Behind the Curtain: Characterization of Measure Technologies within Technical Reference Manuals

Zack Tamble, Mark Brown, Ben Parnell and Steve Lynch, QuadROI
Rachel Buckley and Adam Maxwell, E Source

ABSTRACT

Our ratepayer-funded demand-side management (DSM) industry is comprised of energy efficiency and load management programs that serve to accelerate the adoption and installation of energy efficient technologies, often referred to as measures, or energy conservation measures (ECMs). These distinct technologies range from simple materials and devices (e.g., pipe insulation, showerheads, etc.) to more complex system interventions and automation (e.g., demand controlled ventilation, occupancy sensors, etc.). In order to standardize the calculation of energy savings associated with the various technology types, more than two dozen jurisdictions in the U.S. and Canada have established references, often in the form of a technical reference manual, or TRM. These references, based upon a foundation of empirical evidence, research and evaluation studies, serve to inform program administrators, practitioners and regulators about the agreed upon calculation methods, inputs and assumptions relevant to specific technology types in specific end use contexts.

By aggregating data about the types of technologies, calculation methods, and values documented in each jurisdiction's TRM or data repository, insights can be gained about the uniformity and variation of the scope of technologies and associated values across these references. Examining details on the technology types contained in 19 discrete reference manuals and repository across the U.S. and Canada shows that far more of the distinct technologies detailed in the TRMs are found to only be included in a minority of TRMs than are common to a majority. In other words, there is more difference in the TRMs in terms of technology coverage than there is similarity.

Introduction

Technical Reference Manuals are used by a variety of stakeholders including Utilities, Service Providers, and Regulators. The stakeholders tend to rely heavily on the TRM which addresses their jurisdictions. However, not every state or region has a TRM. Even when a state or region has a TRM, but especially when they do not, stakeholders will look to neighboring jurisdictions to gather information on technologies from other TRMs. This type of research and comparison has many benefits, including: identification of new measures which could be incorporated into other TRMs, understanding what is a reasonable range of inputs and assumptions, accessing work papers that may support improved inputs and assumptions. There are 24 states that have at least one type of TRM within the United States energy efficiency industry. Many of these are statewide or regional documents, while others are utility-specific documents and only apply to a service territory. Each TRM is comprised of assumptions on performance and interaction of technologies, and those assumptions are the basis for the energy savings behind our energy efficiency programs. Value types such as annual operating hours, effective useful life, and coincidence factors are a few of the most common assumptions we see across all the TRMs. Other factors such as building type, location, climate zone, equipment interaction, and fuel type also contribute to the energy savings associated with technologies. The assumptions within TRMs come from many sources, most commonly from academic work papers and evaluation studies, which often are filled with complex issues and contain many of their own judgment calls. Once the assumptions make their way from work paper to TRM, they are often borrowed for use in other TRMs, beginning a cycle of references. The circular reference instance causes practitioners to question the validity of the assumptions behind the technologies contained within TRMs. Perhaps further analysis with respect to citing work papers could lead to a study which identifies the technologies within TRMs that cite the same work papers or other TRMs which cite the same work papers.

