Federal Regulations and State Compliance for Energy Efficiency

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List of Acronyms

AFUE .... Annual Fuel Utilization Efficiency

CFL .... Compact Fluorescent Lamp

DOE .... Department of Energy

DSD .... Deemed Savings Database

EGU .... Electric Generating Units

EISA .... Energy Independence and Security Act

EM&V .... Evaluation, Measurement, and Verification

EPA .... Environmental Protection Agency

HVAC .... Heating, Ventilation, and Air-Conditioning

LED .... Light Emitting Diode

PUF .... Part-Use Factor

TRM .... Technical Reference Manual

UMP .... Uniform Methods Project

Introduction

In this paper, I examine the consequences of using different methods of evaluation, measurement, and verification, or EM&V, for demand-side energy efficiency measures installed as part of state-directed programs. This is important to explore because many states currently have legislated reductions in energy use and have developed programs to implement specific measures to achieve their savings goals. These programs are effective for a single state, but there has historically been a lack of coordination between states regarding their methods of program evaluation. Now that these programs are being used to fulfill a federal regulatory mandate, it is important to be able to compare different approaches as part of overall program evaluation. If a specific measure, implemented under similar conditions, is reported as having significantly different levels of energy and carbon savings, it will be difficult to compare the effectiveness of different approaches to energy efficiency.

This is an important time to consider the issue because of the requirements to reduce carbon emissions under section 111(d) of the Clean Air Act proposed by the Environmental Protection Agency (EPA). As part of their path to compliance under 111(d), states can count toward their goal set by the EPA the emissions savings achieved as a result of their individual energy efficiency programs (United States Environmental Protection Agency, 2014b). In order for individual states to comply under the requirements set by the EPA, there must be a standard, transparent method of measuring carbon emissions reductions that can be reported from energy efficiency measures implemented as part of state plans. This could be an opportunity to harmonize the different methods of energy efficiency measurement across state and utility boundaries.

While the existing state plans may work well on an individual level, there are distinct advantages to adopting a common set of standards for energy efficiency evaluation. One of the most important benefits of a common standard is increased reliability of energy efficiency reporting from different programs. It is important for regulators and customers to know that the programs they are facilitating are having the expected result. Having a set method of evaluation can increase the pool of available data for researchers and industry stakeholders to use to analyze different approaches to achieve energy efficiency reductions. With a more reliable set of data, we could design better programs that can be tailored to achieve the greatest level of savings possible, while reflecting the priorities of the states and utilities involved. Establishing a standard can also decrease program costs for utilities and regulators. States that are starting new energy efficiency programs or redesigning existing programs will benefit from not having to develop their own tools and methods for evaluating their programs. While a nationwide standard will need to be adjusted for specific local conditions, the time and money saved would be significant compared to designing a program from the ground up. Additionally, there will be less uncertainty for state regulators and policy-makers when designing programs if there is a standard method of evaluation for efficiency savings in place while the program details are being determined.

A specific challenge in developing a uniform standard of measuring energy efficiency savings is accounting for how behavior affects implementation and usage rates of new technology. Every program that uses a model for determining energy savings includes assumptions about customer behavior through factors that estimate annual hours of usage and or baseline wattage of lighting equipment. In developing these programs, there is a tension between accuracy and uniformity between programs. If the most accurate estimate of savings from state programs are heavily dependent on factors reflecting local conditions, these programs and methods might not be easily compared to programs in other states. Having independent programs in each state allows for greater flexibility and innovations that might not come into force as part of a national standard.

One of the proposals for establishing a national evaluation method is the Uniform Methods Project (UMP), which was developed by the Department of Energy as a strategy of providing a uniform standard available for optional adoption by states and utilities (United States Department of Energy). For the following analysis, I evaluate the differences between existing state programs and the UMP by first providing background on the political and regulatory environment that led to the new requirements under 111(d). Then, I explain the different types of efficiency programs available in different states and how these programs would be affected by a standard for EM&V. This analysis leads into a case study to compare how the protocols in Minnesota, Wisconsin, Michigan, and Massachusetts estimate savings from residential lighting measures and refrigerator recycling compared to the recommendations in the UMP. This analysis focuses on a test scenario designed to demonstrate the differences between each state method of evaluation and attempts to calculate the impact on each state's energy efficiency reporting if it were to adopt a standard for EM&V. While the requirements under 111(d) relate only to carbon emissions from Electric Generating Units (EGU), and therefore do not cover energy efficiency measures directed toward natural gas savings, the UMP provides guidance on both gas and electric measures. 111(d) should be seen as a catalyst for discussion of a standard for EM&V, but we should not limit the focus to those programs that would be affected by that regulation. The analysis of these case studies will be followed by a discussion of how adopting a uniform standard of EM&V will affect individual states that currently use separate methods of reporting for energy efficiency savings, along with how the many distinct methods of EM&V currently used by state programs can comply under the carbon emission requirements of 111(d).

Background

In June 2014, under section 111(d) of the Clean Air Act, the EPA proposed regulations on carbon emissions, known as the "Clean Power Plan." Compared to 2005 levels, this proposal is designed to reduce carbon emissions 30% by 2030, with measurable progress by 2020. Under the Clean Power Plan, the EPA will establish specific goals for each state, and the states will work individually, or collectively, with the EPA to develop plans to achieve these goals (United States Environmental Protection Agency, 2014b).

Clean Power Plan

In 2009, the EPA issued the Endangerment Finding under the Clean Air Act section 202(a)(1), which found that atmospheric greenhouse gases were likely linked to significant public health and welfare concerns related to climate change. The public health impacts of climate change include increased heat-related mortality, increased ozone pollution in major cities, and increased frequency of extreme weather events, and these affect children, elderly, and poor communities more than the general population. The EPA also reported on several impacts on public welfare, including reduced water supply, increased demand on the electric grid, and changing agriculture systems. Based on this understanding, the EPA sought to address carbon emissions at the electricity-generation level, which is the largest source of emissions. In 2012, electricity generation from fossil fuels accounted for 31% of all greenhouse gas emissions in the United States. Additionally, the generation and transmission infrastructure in the United States is aging, and the EPA recognizes this as an important time to increase the reliability, while reducing the carbon-intensity, of the system (United States Environmental Protection Agency, 2014).

Key outcomes

In addition to cutting carbon emission by 30%, the Clean Power Plan will reduce soot and smog-creating pollution by 25%. The EPA estimates that the public health and climate-related benefits of this proposal will be over $50 billion, eliminating thousands of premature deaths and approximately 150,000 asthma attacks. As a result of the infrastructure updates and efficiency measures, the UMP predicts that electricity bills are estimated to drop by 8% by 2030 (United States Environmental Protection Agency, 2014c).

Key dates

The comment period for the Clean Power Plan proposal ended in December 2014, and the EPA is expected to issue final rules in summer 2015, when the agency will propose a federal plan for meeting the goals set in the Clean Power Plan. Following that, states will submit compliance plans in summer 2016, with the option for either a one- or two-year extension. Finally, summer 2020 is the proposed start of compliance under the Clean Power Plan (United States Environmental Protection Agency, 2015).

