Title
Status and Opportunities for Improving the Consistency of Technical Reference Manuals

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Status and Opportunities for Improving the Consistency of Technical Reference Manuals[1]

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ABSTRACT

Across the United States, energy-efficiency program administrators rely on Technical Reference Manuals (TRMs) as sources for calculations and deemed savings values for specific, well-defined efficiency measures. TRMs play an important part in energy efficiency program planning by providing a common and consistent source for calculation of *ex ante* and often *ex post* savings. They thus help reduce energy-efficiency resource acquisition costs by obviating the need for extensive measurement and verification and lower performance risk for program administrators and implementation contractors.

This paper considers the benefits of establishing region-wide or national TRMs and considers the challenges of such undertaking due to the difficulties in comparing energy savings across jurisdictions. We argue that greater consistency across TRMs in the approaches used to determine deemed savings values, with more transparency about assumptions, would allow better comparisons in savings estimates across jurisdictions as well as improve confidence in reported efficiency measure savings. To support this thesis, we review approaches for the calculation of savings for select measures in TRMs currently in use in 17 jurisdictions. The review reveals differences in the saving methodologies, technical assumptions, and input variables used for estimating deemed savings values. These differences are described and their implications are summarized, using four, common energy-efficiency measures as examples. Recommendations are then offered for establishing a uniform approach for determining deemed savings values.

Introduction

Technical Reference Manuals (TRMs) document savings calculations[2] and deemed savings values[3] for energy-efficiency measures and are available in various formats (e.g.,

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[2] A deemed (or “stipulated”) savings calculation refers to engineering algorithm(s) used to calculate energy and/or demand savings for an installed energy-efficiency measure that: (a) has been developed from common practice widely considered acceptable for the measure and purpose; and (b) is applicable to the situation being evaluated. This may include stipulated assumptions for one or more parameters in the algorithm, but, typically, it requires inputting data, associated with the actual installed measure, into the algorithm(s). (Schiller 2012)

[3] A deemed (or “stipulated”) savings value is an estimate of energy or demand savings for a unit of an energy-efficiency measure that: (a) has been developed from data sources and analytical methods widely considered acceptable for the measure and purpose; and (b) is applicable to the situation being evaluated. Individual parameters or calculation methods can also be deemed. (Schiller 2012)

document, spreadsheet or online searchable database). TRMs provide a resource source for information needed for program design and reporting savings from energy- efficiency programs. TRMs can include savings values for measures, engineering algorithms to calculate savings, adjustment factors such as net-to-gross values, source documentation, technical assumptions, and other relevant material to support the calculation of measure and program savings.

TRMs are used by entities that either manage or implement efficiency projects and include agreed to *ex ante*, or stipulated, savings or calculation methods for measures. The savings values or calculation methods in TRMs reflect agreements between program administrators and regulatory oversight bodies and are used by administrators in their interactions with implementation contractors and end users. A deemed savings value implies that no additional measurements beyond verification of installation of a measure would be necessary for the savings to be accepted by the parties involved.

Program administrators and/or state regulatory commissions are developing and adopting TRMs at an increasing rate. As of March 2012, 17 jurisdictions had adopted a TRM (with several more currently under development), compared to 6 or 7 jurisdictions with TRMs five years ago. This indicates a trend toward using deemed savings values and/or calculations for reporting purposes for certain energy-efficiency measures and thus an increasing use of stipulated *ex ante* per-unit savings values with, presumably, verification of installations.

In early 2011, the State and Local Energy Efficiency Action Network's (SEE Action) EM&V Working Group[4] commissioned a project to determine the feasibility of creating regionally based resources of deemed savings values or deemed savings calculations as well as energy-efficiency evaluation plans and reports. As part of that study, The Cadmus Group, Inc. (Cadmus), under subcontract to Lawrence Berkeley National Laboratory (LBNL), reviewed existing TRMs and other technical resources to determine the current consistency levels in deemed savings calculations and values across various jurisdictions (Jayaweera et al, 2011). This paper summarizes the results of the SEE Action project, focusing on methods used to calculate first-year energy savings for various efficiency measures.