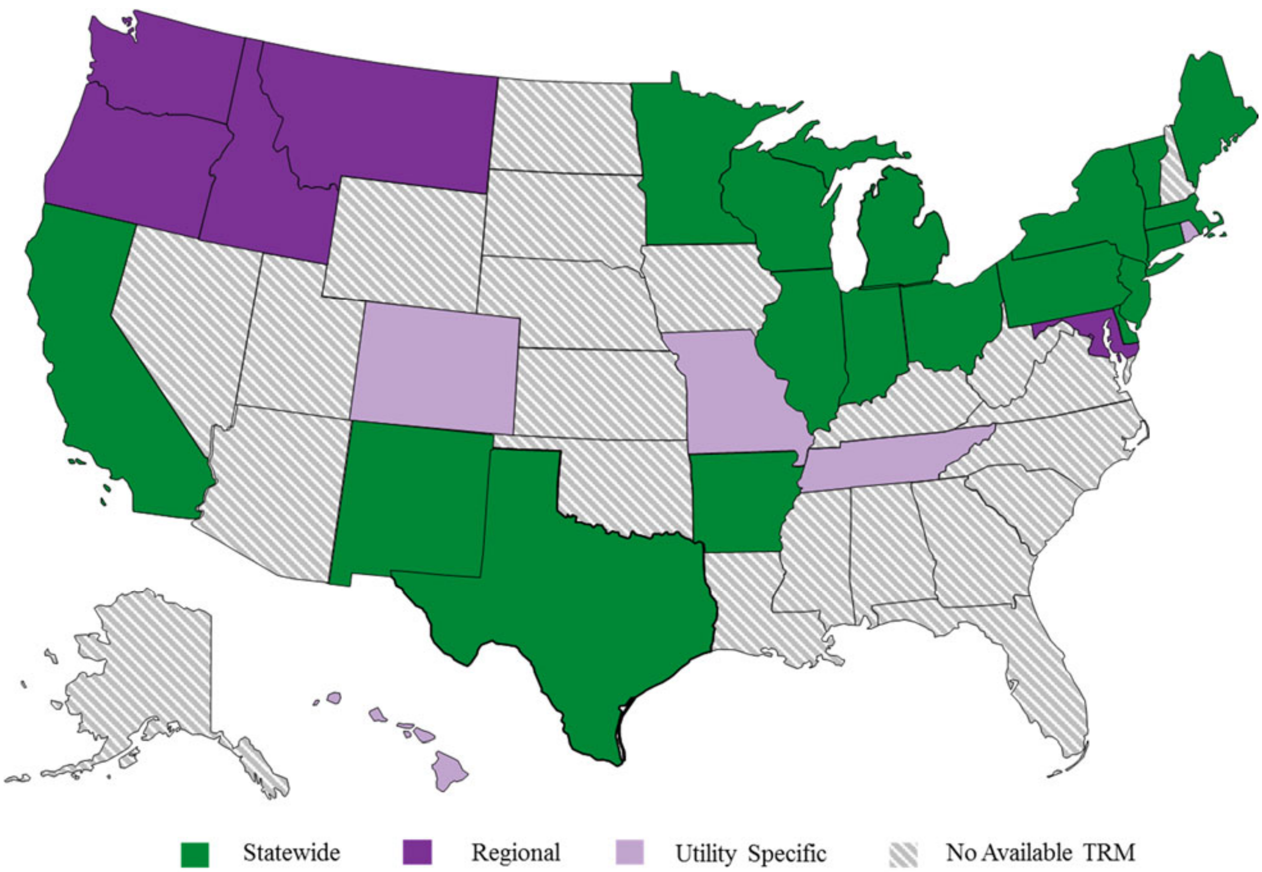

Figure 1. Technical Reference Manuals by State. *Source*: E Source Measure Insights.

Technical Reference Manuals

Most TRMs are statewide documents, covering many utility service territories. There are 18 statewide documents, meaning they detail measures that can be installed anywhere in the state, and there will be a method for calculating savings. In Texas and Maine, there are several TRMs, segmented by market or customer sector. Five TRMs are utility-specific, which means the document only applies to one utility service territory. Utilities with their own TRM include Xcel Energy in Colorado, National Grid in Rhode Island, Hawaii Energy in Hawaii, Tennessee

Valley Authority in Tennessee and the surrounding states, and Ameren in Missouri. Even though utility specific TRMs are unique to certain geographies, other states or utilities with similar climate zones may end up using some of the measure assumptions in their own planning. 26 States do not have a dedicated TRM but many of those states do implement measures within energy efficiency programs and rely on other TRMs for assumptions to include in their program plans. Regional TRMs cover many utility service territories across multiple states with like climate zones. There are two regional TRMs that are used across many states, one covers the Northwest and the other covers the Mid-Atlantic region. In the Northwest, the Regional Technical Forum (RTF) consists of a group of experts who work together to maintain a set of measure assessment workbooks. Each workbook is comparable to the measure assessment sections within other TRMs. The measure assessment workbooks are specific to the climate, building stock, demographics, and markets of Washington, Oregon, Idaho, and Montana. Taken collectively, the measure assessment workbooks, serve as a unique version of a TRM. The other regional TRM is the Mid-Atlantic TRM which applies to Maryland, Delaware, and the District of Columbia. Delaware created their own TRM in 2012 which relies heavily and expands on the technologies within the Mid-Atlantic TRM.

A major benefit of having a statewide TRM is that multiple stakeholders can look to one centralized document or set of documentation rather than having to create and maintain their own. This enables multiple parties to work collectively rather than creating their own documents. TRMs help utilities prioritize measures for inclusion in their programs. Not all utilities in each state have the same service territory or customer segment, so there tends to be variation in energy savings inputs depending on local attributes such as climate zone and building location. Within Maine and Texas, there are multiple TRMs that differ depending on the customer segment utilizing each specific measure. An added benefit to using a statewide TRM is the inclusion of climate zone assumptions which tailor program savings estimates to participants living across a given utility service territory.

The greatest benefit of a utility specific TRM is that the measure technologies and assumptions can be updated at any time and plugged directly into program planning documents. Utility-specific TRMs tend to consist of more measure technologies because a utility may have the same measure technology listed many times but the market sector or other measure attribute can vary. For example, in the Ameren Missouri TRM there are three CFL lighting measures and each have a unique ID. The difference between each CFL lighting measure is the market sector. Ameren considers each identical CFL lighting technology as a unique measure because it may be installed in a low income, multifamily, or single family residential building. Similarly, this situation may occur when technology parameters vary. For example, the same CFL lamp may exist as three separate measures, each with its own rated wattage. This can be confusing if other utilities are looking to use the Ameren TRM but it’s a major benefit to Ameren Missouri because they can simply use the measure code to plug into program planning documents to arrive at savings estimates. Utility specific TRMs tend to be less common, possibly because the effort required to create a TRM is too burdensome for one party and more manageable if split between many companies.