State guidelines

Under the Clean Power Plan, individual states are responsible for designing programs that fit under the guidelines developed by the EPA. The first step of this approach was setting specific goals for each state for reducing carbon dioxide emissions. Individual electric generating units (EGU) do not have any specific targets under this proposal. Rather, these goals are set at the state-level, and individual states have the responsibility to determine an appropriate combination of regulations needed to comply. The states each have different goals, based on their existing emissions levels, current power-generating technology, and implemented efficiency programs. The EPA has a formula for determining state goals, which is "CO2 emissions from fossil fuel-fired power plants in pounds (lbs) divided by state electricity generation from fossil-fuel fired power plants and certain low- or zero-emitting power sources in megawatt hours (MWh)." (United States Environmental Protection Agency, 2014) In addition to the final goal in 2030, of reducing national carbon emissions by 30%, the EPA has proposed a goal that each state must meet starting in 2020, averaged over the following 10 years, to ensure that adequate progress is being made by the states (United States Environmental Protection Agency, 2014b). These goals are initially proposed as rate-based goals, measuring carbon emissions per unit of generation, but states have the option to comply based on the total mass of carbon emissions as well. The interim and final goals for Minnesota, Wisconsin, Michigan, and Massachusetts are shown in table 1, measured in pounds of CO_2 per net MWh from all EGUs affected by the Clean Power Plan (United States Environmental Protection Agency, 2014).

Table 1.Clean Power Plan Emissions Reduction Goals for MN, WI, MI, and MA

	MN	WI	MI	MA
% Change (2030 from 2012)	- 41%	- 6%	- 31%	- 38%
2012	1,470	1,827	1,690	925
2020	911	1,808	1,227	655
2030	873	1,714	1,161	576

Source: (United States Environmental Protection Agency, 2014b)

The proposed Clean Power Plan leaves many choices and freedom to the states to determine how best to comply with their established goals. To develop state-specific goals, the EPA used measures in their calculations that resulted in an achievable goal of carbon-intensity. When designing their own plans for compliance, states do not have to use the same approach that the EPA used when setting goals; they can use any combination of the four "building blocks" that the EPA identified as cost-effective and proven technologies to reduce carbon intensity. The four building blocks are described below, along with the value that the EPA used when setting state goals:

- **Make fossil fuel power plants more efficient** – The value used by the EPA was: "Average heat rate improvement of 6% for coal steam electric generating units (EGUs)" (United States Environmental Protection Agency, 2014b).
- **Use low-emitting power sources more** – The value used by the EPA was: "Dispatch to existing and under-construction natural gas combined cycle (NGCC) units to up to 70% capacity factor" (United States Environmental Protection Agency, 2014b).
- **Use more zero- and low-emitting power sources** – The value used by the EPA was: "Dispatch to new clean generation, including new nuclear generation under construction, moderate deployment of new renewable generation, and continued use of existing nuclear generation" (United States Environmental Protection Agency, 2014b).

- **Use electricity more efficiently.** - The value used by the EPA was: "Increase demand-side energy efficiency to 1.5% annually" (United States Environmental Protection Agency, 2014b).

Following the same plan that the EPA used will result in the carbon reductions mandated by the Clean Power Plan, but states have the option to design their own path to compliance. States can use any combination of the building blocks defined by the EPA, along with other technologies that are not part of the EPA's initial assessment, as long as the required carbon emission reduction is achieved. In addition to the formula used by the EPA to develop state goals, measuring the rate of carbon emissions, the states also have the option to establish a mass-based goal, which will allow them to develop and participate in cap and trade programs to comply with the Clean Power Plan. Each type of goal has distinct advantages and disadvantages, and this flexibility will allow states with different resources and priorities the best option for achieving their goals. While a rate-based objective will provide flexibility to address increased electricity generation, certain states may prefer the greater predictability associated with an absolute mass-based emissions goal, because tracking total emissions across multiple reduction measures can be easier compared to changing emissions rates. While the EPA has granted to the states the responsibility for designing their own path to compliance, common metrics are still important for evaluating and comparing between programs. (United States Environmental Protection Agency, 2014)

Uniform Methods Project

The fourth building block used by the EPA in setting state goals is increased electrical efficiency, and how the requirements under the Clean Power Plan affect monitoring requirements under previously-implemented state programs designed to increase demand-side electricity efficiency. The EPA demonstrated previous success administering energy efficiency program through the Energy Star program, which sets criteria for energy use of appliances, lighting, and new residential construction. Under the EPA's calculation of emissions-reduction goals, they used a 1.5% annual increase in demand-side efficiency (United States Environmental Protection

Agency, 2014a). While this is not a requirement to be a part of any state's final portfolio of methods, many states already have energy efficiency programs in place, and they will be able to use those efficiency increases as part of their compliance under the Clean Power Plan. Because so many states have developed similar programs with little coordination, there is no standard in place for measuring, or estimating, and reporting the efficiency savings from specific measures. The EPA has not yet explained how the savings reported at each state will be accounted for under the savings requirement for the Clean Power Plan, and this could cause potential conflict between different states, within utilities that operate in different regions, and between the states and the EPA. Because each state potentially has a different method for calculating savings from energy efficiency measures, the emissions reductions for these states will not necessarily be the same for the same measures taken.

In the Clean Power Plan, the EPA proposes that states that use the fourth building block: energy efficiency, must provide a description for EM&V of the included efficiency measures. Under the proposed regulations, the EPA would require states to submit their EM&V plans for approval in order to justify their reported level of emissions reductions from efficiency increases, and the type of EM&V plans approved will vary based on the approach that the state takes in developing its plan for compliance under the Clean Power Plan. As described earlier, the states that develop a mass-based reduction goal will be able to directly monitor the carbon emissions in order to verify their level of emissions reductions. For the states that use a rate-based goal, they will need to submit details on the monitoring and verification of the savings derived from energy efficiency measures. In its proposal, the EPA also recognizes that the existing methods of evaluation used by the states are similar for well-established technologies, and it may be possible to quickly approve plans involving these measures, but there are other new, less common measures that do not have a track record of reliable energy efficiency savings. While the final rule has not been published yet, the EPA has suggested three possible approaches for handling EM&V reporting for state plans in the "State Consideration Technical Support Document": (United States Environmental Protection Agency, 2014a)

- “Establishing specific EM&V requirements with a level of defined rigor – such as a required minimum level of precision and accuracy for all energy efficiency programs and measures”
- “Establishing specific EM&V requirements for certain types of widely used energy efficiency programs and measures – such as those addressed by DOE’s Uniform Methods Project (UMP) – while establishing a generalized EM&V approach that states can apply to programs that are relatively new, innovative, or untested”
- “Establishing a set of generalized, process-oriented EM&V requirements that apply to all energy efficiency programs and measures, while providing flexibility to customize EM&V approaches, as appropriate for different types of programs and measures, provided that EM&V meets these minimum requirements”

Even though EM&V can be very similar for well-established measures, due to differences in regulatory structure, level of experience, and individual state techniques, the overall process can still vary considerably between states. Because of this, the EPA may require “harmonization of state EM&V approaches” or supplemental EM&V submissions in order to comply under the requirements of the Clean Power Plan (United States Environmental Protection Agency, 2014). The EPA’s State Consideration TSD explains how different inputs and methods used in determining energy efficiency savings can result in different savings claimed on the same type of measure implemented (United States Environmental Protection Agency, 2014a). In order to address this issue of inconsistent savings reporting, multiple state, regional and national groups are working together to develop standard methods of EM&V. The use of a standard set of protocols in evaluating energy efficiency savings would be useful in streamlining the approval process of state plans submitted under the Clean Power Plan, but the potential costs of a universal evaluation structure must be weighed as well. It would be much easier, and less expensive for states that have already established reporting structures for state-specific reduction programs to use that evaluation for their submission under the Clean Power Plan.