Importance of TRMs

TRMs play an important part in streamlining planning and reporting functions for program administrators, and in establishing regulatory compliance, particularly in jurisdictions where energy-efficiency performance standards (EERS) are in effect. Generally subject to approval or acceptance by regulators, a TRM is generally available as a document or an electronic database. TRMs also facilitate savings calculations, standardize reporting processes, and promote greater transparency and predictability in claimed savings for program administrators investing in energy efficiency (Cleff et al. 2011).

Processes for developing TRMs vary. Jurisdictions developing TRMs for the first time tend to borrow from TRMs in other jurisdictions or from secondary resources, incorporating modifications for climate or other local variations. This inexpensive approach allows relatively expedient development of a TRM, but can perpetuate errors or outdated information. In some states that have developed TRMs recently, TRMs often borrow from multiple sources and the sources are not always properly documented. If TRMs used more consistent approaches with transparent documentation of sources, the overall accuracy of TRMs would likely increase,

[4] www1.eere.energy.gov/seeaction/

resulting in greater comparability across jurisdictions and higher confidence in the reported savings that are based on those TRMs.

Methodology

To conduct this review, Cadmus explored three areas of the TRMs: (1) methodology used to estimate savings (e.g., engineering algorithm or formula vs. building simulation), (2) inclusion/exclusion of parameters within an algorithm, and (3) relative transparency and documentation of assumed values used. We focus on consistency across TRMs, rather than accuracy, although we notes errors where they were observed.

This study reviewed 20 measures across 17 TRMs, as shown in Table 1.

Table 1. List of TRMs Reviewed*

TRM ID	Territory	Resource Name
TRM 1	National	ENERGY STAR savings calculator (2011)
TRM 2	Regional Pacific Northwest	Regional Technical Forum Deemed Measures (2011)
TRM 3	Regional Northeast	Mid-Atlantic Technical Reference Manual Version 1.1 (2010)
TRM 4	Arkansas	Arkansas Deemed Savings Quick Start Programs (2007)
TRM 5	California	Database for Energy Efficient Resources (2005, 2008)
TRM 6	Connecticut	CL&P and UI Program Savings Documentation 2008 Program Year (2007)
TRM 7	Hawaii	Hawaii Energy Efficiency Program Technical Reference Manual No. 2009-1 (2009)
TRM 8	Maine	Efficiency Maine Technical Reference Manual No. 2006-1 (2007)
TRM 9	Massachusetts	Massachusetts Statewide Technical Reference Manual for Estimating Savings from Energy Efficiency Measures 2011 Program Year (2010)
TRM 10	Michigan	Michigan Energy Measures Database (MEMD) (2009)
TRM 11	New Jersey	New Jersey Clean Energy Program Protocols to Measure Resource Savings (2009)
TRM 12	New York	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs (2010)
TRM 13	Ohio	Ohio TRM (2010)
TRM 14	Pennsylvania	Pennsylvania PUC Technical Reference Manual (2011)
TRM 15	Texas	Deemed Savings, Installation & Efficiency Standards (2010)
TRM 16	Vermont	Efficiency Vermont Technical Reference User Manual (2010)
TRM 17	Wisconsin	Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0 (2010)

* The TRMs listed were current at the time of review, but some have been supplanted with more recent versions.

Four efficiency measures—based on their fuel and market diversity, relative complexity, and frequency of appearing in TRMs—received more in-depth analysis:

1. Residential compact fluorescent lighting (CFL)
2. Residential high-efficiency gas furnaces
3. Commercial high-efficiency motors
4. Commercial roof insulation

For each efficiency measure, five TRMs, representing diverse climates and different methods, were selected. Given limited resources, the intent of this approach was to provide program administrators and regulators with insights into current approaches used to estimate savings, suggest ways to improve the consistency of TRMs, and if appropriate, provide suggestions on improving the accuracy of calculation methods or savings values in TRMs. The long-term goal is to increase the confidence of policymakers, regulators, and stakeholders in energy efficiency's value as a reliable resource.

Findings

The review of the four efficiency measures in the five TRMs consisted of comparing the methodologies and resulting algorithms used for calculating savings, and, where applicable, assumed stipulated parameters used in calculations. We described stated or implied reasons for observed differences in each of these methodologies, algorithms and parameter assumptions. Certain differences were expected: climate conditions in southern states naturally resulted in different savings values for HVAC measures compared to northern states. Not surprisingly, baseline conditions (and other assumptions) varied across states, depending on local codes or program maturities. However, differences in algorithm parameters emerged, leading to unexpected differences in savings. Table 2 compares general findings for the four measures examined in depth.