TRM (Statewide, Utility, Regional)	Jurisdiction	Format (Type and length)	Update Frequency (Annual, Cycle)
Arkansas – Statewide	Arkansas	PDF – 831 Pages	Updated Annually
California – Statewide	California	Database (DEER)	Updated Each Program Cycle
California – Public	Municipal Utilities	PDF – 136 Pages	Updated Annually
Colorado – Utility	Xcel Energy Service Territory	PDF (printed workbook) – 151 Pages	Updated Each Program Cycle
Connecticut – Statewide	Connecticut	PDF – 332 Pages	Updated Annually
Delaware – Statewide	Delaware	PDF – 430 Pages	Updated Infrequently
Hawaii – Utility	Hawaii	PDF – 224 Pages	Updated Annually
Illinois – Statewide	Illinois	PDF – 801 Pages	Updated Annually
Indiana – Statewide	Indiana	PDF – 405 Pages	Updated Infrequently
Maine – Statewide	Maine	PDF – 335 Pages	Updated Annually
Massachusetts – Statewide	Massachusetts	PDF – 436 Pages	Updated Each Program Cycle
Michigan – Statewide	Michigan	Database – Spreadsheets	Updated Annually
Mid-Atlantic – Regional	Maryland, Delaware, Washington DC	PDF – 463 Pages	Updated Annually
Minnesota – Statewide	Minnesota	PDF – 408 Pages	Updated Annually
Missouri – Utility	Ameren Missouri Service Territory	Database (iTRL)	Updated as Needed
New Jersey – Statewide	New Jersey	PDF – 133 Pages	Updated Annually
New Mexico – Statewide	New Mexico	PDF – Not Publicly Available	Uncertain Update Cycle
New York – Statewide	New York	PDF – 516 Pages	Updated Annually
Ohio – Statewide	Ohio	PDF – 397 Pages	Updated Infrequently
Pennsylvania – Statewide	Pennsylvania	PDF – 575 Pages	Updated Annually
Regional Technical Forum – Regional	Washington, Oregon, Idaho, Montana	Measure Assessment Workbooks	Updated as Needed
Rhode Island – Utility	National Grid Service Territory	PDF (printed workbook) – 781 Pages	Updated Annually
Tennessee – Utility	Tennessee Valley Authority (TVA) Service Territory	PDF – 414 Pages	Updated Annually
Texas – Statewide	Texas	PDF – 603 Pages	Updated Annually
Vermont – Statewide	Vermont	PDF – 572 Pages	Updated Annually
Wisconsin – Statewide	Wisconsin	PDF – 765 Pages	Updated Annually

Figure 2. Types of Publicly Available Technical Reference Manuals. *Source*: E Source Measure Insights.

Figure 2 shows the format and applicability of all identified TRMs in the United States. The vast majority of TRMs are updated on an annual basis or with each new program cycle, whether that is annual, biennial, or triennial.

Regional TRMs are highly favorable documents because with so many utilities using them, there is a high level of scrutiny behind the assumptions which define each measure. In addition to utilities, there are several other stakeholders that view, analyze, and rely on Regional TRMs. The Regional Technical Forum consists of 118 measure assessment workbooks and webpages, 76 of which are active. Rather than updating the entire collection of measure assessment workbooks annually, like many other TRMs' update cycles, the webpages and workbooks are updated independently of one another. As new technologies are introduced and innovative program delivery types are discovered, the measure assessment webpages and workbooks are added, removed, or updated. The transparency, reliability, and timeliness of the RTF measure assessment workbook documentation are perhaps the most beneficial aspects of a regional TRM.

California's DEER database is updated for each new program cycle with results from the previous cycle. Thousands of input values are provided based on dozens of separate studies and workpapers. Compounded by the state's size and diversity, especially with regard to its 16 different building climate zones, the input values taken together with the various permutations of facility-specific and measure-specific attribute combinations result in hundreds of thousands, if not millions, of distinct output values such as the kWh savings that can be claimed for a particular measure installation in a particular facility type in a particular zone. Since California is moving to a rolling portfolio cycle, it is unclear what the new update process will be moving forward. The state also has a municipal TRM, used by many of the utilities within the California Municipal Utilities Association (CMUA).

Delaware last published their TRM in 2012. This was originally meant to expand upon the Mid-Atlantic TRM, which includes Delaware. The state has not published a new TRM – possibly because the Mid-Atlantic TRM has grown in sophistication since then and may be considered adequate now. The Michigan Energy Measures Database (MEMD) is a workbook with market sector specific measures listed in each tab.

The Ameren Missouri TRM is a utility-specific online database accessible only by Ameren and interested parties at the Missouri Public Service Commission. It was developed using the iTRL software in partnership with Nexant. This database platform offers many benefits to Ameren, such as updating the measure assumptions anytime and plugging the assumptions from the TRM directly into program planning documents.

The most recent Ohio TRM, published August 2010, is currently a draft TRM. It is unclear if any utilities are actually using or referencing the document, due to the state's new regulatory environment. Indiana has a new TRM, published July 2015, but it is uncertain whether or not any utilities are actually using it given the regulatory dismantling of the Indiana EE portfolios.