One program mentioned is the UMP, which is being developed by the U.S. Department of Energy (DOE) – Office of Energy Efficiency & Renewable Energy, in collaboration with industry stakeholders. The DOE is developing the UMP in order to provide a structure of EM&V for the most common measures implemented in energy efficiency programs. The UMP is being developed for voluntary use for states and utilities, but provides several benefits to its adopters, such as increased consistency and easier, cheaper program implementation. Widespread use of a standard method of EM&V will also result in stronger efficiency programs in the future through the development of best practices and increased reliance on the reported savings from program implementation. While the government acknowledges in its proposal that the UMP is not the only reliable method for calculating EM&V, a uniform method provides certain benefits to regulators and industry stakeholders when designing energy efficiency programs because "they are consistent with accepted practices" and "they have been vetted by technical experts in the field of energy efficiency program evaluation." For many programs, using a standard like the UMP will help keep costs lower and more predictable. (United States Department of Energy)

The UMP is directed toward developing a set of standard protocols for the most widely-adopted residential and commercial energy efficiency measures that are part of utility-administered programs. The residential proposals developed by the UMP include furnaces and boilers, lighting, behavior, and refrigerator recycling, while the commercial protocols include measures such as lighting and lighting control, HVAC controls, chillers, new construction, and retrocommissioning. Additionally, UMP provides guidance on the evaluation of technologies that are applicable to both commercial and residential customers: efficiency upgrade of small unitary and split system HVAC cooling equipment and whole-building retrofit with consumption data analysis. The development of these measures was initially divided into two phases, so there are still several protocols to be published, including residential new construction. Further analysis of these measures is recommended once they have been published and are able to be compared to currently used methods (United States Department of Energy).

Residential lighting has been a significant part of demand-side energy efficiency programs that utilities have offered as part of state programs. According to the DOE, existing programs focus on subsidizing the purchase or installation of compact fluorescent lamps, along with Energy-Star rated fixtures and LED lamps. The analysis of savings from these programs has become more difficult due to the Energy Independence and Security Act (EISA), which introduced requirements to increase the energy efficiency of the most common types of light bulbs. This requirement has increased the difficulty of calculating savings of utility efficiency programs because it is now more difficult to determine an accurate baseline for comparing energy use of lighting installed as part of an energy efficiency program. The estimated savings from an installed CFL decreases as the efficiency of comparable alternatives increase. The UMP attempts to control for variation like this in its proposed method (Dimetrosky, Parkinson, & Lieb, 2015).

The UMP proposal identifies four typical methods of administering lighting improvements in energy efficiency programs. The first is to target the cost of CFL and LED lamps by either working with manufacturers or retailers to reduce the actual price for customers. The second method is installing CFLs and LEDs as part of energy audits offered as part of their savings plan. The costs of participation vary according to each program, and there may be additional charges based on the amount and type of bulb installed, but this type of program still results in significant savings for the customer and a considerable amount of installed measures for the utility to track. An additional benefit of this type of program is that program administrators can directly track the wattage and lumens of the lamps installed, which makes it easier to directly estimate the overall energy savings. In contrast to programs that rely on customers to purchase and install efficient lamps, it is difficult to know with certainty if each lamp was installed. Finally, direct installation allows administrators to track the type of application for each lamp installed, which also helps to determine the amount of use the lamp gets, based on the location within the house. Replacing lamps in fixtures in the most commonly used areas of the house will result in significantly greater overall savings. The third method of promoting lighting efficiency is giving away CFLs or LEDs to customers. The fourth method is to provide coupons to customers in order to subsidize the price of efficient lighting products. These can be either mail-in or point-of-sale rebates provided at the store. Different approaches may be needed to determine the best estimate of energy savings from each of these methods, and individual programs must prioritize their resources dedicated to program offerings and evaluation methods.

The protocol proposed through the UMP should be used as guideline for developing specific EM&V practices in each individual program. The formulas for estimating kW and kWh savings in the UMP proposal incorporate annual operating hours, peak coincidence factor, in-service rate, and interactive heating and cooling effects. This UMP proposal provides instruction for determining the best way to measure or estimate the factors included in these formulas. This approach allows utilities to tailor their savings estimates to the local conditions of each program (Dimetrosky, Parkinson, & Lieb, 2015).

Residential heating is another significant component to many state energy efficiency programs. Many of these programs use Annual Fuel Utilization Efficiency (AFUE) as a way to evaluate energy efficiency for residential heating equipment. This rating reflects the amount of heat a furnace produces compared to the energy that is put into the system. Additional measures not covered under the UMP proposal are Electronically Commutated Motors (ECMs), which provide for increased efficiency of furnace fan operation and outdoor temperature reset controls, which are used to increase the efficiency of hot water heating systems. While some installations are a part of comprehensive energy audit or whole-house retrofits, they are often administered in the form of a rebate to the customer. In order to determine the savings from each measure installed, the AFUE of the new unit must be compared to a baseline efficiency, which can be the actual efficiency of the unit being replaced, or the lowest efficiency that is legally available, according to applicable building code. The proposed UMP is designed around providing a rebate that offsets a major portion of the incremental cost between a system that operates at baseline efficiency and a higher-efficiency system (Jacobson, 2013).

Residential behavior-based programs are a recent addition to utilities' demand-side energy efficiency programs. According to the UMP protocol, they were first used in 2008, and when used, savings from these programs account for about 5% of total energy use. Applications of behavior-based programs are varied, including: customized energy usage reports to customers, real-time tracking of usage, smart meters, and WiFi-enabled thermostats. These programs typically target behavior modifications that will result in savings across multiple areas of use, and can result in gas, electricity, and water utility savings. Because of this complexity and the relative inexperience programs have with these measures, accurately evaluating and measuring savings can be very difficult (Stewart & Todd, 2015).

Utilities often include refrigerator recycling as part of their energy efficiency programs. These programs specifically target appliances that are still operating, but at a much less efficient rate compared to new models. Participants are offered free recycling and sometimes financial rebates as incentives to participate. One of the main drivers of this type of program is consumer behavior when purchasing a new appliance. If the old refrigerator is still operable, there is a tendency to keep it as a backup or donate or sell it, but either of these actions will negate any of the positive impact the purchase of a new, efficient appliance would have had. (Bruchs & Keeling, 2013). The UMP addresses the savings associated with the recycling of inefficient refrigerators and does not estimate savings based on the purchase of a new refrigerator. The UMP also developed a method for determining net savings from refrigerator replacement, which is adjusted to reflect expected consumer behavior of appliance replacement and recycling. This calculation also considers the increased energy that will be used as a result of new refrigerators that will have to be purchased, due to the recycling of their inefficient unit. The calculations for determining kWh savings take into account the average annual usage of the unit and the portion of the years the unit is used. The UMP protocol explains in detail how to calculate the values needed for each equation, in order to determine an accurate estimate of net or gross kWh saved through this program (Bruchs & Keeling, 2013).

