approach Deviations - Energy	$\Delta kWh = N^{cycle} \times \Delta kWh_{cy}$	Tabulated in workbook: Tab: Savings Cell: N47-V47	$\Delta kWh = N^{cycle} \times \Delta kWh_{cyc}$	Tabulated	$\Delta kWh = \frac{N^0_{res} \times \Delta kWh_{res}}{N^0}$
Calculation Approach Deviations - Demand	NA	ProCost output	NA	Tabulated	NA

Clothes Washer	ENERGY STAR	RTF 2011	OH TRM 2011	MEMD 2009	VT TRM 2010
Annual Gross Energy Savings	Elec DWH and dryer: ΔkWh = 543 Gas DWH and dryer: Δtherm = 22 ΔkWh = 58	Elec DWH and dryer: ΔkWh = 921 Gas DWH and dryer: Δtherm = 34 ΔkWh = 110 Wastewater: ΔkWh =104	Elec DWH and dryer: ΔkWh = 542	Elec DWH and dryer: ΔkWh = 633 Gas DWH and dryer: Δtherm = 27 ΔkWh = 18	Elec DWH and dryer: ΔkWh = 224 Gas DWH and dryer: ΔkWh = 16 ΔMMBtu = 0.76
Annual Gross Demand Savings	NA	Elec DWH and dryer: ΔkW = 0.52 Gas DWH and dryer: ΔkW = 0.08	NA	Elec DWH and dryer: ΔkW = 0.067 Gas DWH and dryer: ΔkW = 0.002	NA
Baseline Condition	Average non-qualified models: Electric DWH and dryer: 2.01 kWh/cycle Gas DWH and dryer: 0.21 kWh/cycle 0.08 therms/cycle	Average efficiency of products available on market per CEC model list, meets or exceeds federal standard. Includes models that also meet ENERGY STAR requirements as part of market baseline.	Federal standard: MEF ≥ 1.26	Federal standard: MEF = 1.26	Top-loading, commercial-grade clothes washer. MEF is federal baseline +10% = 1.39 to account for non-ENERGY STAR models with higher efficiencies.
Efficient Condition	Average ENERGY STAR-qualified Electric DWH and dryer: 1.44 kWh/cycle Gas DWH and dryer: 0.15 kWh/cycle 0.05 therms/cycle	Average appliance that meets or exceeds ENERGY STAR	ENERGY STAR commercial clothes washer: MEF ≥ 1.80	CEE Tier 1 MEF ≥ 1.80	CEE Tier 2 standards, MEF of 2.0 of higher.
Assumption 1: Washer Cycles per Year	N_{cycle} = 950 (fixed)	N_{cycle} = 2,190 (fixed)	N_{cycle} = 950 (fixed)	N_{cycle} = 950* (fixed)	N_{cycle} = 271 (fixed)
TRM Specific Assumptions	NA	Delta temperature = 80°F Electric DWH Recovery = 100% Gas DWH Recovery = 75%	Assumes electric water heater and electric dryer.	NA	N^0_{res} = 1 N^0 = 1 (Cadmus defined to compare on a per washer basis)
Lifetime (years)	11	7	10	10	14
Incremental Costs	$258/clothes washer	$370/clothes washer	$347/clothes washer	$347/clothes washer	$750/clothes washer

Clothes Washer	ENERGY STAR	RTF 2011	OH TRM 2011	MEMD 2009	VT TRM 2010
Secondary Benefits	Lbs of CO_2; water savings	Detergent savings; wastewater treatment	Water savings	NA	Water savings
References	National retail pricing (2009), Appliance Magazine (2008), DOE, MF Laundry Association (2002), EIA AEO (2009), EPA (2007, 2009)	ENERGY STAR, federal standard, DOE (2008), CEC data (2009), homegrocer.com, safeway.com	ENERGY STAR calculator (2009), DEER (2008)	CEE, ENERGY STAR, DEER (2008)	DEER (2005), VT Data, US DOE (2000), VT DPS

*Noted under hours of operation, but Cadmus interprets as number of laundry cycles/year.