Differences by State

A close investigation of 20 TRMs active in different jurisdictions across the U.S. and Canada shows that there is a fair degree of variation in terms of the scope and detail of defined technology measures. The large majority of distinct technology types detailed across the various TRMs are found to be common to only one jurisdiction or a minority of jurisdictions. Only a small minority of distinct technology types appear in more than half of the TRMs.. In other words, there is more difference in the TRMs in terms of technology coverage than there is similarity. Energy efficiency program stakeholders will find that by looking outside of their own jurisdictions at what technologies are being documented for savings estimation methods, there are no shortage of potentially applicable technologies.

For the purpose of this investigation, the team queried data from the E Source *Measure Insights* database that associates individual numerical values documented in a TRM with a corresponding distinct "technology type" that is part of a standardized hierarchical taxonomy. Of the 19 available TRMs and reference repositories indexed in the database at the time of query execution - including two regional references (the Regional Technical Forum repository maintained by Northwest Power & Conservation Council, and the Mid-Atlantic TRM), two utility-specific references (for Xcel in Colorado and the Tennessee Valley Authority), and seventeen state or provincial (Ontario) TRMs – a total of 233 distinct technology types were found to be characterized.

The number of distinct technology types detailed in each jurisdiction range from a low of 40 covered by the Northwest Power & Conservation Council's Regional Technical Forum measure repository to a high of 101 of the distinct technology types documented in the Illinois TRM. It is important to note that for the purposes of this analysis, non-specialty lighting lamps and fixtures (LED, CFL, linear fluorescent, etc.) are grouped as a single technology type and left for future detailed investigation in a separate study. The focus is rather on the diversity of technologies beyond lighting that the various jurisdictions are finding value in including in their reference manuals and repositories in order for program administrators to have a reliable and accepted means to quantify energy-savings impacts.

Of the 233 identified technologies outside of the general commercial lighting category, 65 are found to be unique to a single reference manual or repository. An additional 78 technology types are included in four or fewer of the 19 reference manuals and repositories reviewed, meaning that the majority of distinct technology types are not included in the large majority of jurisdiction references.

Figure 3 details the identified technology types, sorted by ascending number of jurisdictions that contain values related to the specific technology type.

KEY: ☐ Included in TRM or repository ■ Not included in TRM or repository

State/Province/Region

Technology Type	AR	CA	CO	CT	HI	IL	ME	MA	MID-A	MN	NY	ON	PA	NW-RTF	RI	TVA	TX	VT	WI		
Count of Distinct Technology Types	60	48	66	50	46	99	56	73	55	56	61	38	82	38	80	66	41	53	64	N =	% TRMs
Building Envelope																					
Floor Insulation						■														1	5%
Low-Income Weatherization			■																	1	5%
Manufactured Homes																■				1	5%
Roof Insulation						■														1	5%
Roofs																	■			1	5%
Weatherstripping												■								1	5%
Window - Glazing											■									1	5%
Window Awnings	■																			1	5%
Air Leakage	■														■					2	11%
Radiant Barriers	■			■																2	11%
Solar Screen		■															■			2	11%
Passive Mechanical Attic Ventilation		■			■							■								3	16%
Building Envelope			■										■		■			■		4	21%
Envelope Components				■				■						■				■		4	21%
Cool Roof	■			■	■						■					■				5	26%
Window Film	■	■			■						■					■				5	26%
Windows	■		■	■					■		■		■			■	■			8	42%
Sealing Strategies	■	■	■	■		■	■	■	■		■		■			■			■	12	63%
Insulation	■	■	■	■		■	■	■	■	■	■		■	■	■	■	■		■	16	84%
Pipe Insulation	■	■	■	■		■	■	■	■	■	■	■	■		■	■	■	■	■	17	89%
C&I Equipment																					
Air Compressor - Controls			■																	1	5%
Automatic Milker Takeoff													■							1	5%
Compressed Air Controller																			■	1	5%
Grain Dryer																			■	1	5%
High Speed Fan						■														1	5%
Infrared Charbroiler						■														1	5%
Infrared Salamander Broiler						■														1	5%
Infrared Upright Broiler						■														1	5%
Irrigation System													■							1	5%
Oven - Double						■														1	5%
Oven - Rotisserie						■														1	5%
Oven and Range										■										1	5%
Pasta Cooker						■														1	5%
Process Boiler						■														1	5%
Stack Economizer for Process Boilers						■														1	5%
Vacuum Pump																		■		1	5%
Centrifugal Pump					■						■									2	11%
Cycling Air Dryer			■															■		2	11%
Ozone Laundry		■				■														2	11%
Plate Cooler							■											■		2	11%
Screw Compressor								■							■					2	11%
Scroll Compressor							■						■							2	11%
Servers & IT			■										■							2	11%
Compressed Air Receiver							■						■					■		3	16%
Oven-Conveyor	■									■					■					3	16%
Oven-Rack	■									■					■					3	16%
Engine Block Timer for Agricultural Equipment						■					■					■		■		4	21%
Low Pressure Drop Filter						■	■	■							■				■	5	26%
Air Nozzle						■	■				■		■					■	■	6	32%
Circulator Pump				■			■	■			■							■	■	6	32%
Compressed Air Dryer - Refrigerated							■	■			■		■		■				■	6	32%
Air Compressor			■			■	■			■	■				■	■		■	■	9	47%
Food Service - Electric Holding Cabinet		■			■	■		■	■	■				■		■	■			9	47%
General Purpose Motor	■		■		■					■	■	■	■	■	■					9	47%
Griddle	■	■			■	■		■	■	■					■	■				9	47%
Steam Trap	■	■	■	■		■		■		■					■				■	9	47%
Zero-Loss Condensate Drain			■			■		■		■	■		■		■			■	■	9	47%
Fryer	■	■			■	■		■	■	■				■	■	■	■			11	58%
Ice Machine	■	■			■	■	■	■				■	■			■		■	■	11	58%
Oven-Combo	■	■			■	■			■	■				■	■	■	■		■	11	58%
Oven-Convection	■	■			■	■		■	■	■				■	■	■			■	11	58%
Steamer	■	■			■	■		■	■	■			■	■	■	■	■			12	63%