Methods

This analysis will demonstrate the differences in how the methods of calculating energy savings from efficiency programs varies across existing state programs, along with how the proposed protocols under the UMP compare to each state's savings. In order to demonstrate how the proposed UMP protocols differ from existing state methods of estimating energy savings, this analysis focuses on four states with existing Technical Reference Manuals (TRM): Minnesota, Wisconsin, Michigan, and Massachusetts. Wisconsin and Michigan were initially chosen as regionally-similar states for comparison to Minnesota, with similar climates and historical focus on energy efficiency. While Massachusetts is not in the same part of the country, its strong history of energy efficiency programs and recently-updated TRM provided good cause for comparison (Halfpenny, et al., 2012). While not essential for completing this analysis, knowing the differences in climate can be important when evaluating the savings from each program. The four states in this analysis are all heating-intensive, shown by the following heating degree-days[1].

Table 2. Heating Degree-Days for MN, WI, MI, and MA
(Based on data from capital cities, using a base temperature of 65 °F)

	Minnesota (St. Paul)	**Wisconsin (Madison)**	**Michigan (Lansing)**	**Massachusetts (Boston)**
Average HDD (1971-2000) (% difference from MN)	7,876	7,493 (-4.9%)	7,098 (-9.9%)	5,630 (-28.5%)

Source: (National Oceanic and Atmosperic Administration , 2002)

As mentioned earlier, some energy efficiency measures, like lighting and refrigerator replacement, have been used in state programs for many years, and, although they use different methods of evaluating the savings from these measures, the results are more accurate because they are based on these years of experience and data collection. While residential furnace replacement has a long history of implementation in utility energy efficiency programs, I am limiting my analysis to measures that impact electricity savings, while recognizing the

[1] Heating degree-days measure the amount of energy needed to heat a building, based on outside temperature. It is calculated by subtracting average daily outside temperature from the base temperature. In this example, a 40 °F day would equal 25 HDD (65 °F - 40 °F). Each daily HDD value is totaled for an annual estimate of heating demand.

opportunity for future analysis of gas-saving measures like furnace replacement. There are other measures, like residential behavior, that are used by state programs, but there is no widely accepted standard measuring the energy savings. Because of these discrepancies, I am focusing my analysis on residential lighting and residential refrigerator replacement. The available data on past installations, measurement techniques, and recorded energy savings make these measures good candidates for analysis regarding a uniform method of EM&V. An evaluation of new and less-studied measures could show considerable difference between energy savings estimates, but that would not be reflective of the general state of EM&V across programs and measures. By evaluating the most commonly used efficiency measures, I will be able to demonstrate any significant difference between existing state programs and the proposed UMP.

My approach will begin with an evaluation of existing and proposed evaluation methods for residential lighting. While the UMP provides a proposed calculation for estimating kWh and kW from CFLs or LEDs installed, the variables needed for the calculation must be either measured or calculated based on the type of program through which the equipment is delivered to customers. Direct installation programs allow for more direct measurement of these factors, while customer rebates or upstream discounting must rely on estimations for most of the calculation. Additionally, each state considered in this analysis has different methods for calculating the energy savings from lighting installations. Using a common test scenario, and applying the estimation criteria for each existing state and the proposed UMP, I will be able to show any significant difference between program evaluation and measurement of energy efficiency measures.

In order to accurately calculate the difference in energy savings from refrigerator replacement between the four states and the UMP protocol, I will use a standard set of inputs that are applicable to every program, including number of units and average energy use of existing units. I will provide as much relevant data as possible from each method, and compare between each output, acknowledging any discrepancies between inputs or units of measure.

Analysis

This analysis of methods of estimating energy savings from existing state efficiency programs is designed to demonstrate any differences between those programs and the proposed standard UMP protocols. While the most accurate reports of energy savings will be obtained by considering the actual baseline consumption and appliance data, compared to the efficiency of the installed measure, collecting the necessary data is not always feasible for individual programs. As a result, state programs publish databases of deemed savings and TRMs, which provide the calculations needed for determining savings, often along with per-unit estimates of kW and kWh savings. Since the programs compared here provide estimates of deemed savings and estimates of the variables needed to determine overall savings, this analysis focuses on comparing the differences that result from these pre-determined factors. As a result, I have included two estimates of savings from the UMP for residential lighting. One estimate includes actual baseline and efficient wattage, while the other relies on baseline wattage estimates, which is more comparable to the methods analyzed by the other states in this analysis.

Refrigerator Recycling

For the following analyses, the energy efficiency savings protocols from each state program and the UMP will be applied to the following test scenario, which represents possible implementation of this measure across a small sample customer base.

- 15 refrigerators
    - Unknown amounts of use throughout the year.
    - Each method of estimation has a part-use factor from previous analysis.

This test scenario is designed to include all the information needed for thorough analysis, based on the variables that each program considers in its calculations. Table 3 shows the different inputs used by each state.

Table 3. Comparison of variables used for estimating energy savings from refrigerator recycling.

	Part Use Factor	**Annual Usage**
UMP	Estimated from program data	Estimated
Minnesota	Estimated from program data	Estimated
Wisconsin	Not provided	Estimated – adjusted for part-use
Michigan	Not provided	Estimated – adjusted for part-use
Massachusetts	Not provided	Estimated – adjusted for part-use

Refrigerator Recycling - Uniform Methods Project

The UMP protocol on reporting savings from refrigerator recycling includes a detailed assessment of customers' use of the refrigerators being recycled. The data collected includes determining if the appliance was a secondary or primary refrigerator along with an estimate of the months per year that the refrigerator was in use. Knowing the usage of the appliances throughout the year allows for more detailed analysis of energy use that can be used to develop more accurate savings compared to a program-wide estimate of a part-use factor. This protocol recommends that utilities use the most accurate approach for determining annual energy consumption by metering a sample of their customers' energy use. The UMP found that using Department of Energy estimates of energy savings are not as accurate as estimates generated from analysis of local participant data (Bruchs & Keeling, 2013). Once this metering is complete the program can determine deemed savings values that the UMP recommends updating every three years with new metering data. When a program does not have the resources to complete metering and data analysis, the UMP recommends adopting a model developed by another utility operating a program comparable in age, location, and demographics. When a similar program is not available, the UMP provides an annual usage, based on its own analysis of customer metering, of 1,240 kWh/year (Bruchs & Keeling, 2013). This is the approach I will use in my analysis, because conducting a metering study is not feasible, and adopting a model from another utility would negate the benefits of a comparison between the UMP and the state programs. Additionally, the UMP recommends that programs use surveys from their customers to determine a part-use factor, which adjusts the energy savings to account for appliances that were not in use for the entire year. Since this analysis does not have a large customer base, I will use a part-use factor of 0.88, which was identified through an example in the UMP protocol (Bruchs & Keeling, 2013). This fits within the range of 0.85 to 0.95 reported to be common by the UMP. Using the UMP proposed method, the estimated annual savings from the test scenario above is 14,880 kWh.

Refrigerator Recycling - Minnesota

Minnesota's TRM has a specific section for calculating the energy savings from the removal of a secondary refrigerator in residential settings. This protocol requires that the units that are removed must currently be used as a working, secondary refrigerator. If the customer is actually replacing a refrigerator, instead of removing one, the amount of savings will be significantly lower than that calculated using this approach.