Clothes Washer Glossary
N^{cycle} = Number of cycles/uses per year
ΔkWh_{cycle} = kWh savings per unit per cycle
N^0 = Number of units in affected area
N^0_{res}= number of residential units served by laundry facility
ΔkWh_{res} = annual customer kWh savings/residential unit
MEF = Modified energy factor
WF = Water factor

Air Compressor Equipment

Measure Name	Air Compressor Equipment				
Measure Description	Refers to the installation of an efficient air compressor with controls, and not to the improvement of the overall compressed air system (e.g., leak sealing). May include variable displacement controls, load/no load controls, or a variable frequency drive.				
Weather Sensitive?	No	**Sector?**	Commercial/Industrial	**Primary Fuel?**	Electric
Prevailing Energy Savings Methodology	$\Delta \mathrm{kWh} = \mathrm{HP} \times \mathrm{HRS} \times \mathrm{kWHP}$				
Prevailing Demand Savings Methodology	$\Delta \mathrm{kW} = \mathrm{HP} \times \mathrm{kWHP} \times \mathrm{CF}$				
Variables	HP = Nameplate horsepower of equipment motor kWHP = air compressor kW reduction per horsepower(lookup table) HRS = operating hours CF = coincidence factor				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- MA TRM 2011, NY TRM 2010, OH TRM 2011, VT TRM 2010, PA TRM 2011
- Baseline condition: 25 HP modulating air compressor (with blow down)
- Efficient condition: 25 HP with a variable speed drive (VSD).

Energy savings are calculated per compressor on a retrofit basis. The TRM comparison showed that all baselines are the same; namely, modulating air compressors with blow down. The efficient condition varies by type of control installed. While all calculations were correct, some utilize more default assumptions than others. Users provide the size and hours of operation. VT TRM provides default values for hours-of-use for several scenarios. There is some variation in how the savings conversion factor (kWHP or its equivalent) is calculated; tables are provided in each TRM that list the savings factor according to the types of controls installed. Demand savings are calculated by dividing the energy savings by the operating hours. Some TRM's include a coincidence factor; these factors vary greatly. No secondary benefits were reported in any of the TRMs. Measure lifetimes ranging from 10-15 years.

Recommendations

The relatively small variation in air compressor energy savings methodology makes it ideal for a national database of energy-efficiency measures. Database recommendations are presented below:

- The OH TRM calculation breaks down into fundamental components, while the other approaches use tabulated values that roll up multiple factors/assumptions. From a theoretical perspective, it would be preferable to use the OH TRM calculation; from a practical perspective, a user who is not an expert will prefer a methodology with fewer degrees of freedom.
- Users may find a table of operating hours-by-use scenario useful.
- Coincidence factors will need to be developed on a regional basis.
- Definitions and protocols will need to be developed for lost opportunity, retrofit, early replacement, etc.

Air Compressor	MA TRM 2011	NY TRM 2010	OH TRM 2011	VT TRM 2010	PA TRM 2011
Region	Massachusetts	New York	Ohio	Vermont	Pennsylvania
Measure Name	High Efficiency Air Compressor	Air Compressor Upgrade	Efficient Air Compressors (Time of Sale)	Efficient Compressors 40 HP and Below	Variable Frequency Drive Improvement for Industrial Air Compressors
Units	Per compressor	Per compressor	Per compressor	Per compressor ≤ 40 HP	Per compressor
Approach Commentary	Formula with user-supplied variables and lookup tables	Formula with user-supplied variables and lookup tables	Burnout replacement basis. Formula provided with a table of energy savings factors depending on the type of control installed.	Savings calculated using representative baseline and efficient demand values for compressor capacities according to facility's load shape and hours of operation.	Formula applies to systems with single compressor servicing a single load (standard application). Systems with multiple compressors must follow a custom measurement protocol.
Calculation Approach Deviations - Energy	No deviation	No deviation	$\Delta kWh = HP \times HRS \times \frac{0.746}{N_{ee}}$	$\Delta kWh = HP \times HRS \times 0.9 \times$	$\Delta kWh = kWHP \times HP \times \frac{}{N}$
Calculation Approach Deviations - Demand	No CF	No deviation	$\Delta kW = HP \times \frac{0.746}{N_{ee}} \times ESF \times$	$\Delta kW = HP \times 0.9 \times (ACF_{ba}$	$\Delta kW = HP \times 0.106$
Annual Gross Energy Savings	ΔMWh = 23	ΔMWh = 20	ΔMWh = 21	ΔMWh = 21 (deemed, 25 HP with two shifts)	ΔMWh = 11
Annual Gross Demand Savings	CF = NA ΔkW = 5.7	CF = 0.80 ΔkW = 4.12	CF = 0.38 ΔkW = 2.05	CF = NA ΔkW = 4.16	CF = NA ΔkW = 2.65
Baseline Condition	Modulating air compressor with blow down	Modulating air compressor with blow down	Modulating air compressor with blow down	Modulating air compressor with blow down	No VFD