Table 2. Comparison of selected residential and commercial measures: Summary Findings

#	Measure	Main Findings
1	Residential CFL	Savings tend to be subject to many adjustment factors, depending on installation locations, applications, types of HVAC systems for interactive factor calculations, and delivery mechanisms (e.g., upstream marketing, direct install), and storage and removal factors. These factors appear to be considered to varying degrees across TRMs. Variations were noted in assumptions for overall hours of use.
2	Residential Gas Furnace	Savings tend to be calculated using engineering calculations based on hours of use and system parameters. Other saving determinants include annual heating loads by vintages and floor areas. As expected, such inputs vary regionally. Building simulation modeling provides another approach to estimating savings. The methods tend to produce different results, although it remains unclear which is most accurate.
3	Commercial Motor (1-200 HP)	Per-unit savings typically are calculated by comparing baselines, as defined by federal standards and efficiency ratings. Hours of use and rated load factors (RLFs) tend to present as the main variation sources in savings estimates, even under the same assumed horsepower (HP) and applications.
4	Commercial Roof Insulation	Savings are commonly developed from outputs of building simulations and are tabulated using a host of characteristics. Some TRMs use engineering calculations. Measure baselines and efficiency requirements vary regionally.

The review indicated algorithms used in savings calculations generally are correct and based on accepted methodologies used by efficiency industry practitioners. However, the input parameters used within the algorithms vary widely and the level of detail and documentation of these input parameters varies widely across TRMs. For example, some TRMs include parameters such as waste-heat factors, in-service rates, and/or partial load factors, while others do not. For roof insulation, we found that savings values are based on building energy simulations in some cases, while in other cases, engineering algorithms are utilized. Although both approaches may be reasonable, calculated savings results differ, even for similar building types and locations.

Although some of the variations in savings results stem from differences in method used in TRMs, we also found that some differences in deemed savings values appear to result from errors, ranging from obvious typographical mistakes to missing default values for certain assumptions, and calculation errors (in a few cases).[5]

In the remainder of this section, we discuss measure-specific findings in more detail (e.g., our comparative analysis of deemed savings values or calculation methods, and, if applicable, the engineering algorithm used in TRMs to illustrate the wide variance seen). See the SEE Action report (Jayaweera et al, 2011) for a more detailed analysis of engineering algorithms for specific measures. Note that to facilitate comparisons across reviewed TRMs, we define and use common variable names, which may differ from those actually used in a particular TRM.

Measure 1: Residential Compact Fluorescent Lighting

Nearly all TRMs include residential CFL lighting. The prevailing energy savings method includes calculation of a deemed savings value based on these parameters: a baseline and measure lamp wattage, and hours of use. Some TRMs include in-service rates. However, several TRMs include additional factors to calculate these first year savings, such as HVAC interactive factors (to indicate increases or decreases in space heating/cooling energy use associated with decreasing in heat generation associated with lower lighting wattage) and delivery mechanism factors (e.g., direct install vs. retail).

Baseline and measure wattage assumptions vary depending on TRMs. For example, although wattages are often deemed (fixed), they are determined using various approaches. Some TRMs use a delta wattage multiplier (assuming a CFL is three times more efficient than an equivalent incandescent). More recent TRMs tend to base such delta wattage on lumen equivalence, driven largely by requirements of the Energy Independence and Security Act of 2007 (EISA).[6] In some cases, wattages are not stipulated, but may be chosen by program administrators or implementation services providers based on sales or field collected data.

We also found that hours of use vary by TRM, partly by sources used. Most TRMs cite hours of use assumptions based on recent (or not so recent) impact evaluation reports, while others draw upon hours of use assumed within the ENERGY STAR calculator. For example, across 11 TRMs, residential hours of use range from 1.81 to 3.20 hours per day. This difference may be explained by a program’s maturity (e.g. targeting lighting sockets with lower hours of use as number of CFLs per house increase), but often arises because of reliance upon secondary data, which may or may not be applicable within a jurisdiction. An evaluation including lighting usage metering within the jurisdiction can provide the most accurate assessment for this parameter, assuming it is done properly. For TRMs that use in-service rates, these tend to be based on regional surveys, and sometimes vary by delivery mechanisms.