Minnesota's calculations include gross kWh savings per year for each unit per refrigerator removed along with peak kW savings per refrigerator. The calculations are shown below:

Unit kWh Savings per Year = Gross_Annual_kWh

*Unit Peak kW Savings = Gross_kW * Part-Use Factor (PUF)*

(Minnesota Department of Commerce, 2015)

Minnesota's protocol for calculating savings is based on previous data analysis of metered data and modeling. As a result of this analysis, Minnesota uses an estimated energy savings of 915 kWh/year per unit and 0.159 gross kW savings, and assumes a Part-Use Factor of 0.865, which was derived from an analysis of an energy savings from an existing recycling program (Minnesota Department of Commerce, 2015). Additionally, since existing refrigerators have a limited lifespan, Minnesota counts the energy savings from this measure for 8 years. Under Minnesota's protocol, the customer and the contractor removing the unit would have to confirm that the unit to be removed is a working, secondary unit. There is no requirement or ability to use the actual usage of each recycled unit in determining the actual savings associated with this measure. The Part-Use Factor of 0.865 is a statistically-derived variable that accounts for the variation across the entire program.

Using the calculations above, under Minnesota's TRM, the test scenario of 15 refrigerators would report annual savings of 13,725 kWh and 2.07 peak kW savings. Savings from this measure would be reportable for each of the next 8 years.

Refrigerator Recycling – Wisconsin

Wisconsin's TRM provides a method for estimating savings from the removal of an operable refrigerator or freezer. The energy savings from this measure are able to be reported for each year for the remaining life of the appliance. The guidelines included in the protocol estimate the remaining life of participating refrigerators at 8 years. Unlike the UMP protocol analyzed earlier, Wisconsin's criteria do not involve tracking of usage statistics for each appliance. As a result, there may be significant differences between program estimates, especially in situations where removed appliances are not used for much of the year; Wisconsin's program will count the energy savings from those units equal to the removal of a unit that operated full-time. Wisconsin's TRM includes the following calculations.

Summer Coincident Peak Savings Algorithm:

- $kW_{SAVED} = [(kWh\ savings/unit)/HOURS] * Peak\ intensity\ factor$

Lifecycle Energy-Savings Algorithm:

- $kWh_{LIFECYCLE} = kWh_{SAVED} * Effective\ life$

(The Cadmus Group, Inc., 2015)

Wisconsin's annual energy savings are based on a recently-performed analysis that was based on a regionally-similar program and included part-use factors and actual monitoring of customer energy use. The estimated gross annual savings from refrigerator replacement is 1,071 kWh per unit. The TRM also provides an estimate of annual operating hours (8,760), a peak intensity factor (1.01), and a peak demand reduction of 0.123 kW/ unit (The Cadmus

Group, Inc., 2015). The annual energy savings from refrigerator replacement are 16,065 kWh and 1.845 kW.

Refrigerator Recycling – Michigan

Michigan's Public Service Commission has published the Michigan Energy Measures Database (MEMD) as a standard for utilities and energy-efficiency programs across the state to use for calculating savings from various energy efficiency programs. The database is a list of the annual consumption and peak demand savings from efficiency programs that result in both gas and electric savings. Along with the estimates of energy savings for these measures, the database provides estimated values of the variables used to determine the savings per measure, but the Public Service Commission does not provide the actual calculations used when developing these estimates. For kW savings, the database provides estimates for non-coincident and coincident savings. Coincident savings are adjusted to reflect the customer demand that matches the peak demand of the utility. For my comparison, I will use the estimates of coincident savings, because they are more reflective of the demand savings reported by the UMP and other states.

For refrigerator recycling, the database estimates energy savings of per unit of 1,261 kWh and 0.146 kW, using an estimate of 8,760 annual hours and a coincidence factor of 1.0. Additionally, Michigan counts the savings from this measure for 8 years after refrigerator removal (Michigan Public Service Commission, 2015). The total annual energy saved from the test scenario of 15 refrigerators is 2.19 kW and 18,915 kWh.

Refrigerator Recycling – Massachusetts

The Massachusetts TRM is used by program administrators across the state to determine if their measures are cost effective, in order to be approved by the Department of Public Utilities. The TRM provides a table of estimated energy savings from both primary and secondary refrigerator recycling, along with freezer recycling. Other programs provide specific distinctions between removal versus replacement of refrigerators, and for consistency with the scope of those other programs, this analysis focuses on recycling secondary refrigerators that are not replaced once removed. The Massachusetts TRM assumes annual usage of 8,760 hours per appliance and a measure life of 8 years, which leads to a program-wide estimated energy savings of 0.1 kW and 835 kWh per unit (Massachusetts Electric and Gas Energy Efficiency Program Administrators, 2012). As a result of these assumptions, the total annual energy saved from the test scenario of 15 refrigerators is 1.5 kW and 12,525 kWh, reportable for 8 years after removal.

Residential Lighting

For the following analyses, the energy efficiency savings protocols from each state program and the UMP will be applied to the following test scenario, which represents possible implementation of this measure across a small sample customer base of single family and multi-family homes. Table 4 below shows the different inputs used across state efficiency programs. In this instance, “not provided” means that that input has either been considered in a background calculation that was not provided for review or not used by that program.

1. (60) 14-Watt spiral CFLs (800 lumens) replacing 60-Watt incandescent lamps
    a. (15) installed in bedroom with HVAC cooling
    b. (5) installed in bedroom without HVAC cooling
    c. (10) installed in living space with HVAC cooling
    d. (10) installed in living space without HVAC cooling
    e. (20) installed in multifamily common area with HVAC cooling
2. (32) 9-Watt globe CFLs (525 lumens) replacing 40-Watt incandescent lamps
    a. (32) installed in bathroom with HVAC cooling
3. (20) 15-Watt A-lamp CFLs (750 lumens) replacing 60-Watt incandescent lamps
    a. (10) installed in living space with HVAC cooling
    b. (10) installed in living space without HVAC cooling

Table 4. Comparison of variables used for estimating energy savings from residential lighting.

	Number of Installations	Baseline Wattage	Annual Hours	In Service Rate	Interactive Heating and Cooling Effects
UMP	Measured	Estimated from lumens	Estimated	Estimated	Estimated from program data
Minnesota	Measured	Program-wide estimate	Estimated	Not Provided	Estimated from program data
Wisconsin	Measured	Estimated from efficient wattage	Estimated	Not Provided	Not Provided
Michigan	Measured	Not Provided	Estimated	Not Provided	Not Provided
Massachusetts	Measured	Not Provided	Estimated	Not Provided	Not Provided

Residential Lighting - Uniform Methods Project

The UMP protocol for evaluating residential lighting provides guidance for utilities and regulators on how to best estimate energy savings from their programs. While there are four mechanisms for administering a residential lighting program (upstream incentives, direct installation, giveaways, and coupons), my analysis will focus on direct installations, because it allows for the most accurate data collection and verification of product installation. The UMP protocol provides calculations for both kWh and kW saved as a result of lighting installations (Dimetrosky, Parkinson, & Lieb, 2015). The calculations are shown below:

*kWh saved = NUMMEAS * (ΔW/1,000) * HRS * ISR * IEe*

*kW saved = NUMMEAS * (ΔW/1,000) * PCF * ISR * IEe*[2]

A number of factors in these calculations must be determined before the overall energy savings can be reported. The number of lamps installed should be tracked by the program administrator. The difference between the existing lamp and the efficient replacement (ΔW) can be either tracked with actual installation values, or estimated using one of several

[2] NUMMEAS = number of measures sold or distributed through the program
HRS = annual operating hours
ΔW = difference between baseline and efficient lighting measure
PCF = peak coincidence factor
ISR = in-service rate
IEe = cooling and heating interactive effects

approaches outlined in the UMP protocol. If the actual baseline wattage cannot be tracked, the approach recommended by the UMP is to use the ENERGY STAR lumen equivalency ratings, adjusted to incorporate EISA[3] requirements, which has caused baseline lighting efficiency to increase (Dimetrosky, Parkinson, & Lieb, 2015). This approach allows program administrators to estimate a baseline wattage based on the lumens and wattage of the CFL that is installed, without having to track actual replacement wattages. The UMP protocol provides the data needed for estimating baseline wattage using this method. The UMP recommends that each program conducts a metering study to determine average hours of use and peak coincidence factor, but if this is not possible, program administrators can use secondary data for their models. The UMP protocol lists several examples of hours of use from recent studies. For this calculation, I will use 2.8 daily hours (1,022 annual hours) of use, which is the rate reported from studies in Georgia, Massachusetts, Rhode Island, Vermont, Connecticut, and Ohio.