Air Compressor	MA TRM 2011	NY TRM 2010	OH TRM 2011	VT TRM 2010	PA TRM 2011
Efficient Condition	Oil flooded, rotary screw compressor with variable speed drive, load/no load controls, or variable displacement controls and a properly sized air receiver.	Oil flooded, rotary screw compressor with variable speed drive, load/no load controls, or variable displacement controls and a properly sized receiver. Flow controller must be used to maintain 5-10 psi pressure difference between receiver and distribution system.	Compressor with variable frequency drive, load/no load controls, or variable displacement controls.	Compressor with VSD	VFD for air compressor
Assumption 1: Annual Hours of Operation	Actual hours should be used HRS = 3,952 (Cadmus used same hours as VT TRM 2010)	Actual hours should be used HRS = 3,952 (Cadmus used same hours as VT TRM 2010)	Actual hours should be used HRS = 3,952 (Cadmus used same hours as VT TRM 2010)	HRS = 3,952 (table, two shifts)	Actual hours should be used HRS = 3,952 (Cadmus used same hours as VT TRM 2010)
Assumption 2: Energy Savings Factors	kWHP = 0.228 (table, 25 HP for Lost Opportunity VSD)	kWHP = 0.206 (table, 25 HP VSD)	ESF = 0.26 (table, VFD)	ACF_{base} = 0.890 ACF_{ee} = 0.705 (fixed)	kWHP = 0.129
TRM Specific Assumptions	100% in service rates	NA	N_{ee} = actual nameplate efficiency, if unknown assume 90%	NA	Actual values should be used; if unknown, use the following default values. RLF = 0.75 (Cadmus defined based on default motor measure values) N_{base} = 0.90 (Cadmus defined based on OH TRM)
Lifetime (years)	13 (retrofit) 15 (lost opportunity)	NA	15	10	15
Incremental Costs	NA	NA	Load/no load: $200/HP Variable displacement: $250/HP VFD: $300/HP (table)	($127 × HP) + $1,446	NA
Secondary	NA	NA	NA	NA	NA

Air Compressor	MA TRM 2011	NY TRM 2010	OH TRM 2011	VT TRM 2010	PA TRM 2011
Benefits					
References	NSTAR and National Grid (2004 and 2006), ERS (2005), RLW Analytics (2008), KEMA (2010), Demand Management Institute (2006)	NA	US DOE (2003); TRMs from VT, NH, MA, and WI; OH Senate (2009)	US DOE, vendor reports, regression of data	Aspen Systems Corporation (2005)

Air Compressor Glossary
HP = Nameplate horsepower of equipment motor
kWHP = Air compressor kW reduction per horsepower (lookup table)
HRS = Operating hours
CF = Coincidence factor
N_{ee} = Efficiency of efficient motor
ESF = Equipment energy saving factor
ACF_{base} = Baseline air compressor factor
ACF_{ee} = Efficient condition air compressor factor
0.9 = HP to full load kW conversion factor based on linear regression analysis
0.746 = Conversion factor between kW and HP

Electrically Commutated Motor – Walk-in Refrigeration Cooler

Measure Name	Electrically Commutated Motor (ECM) – walk-in refrigeration applications where relevant				
Measure Description	Refers to an efficient motor used in refrigeration applications (low and medium temperature). May apply to walk-in or display applications.				
Weather Sensitive?	No	**Sector**?	Commercial	**Primary Fuel**?	Electric
Prevailing Energy Savings Methodology	Cooler/Freezer: $\Delta kWh = \Delta kW \times HRS$				
Prevailing Demand Savings Methodology	Cooler/Freezer: $\Delta kW = (kW_{base} - kW_{ee}) \times \left(1 + \frac{3.412}{EER}\right)$				
Variables	HRS = Annual operating hours kW_{base} = Baseline equipment demand, in kW kW_{ee} = Efficient equipment demand, in kW 3.412 = Btu per watt-hour EER = Equipment energy-efficiency ratio				

Conclusion/Concerns

The comparison for this measure includes the following TRMs and measure assumptions:

- RTF 2011, DEER 2005, PA TRM 2011, AR TRM 2007, WI TRM 2010
- ECMs for walk-in cooler (medium temperature) applications.