Six TRMs included HVAC interactive factors in estimating savings from CFLs: three TRMs used a combined electric space cooling and electric heating factor, resulting in factors less than 1, while the other three only apply factors based on electric space cooling, resulting in factors greater than 1. Generally, waste heat factors are determined through building simulations

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[5] Several TRMs also had mislabeled data tables, incorrectly numbered footnotes and references, or entirely omitted variable names.

[6] EISA stipulates maximum wattages for a given lumen range, effectively requiring standard incandescent bulbs to be 30% more efficient, starting in 2012.

or by location, using ASHRAE's lighting waste heat factors (Rundquist, Johnson & Aumann 1993).[7]

Table 3 summarizes savings approaches for residential CFL for the five TRMs specifically reviewed, highlighting differences in algorithms used. As indicated, we have expressed the algorithms in each TRM in common nomenclature. For example, HRS represents hours of use, WHF is waste heat factor, ISR is in-service rate. For the TRMs that use a deemed wattage multiplier, that value is given as is (e.g., 2.53 in TRM 5, and 3.25 in TRM 14).

Table 3. Measure 1: Residential CFL: Comparison among TRMs

Residential CFL	**TRM 1 (2011)**	**TRM 2 (2011)**	**TRM 5 (2008)**	**TRM 13 (2010)**	**TRM 14 (2011)**
Region	National	West	West	Midwest	Northeast
Calculation Approach: Energy	$\Delta kWh = kWh_{base} - kWh_{ee}$	Deemed	$\Delta kWh = Watt_{ee} \times 2.53 \div 1{,}000\ \frac{W}{KW} \times HRS$	$\Delta kWh = \frac{\Delta W}{1{,}000} \times HRS \times ISR$ $\Delta MMBTU = \frac{(Watt_{ee} \times 3.25)}{1{,}000 \frac{W}{kW}} \times ISR \times HRS \times 0.003413 \times \frac{HF}{\eta}$	$\Delta kWh = (Watt_{ee} \times 3.25) \div 1{,}000 \frac{W}{KW} \times ISR \times HRS \times WHF_e$
Approach Commentary	• MS Excel® workbook, with built in assumptions. • Input number of lamps, daily hours of use, and baseline incandescent wattages.	• Deemed savings, using MS Excel® workbook. • Tabulated savings and detailed calculations. • Savings based on average energy use per room type and average number of lamps per room.	• Deemed savings calculated by program, based on calculations using input data from an evaluation. • Savings depend on zone, single-family vs. manufactured, and vintage.	• Deemed calculation, based on a ratio of average incandescent wattage removed to average CFL wattage installed. • Savings methodology, based on a delta wattage multiplication factor.	• Savings based on an algorithm calculating differences between existing and new wattage, and average daily hours of use for lighting units replaced. • An in-service rate used to reflect actual installations.

Measure 2: Residential High Efficiency Gas Furnace

We found two primary energy-savings estimation methods for residential, high-efficiency gas furnaces used in TRMs: building simulations (energy modeling) and simplified engineering algorithms. Building simulations, such as DOE-2.2 (DOE2), require multiple assumptions regarding development of prototypical buildings. These include basic characteristics, such as building size, geometry, glazing, operating hours and HVAC setpoints, and HVAC system type and size. TRMs that rely on building simulations are fully or partially based on modeling. *Fully based* modeling provides a deemed or fixed estimate directly from the model. *Partially based* modeling derives values from building simulations. For example, hours of use (generally

[7] ASHRAE's lighting waste heat factors were originally intended for the commercial sector.

expressed as equivalent full load hours [EFLH]) are determined from the building simulation, and then used as inputs in engineering algorithms.

Engineering algorithms calculate energy savings using the following inputs: the system capacity, annual fuel utilization efficiency (AFUE) rating, and EFLH. When algorithms are used, it is often difficult to determine how equipment capacity has been defined. In several cases, it was not clear whether capacity values (generally given in BTUH) referred to the *input* or *output* capacity of a furnace. This can lead to inconsistencies and errors in savings estimates, as these two values are not equivalent, but may be used in identical algorithms. The efficiency (or AFUE rating) is often based on manufacturer's rating, which may not be completely accurate, given in-home conditions. Hours of use (i.e., EFLH) generally are deemed, using a secondary source (often the ENERGY STAR calculator) or modeling results. EFLH assumptions for savings from these types of retrofits are the most crucial assumptions and thus their sensitivity to location leads to expected differences in savings between TRMs. To improve accuracy of assumed EFLH, evaluations can perform billing analysis or metering.