The in-service rate (ISR) is an important factor because it adjusts energy savings for the percentage of lamps that are actually installed as a result of the program. This value can significantly change the energy savings reported, depending on the method of implementation. Studies of upstream CFL programs have reported only 72 – 82% of CFLs are installed within the first year (Dimetrosky, Parkinson, & Lieb, 2015). Since I am evaluating savings based on direct installation of CFLs, I will assume a 100% ISR. The UMP protocol recommends adjusting energy savings based on interactive effects from HVAC systems. This factor adjusts savings estimates to account for the reduced heat that is produced by CFLs compared to incandescent lamps. UMP recommends conducting a simulation model, or coordinating with regional partners, to estimate these effects, but if these are not feasible options for the program, the administrator can use a value from an existing program in a region that shares similar HVAC and climate characteristics. Similarly, the UMP recommends each program perform an analysis based on metered data to determine the peak coincidence factor, but allows for use data from an existing program when it is not feasible to run an independent study (Dimetrosky, Parkinson, & Lieb, 2015). For simplicity, I will use the interactive effects and peak coincidence factor from

[3] EISA (2007 Energy Independence and Security Act) required the energy efficiency of screw-based lamps to increase, beginning in 2012.

Minnesota's lighting protocol, while acknowledging the possible decrease in variability in energy savings between programs as a result. Using the calculations in the UMP for direct installation of CFLs that tracks actual baseline wattage would result in annual savings of 4974.14 kWh and 1.214 kW.

For additional points of comparison, I have included an analysis of the test scenario in a situation where the baseline wattage of the lamps that were replaced is not able to be recorded. For this estimate, I used the ENERGY STAR guidelines described in the UMP protocol. Using the calculations in the UMP for indirect installation of CFLs that estimates baseline wattage would result in annual savings of 3600.32 kWh and 0.809 kW.

Residential Lighting - Minnesota

Minnesota's TRM has a specific section for calculating the energy savings from CFLs in residential applications. This protocol allows for the replacement of both working and non-working lamps. In order to accurately estimate the energy savings from this measure, the contractor or customer should provide information on the type of room where the lamp was installed and the HVAC system of the house.

Minnesota's calculations include kWh savings per year for each lamp replaced, along with peak kW savings per lamp (Minnesota Department of Commerce, 2015). The calculations are shown below:

Unit kWh Savings per Year = (kW_Base - kW_EE) x Hours x HVAC_cooling_kWhsavings_factor

Unit Peak kW Savings = (kW_Base - kW_EE) x CF x HVAC_cooling_kWsavings_factor[4]

Minnesota's protocol for calculating savings from CFLs is based on an analysis of Xcel Energy's Home Lighting Program and existing DOE and California building models and simulations

[4] kW_EE = Deemed average wattage for efficient lamp
kW_Base = Deemed average wattage of baseline lamp
CF = Coincidence Factor, the probability that peak demand of the lights will coincide with peak utility demand
HVAC_cooling_kWhsavings_factor and HVAC_cooling_kWsavings_factor = Cooling system energy savings factor resulting from efficient lighting

(Minnesota Department of Commerce, 2015). As a result of this analysis, Minnesota uses an estimated baseline wattage of 0.0488 kW and an estimated wattage of efficient lamps of 0.0190 kW. For homes that have HVAC cooling, Minnesota's protocol provides a HVAC Cooling kW Savings Factor of 1.248 and a HVAC Cooling kWh Savings Factor of 1.075 (Minnesota Department of Commerce, 2015). These factors are used to adjust the estimated savings from lighting replacement, because efficient lighting emits less heat than incandescent lamps, which will decrease the cooling load for the house. Minnesota also provides a Coincidence Factor (CF) of 9.5% for interior living space, 75% for multifamily common areas, and 0% for exterior spaces (Minnesota Department of Commerce, 2015). This factor is important in calculating the peak kW savings, since it accounts for the times that the peak demand of a home's lighting and the utility's peak demand overlap. Higher CF values will have a greater impact on reducing a utility's peak demand. Programs using Minnesota's protocol for to determine energy savings use estimates of annual hours of operation of 938 hours for interior living spaces, 5,950 hours for multi-family common areas, and 1,825 hours for exterior spaces (Minnesota Department of Commerce, 2015). Using the calculations provided by Minnesota's TRM, the test scenario detailed above would result in annual savings of 6,524.25 kWh and 0.865 kW.

Residential Lighting – Wisconsin

Wisconsin's TRM provides a variety of methods for estimating energy savings from efficient lighting, including CFL and LED direct install and retail markdowns. For this analysis, I will focus on the direct installation, for which Wisconsin has developed a series of calculations and estimated values in order to produce a set of deemed savings for both single family and multi-family residences. These deemed savings estimates make program administration easier, but such reliance on broad estimates of savings can result in less accurate analysis compared to programs that record actual baseline data. This model uses the following equations to determine energy savings (The Cadmus Group, Inc., 2015).

- $kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * \text{Annual hours of use}$
- $kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * CF$

While $Watts_{EE}$ is recorded as the wattage of the new lamp installed, values for $Watts_{BASE}$ are provided in the evaluation protocol, along with estimates of hours of use and effective life. Since the deemed savings database published with Wisconsin's TRM does not include a savings estimate for 15W CFLs, I will use the equation provided above, estimating the baseline wattage being replaced as 43 watts, based on EISA lighting efficiency guidelines. The annual energy savings as estimated by Wisconsin's TRM for the test scenario detailed above are 2388.24 kWh and 0.21 kW.

Residential Lighting – Michigan

The Michigan Energy Measures Database lists estimates of energy savings from direct installation of CFLs for a variety of wattage, but it does not provide the exact calculations used to determine the kW and kWh savings that are reported (Michigan Public Service Commission, 2015). Most of the measures that are part of the test scenario are included in the database, but there was no entry for determining savings from a 15W CFL, so I have used the information provided by the state for 14W CFLs, while acknowledging this slight difference in usage.

For residential lighting, the Michigan Energy Measures Database reports the annual energy use and peak demand savings, along with the assumed values for hours of operation and coincidence factors used to generate those estimates. According to the Michigan Energy Measures Database, the test scenario would save an estimated 5,290 kWh and 0.9028 kW.