Energy savings are typically calculated using either an algorithm or spreadsheets (RTF). DEER used evaluation data to determine savings. Out of the five sources reviewed, three contained deemed savings values, and three also contained algorithms for determining savings. The WI TRM provides both deemed savings and a supporting algorithm. The algorithm chosen for the prevailing methodology captured methodologies reviewed on the most general level. Two of the three calculation approaches (PA and WI) mentioned that the calculation includes direct savings from improved motor efficiency and indirect savings from reduced heat produced by the motor. As such, the methodology contains parameters for capturing both these effects. RTF savings are based on an ECM controller that functions by sensing the operational status of the cooling system, and controls for the speed of the evaporator fans. This measure does not directly include savings for installation of an ECM, rather for the controller of the ECM. However, the RTF does include direct fan motor savings by the controller and refrigeration system savings.

In the PA and WI TRMs, the demand savings are calculated first, and then energy savings are determined by multiplying demand savings by hours of operation. In the AR TRM, the ECMs are categorized by rated wattage, which is different from the PA and WI TRMs. Reference tables in the AR TRM contain annual energy consumption and demand per rated equipment watt, which is scaled up depending on the size of the ECM. In addition, the AR TRM applies this methodology to commercial refrigeration applications such as display cases, walk-in coolers/freezers, refrigerated vending machines, and bottle coolers, while other TRMs focus primarily on walk-in systems.

The PA TRM contains tables that list the various measure combinations, input values, and resulting demand and energy savings. Another table contains default deemed savings when the type of application is unknown (assuming a cooler uses medium temperatures vs. a freezer using low temperatures). Direct savings from this measure derive from increased motor efficiency; indirect savings derive from reduced cooling load on the unit due to less heat produced by motors. The WI TRM contains savings for each motor HP range, and calculates type from a weighted average of savings values. Reference tables and other supporting data are provided, such as hours-of-use and motor demand. Direct savings from this measure are from increased motor efficiency; indirect savings are due to a reduced cooling load on the unit due to less heat produced by the motor.

The assumptions used for this calculation are based on whether the walk-in refrigeration system is cooling or freezing. The concern is there are many possible degrees of freedom in the deemed savings value. For example, DEER contains four possible deemed values for different building vintages, while other sources provide one value. The WI TRM's deemed savings table contains six possible choices, varying by type of motor replaced, size range, and application.

Measure lifetimes were found to be 15 years. The RTF includes CO_2 reduction (tons over expected measure life) as a secondary benefit; all other TRMs do not include any secondary benefits.

Recommendations

Walk-in coolers with ECMs could be included in the national measures database. Tolerance for variations in the following need to be included:

- Savings depending on refrigeration load (low or medium temperature applications)
- Motor size and/or input wattages
- Baseline and measure equipment: shaded-pole motor or PSC motor as the baseline and ECM or ECM with controller.

Sourcing savings based on metered data for these variations is preferred.

ECM	RTF 2011	DEER 2005	PA TRM 2011	AR TRM 2007	WI TRM 2010
Region	Pacific Northwest	California	Pennsylvania	Arkansas	Wisconsin
Measure Name	Evaporator Fan ECMotor Controller on Walk-ins	High Efficiency Walk-in Fan Motors - substitute high-efficiency motors for standard efficiency	High-Efficiency Evaporator Fan Motors for Walk-in Refrigerated Cases	Electronically Commutated Motors	ECM Motors in Walk-in Coolers or Freezers
Units	Per motor controlled	Per motor	Per motor	Per motor	Per motor
Approach Commentary	Spreadsheet with deemed savings based on the weighted average of metered data for medium temp and low temp systems	Tabulated table (Access database) by region and vintage. Based on California evaluation data.	Calculation based on size of ECM, cooler or freezer type, and input wattages. Algorithms provided for coolers and freezers; default algorithm provided where case service temperature is unknown.	Calculation based on rated wattages, reference tables provided for use in cases where values are unknown.	Deemed savings based on motor HP range, baseline motor type (PSC or shaded-pole), and application type (freezer or cooler).
Calculation Approach Deviations - Energy	Deemed	Deemed	No deviation	$\Delta kWh = Watt_{rated} \times (kW$	No deviation
Calculation Approach Deviations - Demand	Deemed	Deemed	Cooler algorithm $\Delta kW = \frac{(Watt_{base} - Watt_{e}}{1,000}$	$\Delta kW = Watt_{rated} \times (kW_{ba}$	$\Delta kW = (kW_{base} - kW_{ee}) \times$
Annual Energy Savings	∆kWh = 264	∆kWh = 431 kWh (table, averaged over four different vintages)	∆kWh =1,216	∆kWh = 465	∆kWh = 1,670 (calculated 1/15 HP) ∆kWh = 2,033 (table, deemed savings weighted result for ECM replacing shaded-pole motor, from 1/20 HP to 1 HP, for a walk-in cooler)