Few TRMs include electrical savings for inclusion of electronically commutated motors (ECMs), though such inclusions provide utilities with additional resources to develop and claim savings within their programs.

Table 3 compares savings approaches from five TRMs.

Table 3. Measure 2: Residential Furnaces: Comparison among TRMs

Residential Furnace	**TRM 1 (2011)**	**TRM 5 (2008)**	**TRM 9 (2011)**	**TRM 12 (2010)**	**TRM 13 (2010)**
Region	National	West	Northeast	Northeast	Midwest
Calculation approach: Energy	$\Delta\text{MMBtu} = \frac{A_{\text{heat}} \times \text{HL}}{1{,}000\,\frac{\text{kBtu}}{\text{MMBtu}}} \times \left(\frac{1}{\text{AFUE}_{\text{base}}} - \frac{1}{\text{AFUE}_{\text{ee}}}\right)$	Deemed savings, based on DOE-2.2 modeling. Savings calculated in therms.	A deemed table, with values based on an impact evaluation. High-efficiency furnaces equipped with ECM fan motors also save electricity from reduced fan energy requirements.	$\Delta\text{Therms} = \text{EFLH}_{\text{heat}} \times \text{BTUH} \times \left(1 - \frac{\text{AFUE}_{\text{base}}}{\text{AFUE}_{\text{ee}}}\right) \times 10^{-2}$	$\Delta\text{MMBtu} = \text{EFLH}_{\text{heat}} \times \text{BTUH} \times \left(1 - \frac{\text{AFUE}_{\text{base}}}{\text{AFUE}_{\text{ee}}}\right) \times 10^{-6}$.
Approach commentary	• Calculation worksheet, with inputs and lookup tables, allowing users to customize to regions and houses.	• Deemed savings, based on DOE-2.2 modeling. • Uses the Heat Input Ratio (HIR), a variable used by DOE modeling software.	• Deemed savings, based on study results provided in a table for 92%, 94%, and 96% AFUE. • Table shows assumed factors for calculating adjusted gross savings, such as ISR. • Reduction of electric use deemed at 478 kWh.	• Savings based on an algorithm. • Heating EFLH for single-family and multifamily residential buildings, calculated from a DOE-2.2 simulation of prototypical residential buildings. • EFLH values given as a function of building type,	• Savings calculated using differences in required gas, based on furnace efficiency and average annual heating loads for TRM state residences. • No change in distribution system efficiency (including fan motor) assumed.

Residential Furnace	TRM 1 (2011)	TRM 5 (2008)	TRM 9 (2011)	TRM 12 (2010)	TRM 13 (2010)
Region	National	West	Northeast	Northeast	Midwest
				vintage, and city.	

Measure 3: Commercial High-Efficiency Motors

Of all measures reviewed across the TRMs, commercial high-efficiency motors showed the most similarity in energy-savings calculation methodologies, with energy savings calculated per motor on a retrofit basis. As seen in Table 5, formulas are relatively consistent, and baseline assumptions largely the same, based on the 1992 Energy Policy Act (EPAct). One TRM includes additional tables referencing the 2007 EISA standards for motors.[8] The efficient condition is defined as meeting or exceeding National Electrical Manufacturers Association (NEMA) premium efficiency requirements. Calculations reviewed were technically correct, with some approaches relying more on default assumptions (such as HP) than others. Typically, motors greater than 200 HP are not included as part of TRMs, given NEMA's standard only applies to motors up to that size. Some TRMs refer these large motor sizes for inclusion as part of a custom measure protocol.

In most cases, motor HP, types, and RPMs are determined by the user. Some TRMs provide a lookup table to determine hours of use, based on application types, building types, or HP. One TRM weights values for a given HP, providing a single, deemed demand savings value, weighted by motor type and RPMs. RLFs vary from 0.5 to 0.75, with 0.75 most commonly used within TRMs. Overall, calculated energy savings vary little for this measure.