Residential Lighting – Massachusetts

Massachusetts's TRM provides estimates of energy savings from CFLs for a variety of applications. Included in this protocol are deemed savings from rebates of Energy Star CFLs, low-income and multi-family installation, new construction, and Home Energy Services, which is a program that provides direct installation of CFLs, along with other products and information on home performance (Massachusetts Electric and Gas Energy Efficiency Program Administrators, 2012). This analysis focuses on the savings from Homes Energy Services, which is similar to direct-installation programs in other states. Massachusetts uses an estimated 1,022 annual hours of operation, and considers the impact of in-service rates, coincidence factors, and persistence factors to calculate an estimated annual energy savings for any type of screw in lamp in the Home Energy Service of 0.008 kW and 26 kWh (Massachusetts Electric and Gas Energy Efficiency Program Administrators, 2012). There is no distinction in the deemed savings provided for variation based on the wattage of the CFLs installed. According to the Massachusetts TRM, the estimated annual savings from the test scenario would be 0.90 kW and 2,912 kWh annually.

Results and Discussion

As shown in the following tables, there is a significant variation in the energy savings calculated and reported for both refrigerator recycling and residential lighting. There is no specific error causing these differences, but when states and utilities create their own databases of deemed savings and calculations used for estimating energy savings, the different factors considered and the different values used have a large impact on the overall savings that are reported.

For the measures used to conduct this analysis, 15 refrigerators and 112 CFLs, there is a significant difference between Minnesota, Wisconsin, Michigan, Massachusetts and the UMP recommended protocols. Overall, the UMP recommended more direct monitoring of baseline behavior and baseline energy use, where Minnesota, and to a greater extent, Wisconsin, Massachusetts, and Michigan relied more heavily on predetermined deemed savings values and estimates of usage. While program administrators in these states can conduct monitoring and use actual implementation data, the TRMs and deemed savings values are organized and produced because they are easier to use than calculating actual savings for each measure.

Refrigerator Recycling

As shown below in Table 4, there was a significant difference between the energy savings reported from the same test scenario of refrigerator removal, as measured by each state's method of calculation or deemed savings database.

While Wisconsin's estimate was very close to that from the UMP, Minnesota and Michigan both were around 16% less than the UMP estimate, and Massachusetts estimated significantly lower savings compared to the UMP (-23.5%). A difference of this magnitude can be an important factor when program administrators are deciding on the individual programs that will make up their portfolio of demand-side efficiency measures. The UMP does not include a method of estimating kW savings from refrigerator recycling. Table 4 shows the variation between the fours states' electricity demand savings.

Table 5. Annual Energy Savings reported from Refrigerator Recycling

	Refrigerator Recycling (kWh)	Deviation from UMP - kWh	Refrigerator Recycling (kW)	Difference from MN
UMP	16,368		n/a	
Minnesota	13,725	-16.1%	2.07	
Wisconsin	16,065	-1.9%	1.85	-10.6%
Michigan	18,915	15.6%	2.19	5.8%
Massachusetts	12,525	-23.5%	1.5	-27.5%

The primary reasons for this difference are the different values that each program uses for the variables that are part of the calculation of energy savings. For refrigerator recycling, the main factors that can influence total savings estimates are the part-use factor and annual usage of the refrigerator.

For refrigerator recycling, the UMP protocol recommends that each program conduct sampling and data analysis in order to determine a part-use factor that can be used as an average program-wide estimate. Since the UMP is not an actual program, no part-use factor has been developed, so I used 0.88, which was identified in an example in the UMP protocol, and falls in the common range of 0.85 – 0.95 (Bruchs & Keeling, 2013). For comparison, Minnesota uses a part-use factor of 0.865, which is very close to that used for the UMP estimate and would not be responsible for the difference in calculated savings (Minnesota Department of Commerce, 2015). The TRMs for Wisconsin, Michigan, and Massachusetts do not provide the part-use factors used to determine their deemed savings estimates, but each program explained that their values used were based on data analysis of their own program or an existing evaluation of a similar program. This analysis does not suggest that each program should use the same part-use factor. In fact the UMP recommends that each program should monitor their own statistics in order to determine a factor that reflects the actual local conditions where they operate. While this factor might contribute to the different energy savings reported, as long as each program has developed their factor based on the correct local data, this difference in energy savings reported does not reflect a difference in the method used.

Another significant factor in determining energy savings is the assumed annual usage of the refrigerators being recycled. Again, like with the part-use factor, the UMP recommends that each program conduct metering of local data, or use the evaluation of a similar program, to determine the average energy use of each refrigerator, and the UMP recommends programs update their deemed savings values every three years. The UMP provides an example calculation for annual energy use of 1,240 kWh, and recommends that programs use this data for their analysis if they cannot conduct their own metering and there is no similar program whose data can be used. After being adjusted for part-use, the states and the UMP reported the following values for annual usage.

Table 6. Adjusted Annual Usage for Secondary Refrigerators

	UMP	Minnesota	Wisconsin	Michigan	Massachusetts
Annual Usage (kWh) (Difference from UMP)	1,091	915 (-16.1%)	1,071 (1.8%)	1,261 (15.6%)	835 (-23.5%)

Source: (Bruchs & Keeling, 2013) (Minnesota Department of Commerce, 2015) (The Cadmus Group, Inc., 2015) (Michigan Public Service Commission, 2015) (Massachusetts Electric and Gas Energy Efficiency Program Administrators, 2012)

As with the previously explained part-use factor, as long as each state is conducting accurate monitoring and testing, or basing their values on a similar program, there is nothing to suggest any of these estimates are incorrect. Although these estimates might be correct based on analysis of local data, it makes it very difficult to compare programs or to use this data as a means to comply with a federal regulation like the Clean Power Plan. States might design very different programs to meet their emissions reduction goals if they use their current method of estimating savings. While it is possible that the existing stock of refrigerators and behaviors related to their use vary significantly between these states, the results of this scenario suggest that the data analysis and modeling need further review.

Residential Lighting

As shown in table 7, there was significant variation in the estimate of energy savings as a result of the test scenario, with annual energy consumption savings from 2,912 kWh to 6,524 kWh, and demand savings ranging from 0.81 kW to 1.21 kW. There are three main factors that contribute to the significant differences shown here: baseline wattage, annual hours of use, and interactive cooling effects.

Table 7. Annual Energy Savings Reported from Residential Lighting Installation

	Residential Lighting (kWh)	Deviation from UMP – estimated (kWh)	Residential Lighting (kW)	Deviation from UMP – estimated (kW)
UMP (estimated baseline)	3,600 kWh		0.81 kW	
UMP (recorded baseline)	4,974 kWh	38.2%	1.21 kW	49.4%
Minnesota	6,524 kWh	81.2%	0.87 kW	7.4%
Wisconsin	2,388 kWh	-33.7%	0.21 kW	-74.1%
Michigan	5,290 kWh	46.9%	0.90 kW	11.1%
Massachusetts	2,912 kWh	-19.1%	0.90 kW	11.1%

In order to have an accurate basis for comparison, this analysis focuses on comparing the estimates based on the savings estimates provided by the states' TRMs. For the most accurate estimates of energy savings, the UMP recommends that programs record actual baseline wattages, and that each state conduct its own metering and data analysis to determine values for all the variables that are used when calculating total energy savings (Dimetrosky, Parkinson, & Lieb, 2015). While individual states allow programs to submit data on savings based on actual values, the TRMs are designed with many assumptions built in so program administrators do not have to collect such detailed information.