ECM	RTF 2011	DEER 2005	PA TRM 2011	AR TRM 2007	WI TRM 2010
Annual Gross Demand Savings	ΔkW = 0.02	ΔkW = 0.06 (table, averaged over four different vintages)	ΔkW = 0.15	ΔkW = 0.05	ΔkW = 0.20 (calculated 1/15 HP) ΔkW = 0.24 (table, deemed savings weighted result for ECM replacing shaded-pole motor, from 1/20 HP to 1 HP, for a walk-in cooler)
Baseline Condition	Standard efficiency shaded-pole evaporator fan motor kW_{base} = 0.05 (fixed)	Shaded-pole motor	Input wattage of existing/baseline evaporator fan motor, if unknown reference table provided. $Watt_{base}$ = 191 (table, 1/15 HP shaded-pole motor)	Shaded-pole motor $kWh_{base,watt}$ = 18 $kW_{base,watt}$ = 0.002 (table, refrigeration application)	Shaded-pole motor kW_{base} = 0.207 (table, 1/15 HP)
Efficient Condition	ECM motor and controller kW_{ee} = 0.03 (fixed)	EC motor	Input wattage of new energy-efficient evaporator fan motor, if unknown reference table provided. $Watt_{ee}$ = 75 (table, 1/15 HP EC motor)	ECM up to 1 HP in size $kWh_{ee,watt}$ = 8.7 $kW_{ee,watt}$ = 0.001 (table, refrigeration application)	ECM motor kW_{ee} = 0.065 (table, 1/15 HP)
Assumption 1: Hours-of-use	HRS = 8,760 (fixed)	NA	HRS = 8,273 (fixed)	NA	HRS = 8,395 (fixed)
Assumption 2: System Efficiency	NA	NA	COP_{cooler} = 2.5 (fixed)	NA	EER = 8.5 (fixed, cooler) EER = 4.4 (fixed, freezer)
TRM Specific Assumptions	Type: Walk-In - Medium Temp: 1/10-1/20 HP; 1 motor per controller (from list)	Climate zone: Mt. Shasta Building type: Grocery (from list)	DC_{evap} = 100% (fixed) DG = 0.98 (fixed) RLF = 0.9 (fixed)	$Watt_{rated}$ = 50 (Cadmus converted from 1/15 HP)	NA
Lifetime (years)	15 years	15 years	15 years	15 years	NA
Incremental Costs	$110	$6.79	NA	NA	NA

ECM	RTF 2011	DEER 2005	PA TRM 2011	AR TRM 2007	WI TRM 2010
Secondary Benefits	0.1 CO_2 reduction (tons over expected measure life)	NA	NA	NA	NA
References	EPM2 (2009), PECI (2010), National Resource Management Energy North Meter Study	Based on California evaluation data	ActOnEnergy Business Program - Year 2, TRM (2009), Efficiency Maine (2007), PECI presentation to Regional Technical Forum (2009), AO Smith (2010)	Ecotope (2003), PG&E (2003), Stellar Processes (2006), CEE, NPCC (2005), kW engineering (2005)	EPRI (1994), Arthur D Little (1996)