Technology Type	AR	CA	CO	CT	HI	IL	ME	MA	MID-A	MN	NY	ON	PA	NW-RTF	RI	TVA	TX	VT	WI	N =	% TRMs
HVAC & Refrigeration																					
Boiler Turbulators							■													1	5%
Centrifugal Water Chiller			■																	1	5%
Cooling Tower Fan - General Purpose Motor											■									1	5%
Direct Vent Furnace	■																			1	5%
Electric Furnace												■								1	5%
Fireplace										■										1	5%
Furnace Whistle													■							1	5%
Groundwater Source Heat Pump															■					1	5%
Heating - Fuel Switching													■							1	5%
Hydronic Heating System	■																			1	5%
Mist Eliminator Filter			■																	1	5%
Non-refrigerative Cooling											■									1	5%
Package Terminal AC			■																	1	5%
Refrigeration - Line Insulation													■							1	5%
Refrigeration - Tune Up			■																	1	5%
Refrigeration - Walk-in Cooler			■																	1	5%
Residential Evaporative Cooler			■																	1	5%
Room Air Conditioner Recycling						■														1	5%
Room Air Conditioner Retirement													■							1	5%
Variable Refrigerant Heat Pump							■													1	5%
Wood Pellet Boiler							■													1	5%
Wood Stove							■													1	5%
Bathroom Exhaust Fan						■			■											2	11%
Heat Exchanger			■																■	2	11%
HVAC - Correct Sizing											■				■					2	11%
HVAC Exhaust Fan - General Purpose Motor												■						■		2	11%
Notched/Synchronous Belts for HVAC Systems						■						■								2	11%
Occupancy-Based HVAC Controls	■														■					2	11%
Oxygen Trim Controls for Space Heating Boilers						■	■													2	11%
Programmable Thermostat Adjustments			■			■														2	11%
Pump Optimization						■											■			2	11%
Refrigerant Charge Correction											■		■							2	11%
Refrigerated Vending Machine						■									■					2	11%
Refrigeration Economizers						■												■		2	11%
Shut Off Damper for Space Heating Boilers or Furnaces	■					■														2	11%
Stack Economizer for Boilers						■	■													2	11%
Water Source Heat Pump			■												■					2	11%
Condensing Unit Heaters						■		■							■					3	16%
Energy Recover Ventilator						■		■		■										3	16%
Furnace Blower Motor						■		■	■											3	16%
Gas Hot Water Boiler	■		■			■														3	16%
High Turndown Burner for Space Heating Boilers	■		■			■														3	16%
HVAC Ventilation Fan - General Purpose Motor											■		■					■		3	16%
Refrigeration - Automatic Door Closer						■							■			■				3	16%
Refrigeration - Low/No Heat Doors			■										■			■				3	16%
Refrigerative Cooling			■								■						■			3	16%
Refrigerator Recycling			■								■				■					3	16%
HVAC - Correct Refrigerant Charge											■				■	■			■	4	21%
Refrigeration - Compressor							■					■	■					■		4	21%
Refrigeration - Door Gasket	■												■	■		■				4	21%
Refrigeration - Floating Head Pressure Controls			■				■							■		■				4	21%
Refrigeration - Vertical (multi-deck) Display Fixture		■		■									■						■	4	21%
Refrigeration - Zero Energy Doors	■						■										■	■		4	21%
Whole House Fan		■			■								■			■				4	21%
Air Purifier						■	■	■	■						■					5	26%
Energy Management System (EMS)			■			■		■							■	■				5	26%
Heat Recovery										■			■		■			■	■	5	26%
High Volume Low Speed Fan						■	■			■		■	■							5	26%
HVAC Variable Speed Fan Motor					■	■	■						■			■				5	26%