Specifically, Minnesota's TRM requires the following for calculating energy savings:

> **Required from Customer/Contractor**: device type (CFL lamp or ENERGY STAR Torchiere), space type (interior living quarters, multifamily* common areas, or exterior/unconditioned space), HVAC System (heating only, heating & cooling, exterior/unconditioned) (Minnesota Department of Commerce, 2015)

This program requires several important factors to be considered to estimate energy savings, but nowhere in the details of this measure for Minnesota is a requirement to collect baseline wattage data from program participants. As a result of this and similar requirements for the other states in this analysis, the method most likely to be used by local administrators would incorporate the estimates provided in the TRMs, instead of more intensive data tracking. As a basis of comparison, I have included UMP savings estimates calculated using the actual baseline wattage, since that is the recommended method, but also the energy savings calculated using baseline wattage estimated according to the UMP protocol. This estimated baseline will serve as the comparison for this analysis, since it is a closer representation to the methods used by the states. Of the four states reviewed, Minnesota and Wisconsin provide calculations and estimates of baseline wattage, while Michigan and Massachusetts do not provide the same level of detail.

Baseline wattage is one of the most important factors that vary between programs and has a significant impact on the savings estimated by each state. For standard CFLs, the UMP uses an EISA-adjusted baseline wattage based on lumens. The following table shows how the UMP estimates baseline wattage.

Table 8. Standard Lamp Estimated Baseline Wattage for Lumen Equivalencies in the UMP Residential Lighting Protocol

Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent Wattage	
		Baseline (Exempt Bulbs) (c)	Baseline (Post-EISA) (d)
2,000	2,600	150	72
1,600	1,999	100	72
1,100	1,599	75	53
800	1,099	60	43
450	799	40	29
310	449	25	25

Source: (Dimetrosky, Parkinson, & Lieb, 2015)

For comparison, Minnesota's TRM provides a composite estimate for baseline wattage of 48.8W and a composite for new CFLs of 19W (Minnesota Department of Commerce, 2015). Although these value are calculated using adjusted values similar to those used by the UMP for estimating savings, the composites values are the inputs used for calculating savings. This value for all CFLs in MN programs, although easier for program administrators, leads to less accurate savings estimates.

Wisconsin uses the following estimates for baseline wattage, based on the wattage of the new CFLs. This method differs significantly from the UMP and MN, which determine baseline wattage from lumens, instead of CFL wattage. This difference is shown in the following table.

Table 9. Baseline and Efficient CFL Wattage from Wisconsin TRM

$Watts_{BASE}$	MMIDs	$Watts_{EFFICIENT}$
72	2119 and 2135	23
53	2118 and 2134	19
43	2117 and 2133	14
29	2116 and 2132	9

Source: (The Cadmus Group, Inc., 2015)

For most standard CFLs, this different approach will not result in substantial differences between methods. Since CFL wattage corresponds to a set lumen range, based on Energy Star standards, there is not much difference between the UMP and Wisconsin's methods. Minnesota's method of providing composite values for wattage can result in significantly different outcomes. For example, as seen in table 10, a 14W, 800 lumen CFL will result in the following ΔWatt.

Table 10. Baseline wattage for a 14W, 800 lumen spiral CFL.

	$Watts_{BASE}$	$Watts_{efficient}$	ΔWatt
UMP	43W	14W	9W
Minnesota	48.8W	14W	14.8W
Wisconsin	43	19W	9W

While determining baseline wattage values is an important part of this analysis, there are other factors that can impact the energy savings from these measures. Annual hours of operation can vary significantly between programs, and this difference is reflected in the overall savings reported. The UMP recommends each program conduct data analysis to determine the most accurate values for hours of operation. As shown below in table 11, the variation for single family installation is not very significant, but multi-family installations have drastically different estimates of hours, which will impact overall energy savings.

Table 11. Hours of Operation for CFLs Based on Housing Type

	UMP	Minnesota	Wisconsin	Michigan	Massachusetts
Single Family (Difference from UMP)	1,022 hours	938 hours (-8.2%)	829 hours (-18.9%)	840 hours (-17.8)	1,022 hours (0%)
Multi-family Common Area (Difference from UMP)	1,022 hours	5,950 hours (482.2%)	734 hours (-27.8)	4,380 hours (328.6%)	1,022 hours (0%)

Source: (Bruchs & Keeling, 2013) (Minnesota Department of Commerce, 2015) (The Cadmus Group, Inc., 2015) (Michigan Public Service Commission, 2015) (Massachusetts Electric and Gas Energy Efficiency Program Administrators, 2012)

One additional factor that can impact total savings is interactive effects between lighting and heating and cooling loads. The decreased heat produced from CFLs compared to incandescent lamps will cause air conditioning units to run less frequently. The UMP recommends programs account for these effects in their calculations. In this sample, only Minnesota explicitly provides their value for this effect. The additional energy savings from reduced cooling load in Minnesota increases kWh savings 7.5% and kW savings almost 25% (Minnesota Department of Commerce, 2015).

Conclusions

If we use the UMP protocols as a guide for comparison, the states analyzed have followed the general advice for conducting program monitoring and data analysis or have used values from a similar program and still generate very different estimates of savings. These differences lead to several recommendations for further analysis:

Direct monitoring of energy use

Although each program has conducted monitoring or based their estimates of energy savings on data from existing programs, there is still a large difference in savings reported from a common scenario. Extensive monitoring of actual usage can help determine if a standard for energy savings can be proposed, if not nationally, at least on a regional scale. The increasing implementation of smart meters and sub-metering in residential and commercial applications will be an important part of revising estimates for the factors used for many efficiency calculations. As adoption of this technology increases, these programs can rely less on estimates and more on program-specific consumption data when calculating savings.

Analysis of other methods of lighting implementation

This analysis evaluated the savings from direct installation of CFLs in a residential setting only, and there are many other methods of delivery that should be considered, as well as entirely different protocols for commercial and industrial applications. Further work is recommended to show if the similarities and differences shown here carry over into these other applications.

Analysis of states with no TRM

While many states have TRMs, there are other states that have either not developed any efficiency programs, or have not developed a standard way of reporting savings from their program. Further analysis into the calculation and reporting structure for the utilities in these states would possibly present a good opportunity for introducing a standard, such as the UMP.

Analysis of HVAC savings

While this analysis focused on electrical savings because the Clean Power Plan is focused on reducing carbon emissions from electricity generation, natural gas is a significant source of energy in our lives, and HVAC equipment is the highest use of gas in residential settings. HVAC replacement is a significant part of existing state efficiency programs, and the methods and savings reported from these measures should be compared against the proposed UMP protocol to see what effect a proposed standard would have on reported savings.

This analysis has shown that there are significant differences between ways that existing state programs and the proposed UMP protocols estimate savings from demand-side efficiency measures. While these differences are not noticeable when each state is working on a local scale, it is becoming a more important issue as we consider the uncertain regulatory requirements for compliance under the Clean Power Plan. If states are allowed to submit demand-side efficiency savings using their own justifications, the reduction of carbon emissions for some measures will be much different based on the method used. While this is not as much a concern for states that have developed and accepted these methods, there are many states with little structure in place for calculating and reporting efficiency savings. Seeing the difference between existing methods shown here, it will be important to determine how states that have to develop evaluation criteria for compliance under the Clean Power Plan will be influenced to by the different estimates of savings between existing programs.

The EPA has created an opportunity with the introduction of the Clean Power Plan to reevaluate how existing utilities and state regulatory agencies measure and report savings from demand-side energy efficiency measures. When states' efficiency programs were independent from the review of the federal government, there was little issue with differences in evaluation methods and assumptions, but not when individual state plans are to be used for compliance under EPA regulations, there is a need for greater scrutiny of the methods used by each state.

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