Table 5. Measure 3: Commercial Motors: Comparison among TRMs

Motors	TRM 3 (2010)	TRM 4 (2007)	TRM 13 (2010)	TRM 14 (2011)	TRM 17 (2010)
Region	South	South	Midwest	Northeast	Midwest
Calculation approach: Energy	$\Delta kWh = HP \times RLF \times 0.746 \times \left[\frac{1}{N_{base}} - \frac{1}{N_{ee}}\right] \times HRS$	$\Delta kWh = HP \times RLF \times 0.746 \times \left[\frac{1}{N_{base}} - \frac{1}{N_{ee}}\right] \times HRS$	$\Delta kWh = HP \times RLF \times 0.746 \times \left[\frac{HP_{base} X RLF_{base}}{N_{base}} - \frac{HP_{ee} X RLF_{ee}}{N_{ee}}\right] \times HRS$	$\Delta kWh = HP \times RLF \times 0.746 \times \left[\frac{1}{N_{base}} - \frac{1}{N_{ee}}\right] \times HRS$	$\Delta kWh = HP \times RLF \times 0.746 \times \left[\frac{1}{N_{base}} - \frac{1}{N_{ee}}\right]$ Deemed formula: $\Delta kWh = 0.1075 \times HRS$

[8] The 2007 EISA standards required general-purpose electric motors (subtype I) meet "NEMA Premium" levels, which became federal minimum efficiency levels, effective December 19, 2010.

Approach Commentary	• Applicable to replacement with the same-rated HP. • Lookup tables from EPACT and NEMA, by HP; broken out motor type.	• Calculation based on actual or tabulated motor efficiencies. • Lookup tables for hours, load factors, and efficiency by motor size. • Does not differentiate motor type.	• Calculation, but allows different HP and RLF factors between baselines and efficient conditions. • Lookup tables from EPACT and NEMA, by HP; broken out by motor type.	• Applicable to replacement with the same-rated HP, single-motor systems. • Lookup tables from EPACT and NEMA, by HP; broken out by motor type.	• Approach one: weighted average by type to determine deemed savings by size; • Approach two: based on calculation for particular motors (type, size, RPMs).

Measure 4: Commercial Roof Insulation

Simulations of prototypical buildings provide the most common method for determining energy savings values for roof insulation. Most TRMs have adapted building prototypes from the California's Database for Energy Efficient Resources (DEER) study prototypes, modifying them for local construction practices and climates. DEER prototypes use DOE-2.2 to simulate energy savings for various buildings. As stated, energy modeling requires multiple assumptions regarding development of prototypical buildings, and may not necessarily be applicable in other jurisdictions, where home characteristics (e.g., average home age, size, construction material) can significantly differ.

Another methodology used for this measure is based on engineering calculations, based on derivatives of the basic heat transfer equation. This involves using tables, developed for the TRM, to calculate energy savings and to factor in climate differences, based on cooling and heating degree days. This method is easier and less expensive to use than simulation modeling. However, it does not account for variations in commercial building characteristics, only efficiencies of heating and cooling equipment and baseline R-values. Billing analysis performed as part of an evaluation helps inform the accuracy of tables or algorithms.

Table 6. Measure 4: Commercial Roof Insulation: Comparison among TRMs

Ceiling / Roof Insulation	TRM 5 (2005)	TRM 12 (2010)	TRM 16 (2010)	TRM 13 (2010)	TRM 14 (2011)
Region	West	Northeast	Northeast	Midwest	Northeast
Calculation approach: Energy	Tabulated savings values by climate zone, 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	Tabulated savings values by climate zone, 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	$\Delta MMBTU = HDD \times 24 \times A \times \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \div (\eta \times 10^6)$	$\Delta kWh = A \times \Delta kWh_{sqft}$	$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$ $\Delta kWh_{cool} = \frac{A \times CDD \times 24}{EER \times 1{,}000} \times \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right)$ $\Delta kWh_{heat} = \frac{A \times HDD \times 24}{COP \times 3413} \times \left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right)$

Ceiling / Roof Insulation	TRM 5 (2005)	TRM 12 (2010)	TRM 16 (2010)	TRM 13 (2010)	TRM 14 (2011)
Region	West	Northeast	Northeast	Midwest	Northeast
	user scaling up the value appropriately.	user scaling up the value appropriately.			
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 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.	• This algorithm is specific to central AC and ASHP. • Insulations are fixed for new construction/ unknown and variable for existing.

Discussion of Findings

As the four examples show, approaches vary in estimating savings for a given measure. Variance sources can be summarized using three main themes: consistency in methodologies; consistency in assumptions; and transparency around sources for savings (and thus, greater confidence in its accuracy).