Technology Type	AR	CA	CO	CT	HI	IL	ME	MA	MID-A	MN	NY	ON	PA	NW-RTF	RI	TVA	TX	VT	WI	N =	% TRMs
Infrared Heater				■		■		■		■					■					5	26%
Outdoor Reset Control for Hydronic Boiler			■	■				■			■							■	■	6	32%
Boiler Controls for Space Heating	■					■	■	■	■	■		■			■					8	42%
Heating Plants		■		■			■	■		■	■				■			■		8	42%
Refrigeration - Strip Curtains	■	■				■							■	■		■	■		■	8	42%
Refrigerator/Freezer	■							■	■	■	■		■	■		■				8	42%
Air Source Heat Pump					■	■	■	■	■		■			■	■				■	9	47%
Ceiling Fan		■			■	■			■	■		■	■				■	■		9	47%
Ductless Heat Pump				■		■	■	■	■				■	■	■	■				9	47%
HVAC Controls & Strategies			■	■		■		■			■	■		■		■			■	9	47%
Package Terminal Heat Pump	■	■		■		■	■				■		■			■		■		9	47%
Space Heating Boiler			■	■		■		■	■	■	■				■				■	9	47%
Air Economizer				■				■	■	■	■		■		■	■		■	■	10	53%
Central Air Conditioning	■			■	■			■	■	■	■	■			■			■		10	53%
Demand Controlled Ventilation	■	■	■		■	■	■	■		■					■				■	10	53%
Gas Furnace	■		■	■		■		■	■		■	■			■				■	10	53%
HVAC Tune Up	■		■	■		■		■	■	■	■				■				■	10	53%
HVAC Variable Speed Drives		■	■	■		■	■		■	■				■			■		■	10	53%
Refrigeration - Reach-In Storage		■	■		■	■	■				■					■	■	■	■	10	53%
Duct Insulation & Sealing	■			■		■		■	■		■		■	■	■	■	■			11	58%
Evaporator Fan Control	■		■	■		■		■						■	■	■	■	■	■	11	58%
Ground Source Heat Pump	■		■	■		■	■		■		■			■	■	■			■	11	58%
Refrigerator and Freezer Recycling		■	■			■		■		■	■		■		■	■	■		■	11	58%
Room AC		■		■	■		■	■	■	■		■	■			■		■		11	58%
Variable-frequency Drives			■		■		■	■			■	■	■		■	■		■	■	11	58%
Heat Pumps	■	■		■		■	■	■		■			■		■	■	■	■		12	63%
Refrigeration - Display Case Night Cover	■		■	■	■	■		■	■				■		■	■	■	■		12	63%
Chillers	■		■	■	■	■		■	■	■	■		■		■		■		■	13	68%
Freezer				■		■	■	■	■		■	■	■	■	■	■		■	■	13	68%
Vending Machine Controller	■	■		■	■	■		■		■	■	■	■		■	■	■			13	68%
Programmable Thermostat	■		■	■		■	■	■	■	■	■	■	■	■	■				■	14	74%
Refrigerated Case Fan Motor		■		■	■		■	■		■	■	■	■	■	■		■	■	■	14	74%
Refrigeration - Controls	■	■	■	■			■	■	■	■			■	■	■	■	■	■		14	74%
Refrigeration - Lighting		■	■	■	■			■	■	■	■	■	■	■	■	■			■	14	74%
Air Conditioners	■	■	■		■	■	■	■	■		■	■	■		■	■	■		■	15	79%
Blower Fan With Electronically Commutated Motor (ECM)	■	■	■	■	■	■		■		■	■	■	■		■	■		■	■	15	79%
Refrigerator	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	19	100%
Lighting																					
Daylighting - Controls																			■	1	5%
Integral CFL (screw-in)																	■			1	5%
Light Sensor																■				1	5%
Specialty CFL																	■			1	5%
Night Light													■			■				2	11%
Sensing & Switching					■												■			2	11%
Light String		■								■			■							3	16%
Signage Lighting													■			■			■	3	16%
Dimming					■				■			■			■					4	21%
Fluorescent Delamping		■			■	■			■							■			■	6	32%
LED Traffic Light						■				■			■	■	■	■				6	32%
Occupancy Sensor			■		■			■	■			■	■		■	■			■	9	47%
Lighting Controls	■						■	■		■	■	■	■				■	■	■	10	53%
Linear Fluorescent	■		■		■	■			■	■				■	■	■			■	10	53%
LED Exit Sign		■	■		■	■	■		■	■			■		■	■			■	11	58%
Lighting - Lamps and Fixtures	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	19	100%