ECM Glossary
RFL = Rated load factor of motor
$Watt_{base}$ = Baseline wattage
$Watt_{ee}$ = Efficient condition wattage
1,000 = W per kW
COP_{cooler} = Coefficient of performance of compressor in cooler
DG = Degradation factor of compressor COP
DC_{evap} = Duty cycle of evaporator fan motor
$Watt_{rated}$ = Rated motor wattage
$kWh_{base,watt}$ = Annual energy consumption in kWh, per rated watt of baseline equipment
$kWh_{ee,watt}$ = Annual energy consumption in kWh, per rated watt of energy-efficient equipment
$kW_{base,watt}$ = kW demand, per rated watt of baseline equipment
$kW_{ee,watt}$ = kW demand, per rated watt of energy-efficient equipment
kW_{base} = Baseline equipment demand, in kW
kW_{ee} = Efficient equipment demand, in kW
EER = Equipment energy-efficiency ratio
3.412 = Btu per watt-hour

Appendix C. Sources Reviewed for EM&V Plans, Reports, and Market Studies

State	Organization Type	Organization Name	Web Location	EM&V Plans	EM&V Reports	Market Studies	Other Database Features
National	PUC	EE Best Practices	http://www.eebestpractices.com/find.asp	No	No	No	Reports for best practices studies and program profiles.
	Nonprofit	CEE	http://www.cee1.org/search/search.php	No	Yes	Yes	Includes conference proceedings and large numbers of EM&V and other report types.
	Nonprofit	ACEEE	http://www.aceee.org/about	No	No	No	Contains papers on EMV practices and general topics, also contains potential studies
Regional NE	Nonprofit	NEEP	http://neep.org/uploads/EMV%20Forum/EMV%20Studies/Repository%20of%20State%20&%20Topical%20EM&V%20Studies%20-%20CURRENT%20-%2012-1-10.xls	No	Yes	Yes	Repository of studies for NEEP states, also contains info for each state regarding status of EMV and legislation, links to TRM's, and includes a topical database on load shape studies.
Regional PNW	Nonprofit	NEEA	http://neea.org/research/index.aspx	No	Yes	Yes	Repository of reports for NEEA utilities.
Regional MidWest	Nonprofit	MEEA	http://www.mwalliance.org/resources/meea-publications/archive/programs	No	No	Yes	Case study and best practice database.
Regional SE	Nonprofit	SEEA	http://www.seealliance.org/programs/research.php	No	No	No	Contains best practices and other studies.
Regional SW	Nonprofit/Public Interest	SWEEP	http://www.swenergy.org/publications/index.html	No	No	No	Website includes links to SWEEP-published reports and presentations on Regional and State Policy, Building Efficiency, Utilities, but is not a database.
Regional	Public Organization/ Power Producer	Bonneville Power Administration	http://www.bpa.gov/Energy/N/reports/evaluation/index.cfm	No	Yes	Yes	Appears to be a complete repository, although some reports are not posted on site and are only listed by title.

State	Organization Type	Organization Name	Web Location	EM&V Plans	EM&V Reports	Market Studies	Other Database Features
Arizona	Commission	Arizona Corporation Commission (See SWEEP for more info)	http://www.azcc.gov/	No	No	No	
California	Utility	SCE	http://www.sce.com/AboutSCE/Regulatory/eefilings/proposals/default.htm	No	No	No	
	Public University	University of California, California Institute for Energy and Environment	http://uc-ciee.org/pubs/ref_market.html	No	Yes	Yes	Also research papers.
	PUC	CPUC ED	http://www.energydataweb.com/cpuc/default.aspx	Yes	Yes	Yes	
	PUC	CALMAC	http://www.calmac.org/	No	Yes	Yes	
Colorado	PUC	Colorado PUC	http://www.dora.state.co.us/puc/	No	No	No	References at least one DSM Annual Report, but unable to find anything other than proceedings page.
Connecticut	State Utility Partnership	Connecticut Energy Efficiency Fund (CEEF)	http://www.ctsavesenergy.org/ecmb/documents.php?section=22	No	Yes	Yes	Committee and Board agendas and minutes, other documents, presentations, potential studies.
Delaware	3rd Party Administrator	Sustainable Energy Utility	http://www.seu-de.org/	No	No	No	
Florida	PUC	FL PSC	http://www.floridapsc.com/publications/pdf/electricgas/FEECA2010.pdf	No	No	No	
Hawaii	3rd Party Administrator	Hawaii Energy	http://www.hawaiienergy.com/	No	No	No	Began admin of energy efficiency programs after July 2009, in process of having evaluation done, but too new to have evaluation reports posted.
Indiana	Regulatory Commission	Indiana Utility Regulatory Commission	https://myweb.in.gov/IURC/eds/Guest.aspx?tabid=28&dn=SEARCHDOCKETEDCASE	No	No	No	Docketed cases only, not able to locate actual reports.