The two main methods used for calculating savings are engineering algorithms and building simulations. Sometimes, a hybrid approach is used, where building simulations inform assumptions used in the algorithms. While building simulations would often be considered more reliable than simple engineering algorithms, this is only the case if the myriad of input data required to model the baseline and project scenarios are available, accurate and applicable to the application for which a deemed savings value is being applied. Thus, applicability conditions and building specifics should be well detailed and based on actual local building stock conditions. Generally, if these data are available and since hourly temperature data more closely represent actual weather conditions, they provide more accurate results than engineering algorithms. However, compiling this information may be expensive, as building simulations are needed for a wide range of building types. Engineering algorithms are simpler to use, and provide user-defined inputs for some variables, but produce a less nuanced savings estimate (e.g., they use base climate data, such as heating degree days, to approximate hourly weather data).

Further, some engineering algorithms include more parameters than others. For example, some TRMs for residential CFLs include waste heat factors and/or installation rates. These factors typically reduce savings for residential lighting programs. Generally, including additional parameters leads to a more representative savings estimate, though accurately assessing these parameters is necessary. Such factors may be based on evaluation results, borrowed from neighboring jurisdictions or building simulations.

Finally, the most significant variance source appears to be assumptions, which may span a wide range of parameters, such as: assumed baseline efficiencies; measure efficiencies; operating hours; and climate conditions. Differing input parameters result in differing savings estimates across jurisdictions, though this may be justified for many measures (e.g., full load hours for HVAC systems should vary). However, the accuracy of such assumptions can be difficult to verify, and can depend on a TRM's level of detail and transparency. Generally, if based on data obtained through rigorous impact evaluations, one can have more confidence in the values. States new to energy efficiency often draw upon data from other jurisdictions. These assumptions may or may not be applicable, depending on similarities in climates or baseline conditions.

Concluding Observations

TRMs play an important role in furthering energy efficiency policy objectives in two basic ways. They provide a common source for calculation of *ex ante* savings, thus creating consistency in program design and portfolio development. They also supply deemed values for savings, thus eliminating the need for often expensive measurement and verification and lowering performance and compliance risks for program administrators. Therefore, transparency, accuracy and consistency are essential in developing and adopting TRMs.

The apparent wide variations in methodologies and assumptions for determining saving calculations in TRMs for measures commonly offered through programs could lead to diminished confidence in TRM results. Many of the differences in methodologies and variations in savings calculations, and assumptions that reflect unique local conditions are to be expected. Such variations do not necessarily imply inaccuracy and do not invalidate the savings calculations and deemed savings values. However, these differences illustrate the challenge of establishing TRMs at wider regional and possibly national levels.

In contrast, a lack of transparency, inconsistencies, and technical errors (or omissions) do diminish the usefulness of TRMs and have adverse consequences by reducing confidence in savings values for measures. Given the recent surge in TRM adoption across the country, it is important to explore how the accuracy of TRMs and other sources of technical data for energy-efficiency measures might be improved. This might be achieved in two key steps: standardizing the methodologies for estimating savings, and introducing greater transparency in how and from what sources the parameters used in the calculations were selected. These simple steps will improve the quality of TRMs and enhance their utility in facilitating energy efficiency planning and policy making.

Currently, the U.S. Department of Energy is sponsoring the Uniform Methods Project, which aims to formulate common approaches to evaluation and measurement of savings. The standardized methods and protocols resulting from this effort will serve to expedite the first step toward improving TRMs by defining a set of uniform calculations for estimating savings from a set of common energy-efficiency measures that account for a large portion of energy savings potential. These protocols also provide sufficient flexibility so the methods can be easily adapted to unique local conditions in various jurisdictions.

TRMs can also be improved by using impact evaluation results to regularly update the assumptions for specific measures or programs. However, evaluation in states with TRMs have focused more on the verification of installations, and less on measurement of parameters used to estimate savings. More focused, periodic evaluations to investigate particular critical parameters could provide valuable data that can improve TRMs.

Over time, the systematic application of uniform methods and algorithms, incorporating evaluated results, and increased transparency, could significantly improve consistency across jurisdictions, helping to enhance the credibility of saving estimates, and boost utility planners', regulators', and policy makers' confidence in energy efficiency as a reliable resource.

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