Technology Type	AR	CA	CO	CT	HI	IL	ME	MA	MID-A	MN	NY	ON	PA	NW-RTF	RI	TVA	TX	VT	WI	N =	% TRMs
Plug Loads																					
Battery Charger																●				1	5%
Computer Software						●														1	5%
Digital Video Recorder					●															1	5%
Non-Refrigerated Vending Machine															●					1	5%
Office Equipment													●							1	5%
Computer Monitor															●			●		2	11%
Desktop Computer			●												●					2	11%
Fuel Switching - Clothes Dryer													●					●		2	11%
Occupancy Sensor Plug Strip	●	●																		2	11%
Plug-load Controls												●		●						2	11%
Water Cooler					●								●							2	11%
Appliance Recycling								●			●				●					3	16%
Television			●										●					●		3	16%
Clothes Dryer				●		●		●	●			●	●	●	●	●		●		10	53%
Dehumidifier				●		●	●	●	●	●	●	●	●		●			●		11	58%
Power Strip	●	●	●	●	●	●		●	●			●	●	●	●			●		13	68%
Dishwasher	●	●	●	●		●	●	●	●	●	●	●	●			●	●	●	●	16	84%
Clothes washer	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	18	95%
Water																					
Pool Cover						●														1	5%
Boiler/Water Heater Combination								●											●	2	11%
Fuel Switching - Water Heating													●					●		2	11%
Hot Water Plant						●													●	2	11%
Condensing Water Heater			●					●											●	3	16%
Water Fixtures				●											●				●	3	16%
Solar Water Heaters					●								●				●		●	4	21%
Indirect Water Heater						●		●			●				●				●	5	26%
Tankless Water Heaters			●			●	●	●							●				●	6	32%
Water End Uses						●		●					●	●	●				●	6	32%
Water Flow Restriction Valve						●	●	●	●		●		●	●		●				8	42%
Water Heater Temperature Control				●		●	●		●	●			●					●	●	8	42%
Pool Pump	●	●			●			●	●				●		●	●		●		9	47%
Pre-Rinse Spray Valve	●		●		●	●		●	●	●			●	●	●	●	●			12	63%
Heat Pump Water Heaters		●	●	●	●	●	●	●	●		●		●	●	●		●	●		14	74%
Water Heater - Tank Insulation	●	●	●	●		●	●		●	●	●	●	●			●	●	●		14	74%
Water Heater	●	●	●	●		●	●	●	●	●	●		●	●	●	●	●		●	16	84%
Faucet Aerator	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	18	95%
Showerhead	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	19	100%
All Other																					
Building Operator Certification								●												1	5%
Combined Heat & Power															●					1	5%
Commercial Energy Report			●																	1	5%
Energy Code Compliance								●												1	5%
Internal Power Supply																		●		1	5%
Metering & Monitoring					●															1	5%
Predictive Energy Optimization Software			●																	1	5%
Uniterruptible Power Supply		●																		1	5%
Voltage Controllers			●																	1	5%
Comprehensive Retrofit															●			●		2	11%
Home Efficiency Kit					●													●		2	11%
Solar Photovoltaic (PV)																	●		●	2	11%
Submetering					●						●									2	11%
Load Management										●			●				●			3	16%
Residential Energy Audit			●										●		●					3	16%
Transformers				●	●											●				3	16%
Educational Services				●	●			●											●	4	21%
Home Energy Report			●		●			●							●					4	21%
Network Power Management	●		●									●	●							4	21%
Custom Measures			●		●		●	●							●					5	26%
New Homes			●		●			●					●	●		●	●	●		8	42%

Figure 3. Types of Technologies Available in Technical Reference Manuals. *Source*: E Source Measure Insights.

Variability in Assumptions

We began to analyze the input assumptions for one particular measure across 16 TRMs to observe variability with a goal to find out how significant the assumptions can vary for a measure that is used consistently regardless of its installed location. The measure we chose for this was the Faucet Aerator because it one of the most common measures and it is not subject to jurisdictional differences like other measures, such as an air conditioner might be. The way a faucet aerator is used is the same whether it is installed in a hot climate or a cold one. The measure is the same piece of equipment and is expected to act the same no matter where it is installed. The input assumptions we focused on were effective useful life (EUL) and incremental measure cost. All but one of the 16 TRMs had a EUL assumption while seven TRMs had an incremental measure cost assumption for Faucet Aerators. All of the EUL values represent the same input which is the amount of time the measure is expected to last after it is installed. The incremental measure cost, defined as the difference between the cost of the baseline measure and that of the new or efficient measure, was not used in a majority or TRMs. Most of the TRMs actually use the Full measure cost value which is defined as the entire cost of the new or efficient equipment. In some cases, we noticed that the time to install the measure, or labor cost, was included in measure cost assumptions.

The EUL value varied significantly across the 16 observed TRMs. The min value of five years was in two TRMs while the max value of ten years was observed in nine TRMs. Looking across all TRMs, the mean EUL value for the faucet aerator was 8.8 years. This inconsistency was surprising because we expected the EUL assumption for faucet aerators to be well established and agreed upon. The EUL value was found to be five years in the Mid-Atlantic TRM and in the Maine TRM. The source for the Mid-Atlantic TRM states "Conservative estimate based on review of TRM assumptions from other States." The source for the Maine TRM states "2010 Ohio TRM: conservative estimate based on review of TRM assumptions from other states." This is an example of how a TRM sometimes borrow assumptions, citing a different TRM, which actually cited assumptions from many other TRMs and formed a judgement call. The inconsistency for EUL has implications in determining lifecycle energy savings for programs which include a faucet aerator measure. Given the range of EULs, assuming all other things being equal, jurisdictions using the 10-year life will determine a faucet aerator has twice the lifecycle savings as a jurisdiction using the 5-year value. The difference, and accuracy or inaccuracy of these assumptions, has a direct effect on the measure's lifecycle cost effectiveness and potentially program performance where program goals are stated in lifecycle terms. The table below shows an overview of the distribution metrics for faucet aerator EUL values.