State	Organization Type	Organization Name	Web Location	EM&V Plans	EM&V Reports	Market Studies	Other Database Features
Iowa	Regulatory Board	Iowa Utilities Board (Utility association doesn't post documents)	http://www.state.ia.us/government/com/util/index.html	No	No	No	Regulatory plans available.
Maine	Program Administrator	Efficiency Maine	http://www.efficiencymaine.com/documents-services/evaluations	No	Yes	Yes	RFPs on site. Market studies include baseline study and CFL report.
Maryland	Government	Maryland Energy Administration	http://energy.maryland.gov/home.html	No	No	No	Devoted Web page to Reports and Documents, but limited resources posted. Strategic Energy Plan available.
Massachusetts	Nonprofit	NEEP(see regional listing above for details)	http://neep.org/emv-forum/emv-library/research-evaluation-studies	No	Yes	No	Includes a few documents with information on evaluation methodologies, review of energy efficiency plans and reports.
	Public Utility Commission	DPU	http://www.ma-eeac.org/	No	No	No	Includes efficiency reports as well.
Missouri	Nonprofit	Missouri Public Utility Alliance	http://www.mpua.org/	No	No	No	
	Utility	Ameren	http://www.ameren.com/sites/aue/Pages/home.aspx	No	Yes	Yes	You have to have a log in to access a repository of the EM&V reports or market studies. You can, however, access them by using the search feature and using the term "evaluation" or "study." Website includes an integrated resource plan.
Nevada	Public Utility Commission	PUCN	http://pucweb1.state.nv.us/pucn/PUCHome.aspx	No	No	No	Includes some efficiency goals in a strategic plan, but has no separate plan.
New York	Nonprofit	NYSERDA	http://www.nyserda.org/Energy_Information/evaluation.asp	No	Yes	Yes	

State	Organization Type	Organization Name	Web Location	EM&V Plans	EM&V Reports	Market Studies	Other Database Features
	State Department	New York Department of Public Service	http://documents.dps.state.ny.us/public/Common/SearchResults.aspx?MC=0&DFF=2/1/2011&CI=0	Yes	Yes	Yes	
Oregon	3rd Party Administrator	Energy Trust of Oregon	http://energytrust.org/About/policy-and-reports/Reports.aspx	No	Yes	Yes	Dropdown lists for "Report type" (impact, process, market, etc.) and "Program" allow filtering.
Pennsylvania	PUC	PUC	http://www.puc.state.pa.us/electric/Act_129_info.aspx	No	No	No	PUC will evaluate the energy efficiency programs as per Act 129, and they sought a statewide evaluator, GDS, which has a contract through Oct 2011.
Texas	Other	Electric Utility Marketing Managers of Texas	http://www.texasefficiency.com/layout/inside.php?pgID=42&sn=Reports	No	Yes	Yes	Very small list of four reports done for the Texas PUC.
Texas	PUC	Texas PUC	http://www.puc.state.tx.us/electric/reports/index.cfm	No	Yes	Yes	
Vermont	3rd Party Administrator	Efficiency Vermont	http://www.efficiencyvermont.com/pages/Common/AboutUs/AnnualReport/	No	No	No	Includes: oversight table listing verifications, evaluation, audit requirements, who performs it and frequency.
	PUC	Vermont DPS	http://publicservice.vermont.gov/energy/ee_perfomanceevaluation.html	No	No	No	
Washington	Utility	Seattle City Light	http://www.seattle.gov/light/Conserve/cv5_pub.htm	No	Yes	Yes	List of links with embedded reports, listed chronologically.
	Commission	Washington Utilities and Transportation Commission	http://www.wutc.wa.gov/home	No	No	No	
Wisconsin	Utility Organization	Focus on Energy for Wisconsin Utilities	http://www.focusonenergy.com/Evaluation-Reports/default.aspx	No	Yes	Yes	List of links with embedded reports.