Measure	EUL – Min	EUL – Max	EUL – Mean	EUL - # TRMs
Faucet Aerator	5	10	8.8	15

Figure 4. Distribution of EUL values across 16 TRMs. *Source*: E Source Measure Insights

In the TRMs where measure cost was stated, we observed the same level of inconsistency when comparing across TRMs. The incremental measure cost was used in four TRMs while the full measure cost was used in three of the TRMs, and one TRM had both the incremental and full measure cost stated.

Measure	Incremental Measure Cost – Min	Incremental Measure Cost – Max	Incremental Measure Cost – Mean	Incremental Measure Cost - # TRMs
Faucet Aerator	$2	$10	$5.92	4

Figure 5. Distribution of incremental measure cost values across 16 TRMs. *Source*: E Source Measure Insights

We expected that the equipment cost would remain constant regardless of the jurisdiction in which it was installed. Instead, we noticed that the max incremental measure cost value was five times the min value. This level of variance is an example of how significant measure assumptions for a basic technology can vary across different jurisdictions.

Measure	Full Measure Cost – Min	Full Measure Cost – Max	Full Measure Cost – Mean	Full Measure Cost - # TRMs
Faucet Aerator	$8	$32.28	$17.84	4

Figure 6. Distribution of full measure cost values across 16 TRMs. *Source*: E Source Measure Insights

The max value for full measure cost is four times larger than the min value used. This level of variation brings into question the accuracy of the values contained within TRMs.

Conclusion

Although TRMs have been around for more than 20 years, there is opportunity for continued refinement and expansion of the scope of documented technology types and associated inputs and calculation methods. There is a significant amount of variation across distinct measure technologies in various jurisdictional TRMs. This variation creates inaccurate energy savings calculations and leads to missed goals and opportunities for energy efficiency. Without consistent methods for comparing accomplishments in energy efficiency, we will not succeed in our goal to measure and reduce energy consumption.

The majority of distinct technology types appearing in state and regional reference manuals and repositories are documented in only a small minority of jurisdiction references.

Energy efficiency program stakeholders will find that by looking outside of their own jurisdictions at what technologies are being documented for savings estimation methods, there are no shortage of potentially applicable technologies for which their territory has no agreed upon reference values.

Further research into the variety of documented value types and their research sources will help the industry to continue to establish robust guidelines for developing and expediting more accurate energy savings calculations. Continued reliance on referencing other TRMs without regard to the quality and depth of the work behind those sources increases the risk that reported program results deviate from reality. Circular references further erode confidence in our industry's ability to reliably quantify energy savings impacts. Practitioners need to verify a source and the depth of research behind it before borrowing assumptions from other TRMs.

References

E Source. 2016. *Measure Insights.* Accessed February 2016. Boulder, CO: E Source. http://www.esource.com/measureinsights

Technical Reference Manuals sourced from:

Arkansas (Version 5) http://www.apscservices.info/EEInfo/TRM5.pdf

Xcel Energy Colorado (2015/2016) – included within 2015/16 DSM Filing https://www.xcelenergy.com/staticfiles/xe/Marketing/Files/CO-DSM-2015-2016-DSM-Plan.pdf

Connecticut (2016) http://www.neep.org/sites/default/files/2015_10_01_2016%20Program%20Savings%20Document.pdf

California Municipal Utilities Association (2014) http://cmua.org/wpcmua/wp-content/uploads/2014/05/CMUA-_TRM-manual_5-5-2014_Final.pdf

Hawaii Energy (2014) https://hawaiienergy.com/images/resources/TRMProgramYear_2014_FINAL_V15.pdf

Illinois (Version 4) http://www.ilsag.info/technical-reference-manual.html

Mid-Atlantic (Version 5) http://www.neep.org/sites/default/files/resources/Mid-Atlantic_TRM_V5_FINAL_5-26-2015.pdf

Minnesota (2016) http://mn.gov/commerce/industries/energy/utilities/cip/technical-reference-manual/

Maine (2016) http://www.efficiencymaine.com/about/library/policies/

New Jersey (FY 2015) http://www.njcleanenergy.com/files/file/NJCEP%20Protocols%20to%20Measure%20Resource%20Savings%20FY16_11-24-15_Master%20Clean.pdf

New York (2016) http://www3.dps.ny.gov/W/PSCWeb.nsf/All/72C23DECFF52920A85257F1100671BDD?OpenDocument

Pennsylvania (2016)
http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx

Regional Technical Forum
http://rtf.nwcouncil.org/

National Grid - Rhode Island (2016)
https://www9.nationalgridus.com/non_html/eer/ri/PY2016%20RI%20TRM.pdf

Tennessee Valley Authority (2015)
https://www.tva.gov/file_source/TVA/Site%20Content/Energy/EnergyRight%20Solutions/TVA_TRM_2016_Version%204.pdf

Texas (2016)
http://www.texasefficiency.com/index.php/emv

Vermont (2016)
http://psb.vermont.gov/sites/psb/files/docketsandprojects/electric/majorpendingproceedings/TRM%20User%20Manual%20No.%202015-87C.pdf

Wisconsin (2016)
https://www.focusonenergy.com/sites/default/files/TRM%20Fall%202015%20_10-22-15.compressed2.pdf