Statewide Refrigerator Monitoring and Verification Study & Results

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ABSTRACT

Refrigerator rebate and/or replacement programs are popular in utility and government-sponsored energy efficiency programs, particularly in programs serving low-income households. A wide variety of approaches are used in the field to assess the energy usage and savings potential of existing refrigerators including very short term (e.g., 1-2 hour) metering, various adjustments to rated usage values, and simple rules of thumb based on age.

A multi-utility evaluation, sponsored by NSTAR Electric and Gas, National Grid (Massachusetts Electric Co and Narragansett Electric Co) and Northeast Utilities (Western Massachusetts Electric Co), is underway in Massachusetts and Rhode Island to assess and compare alternative approaches for estimating the energy usage of residential refrigerators and develop better estimates for energy and load savings from refrigerator replacements. The research design includes metering 160 existing and 30 new refrigerators for 2-4 week periods over the course of a year. Results from the metering of the first 95 existing and 13 new units are presented in this paper. The analysis has found that:

- The two approaches used by program contractors to estimate refrigerator usage based on the unit's rated usage are not very accurate
- Short-term metering, even for just ½ hour, is more accurate than rated usage approaches, particularly if adjusted for any difference between the current room temperature and estimated annual room temperature
- Short-term metering for one hour provides nearly the same net program benefits as metering for two hours, indicating that programs should not require metering for more than one hour unless the incremental cost is negligible. This finding is at odds with current recommendations and practice and results from the fact that a large proportion of program net benefits derive from replacing very high use units that are easily identified even with the lower accuracy of one hour metering, while the increased accuracy from two hour metering tends to affect decisions on units with a more marginal impact on cost-effectiveness.
- A reasonably accurate audit approach based on rated usage can be developed and needs to account for the estimated annual room temperature where the refrigerator is located and the presence of an icemaker (which is not included in the rating), other factors that may be worth incorporating into the audit include the number of occupants, whether the refrigerator is a primary or secondary refrigerator, and perhaps the age of the refrigerator.

Once all metering is completed, an "optimal" audit approach will be developed and the project results will be used to refine the refrigerator auditing approaches and savings estimation methods for the utility's programs. Interested readers should track down the final project report to get the full results based on the larger sample of units.

Introduction

The energy usage of residential refrigerators has declined dramatically during the past 30 years as Federal energy efficiency standards have reduced the typical usage of new units by about two thirds. Electric utility sponsored residential energy efficiency programs began to experiment with refrigerator replacement as a program measure in the early 1990's, particularly in programs targeted to low-income households that tend to have the oldest and least efficient units. Since then, refrigerator replacements have spread as an energy efficiency retrofit measure to many utility programs (including non-low-income programs), have been incorporated into the federally-funded low-income Home Weatherization Assistance Program, and have been included in government-sponsored programs funded by utility restructuring systems benefit charges in several states. Research on refrigerator replacement selection techniques and measured energy and load savings has been limited and available results may not extrapolate well across utilities, regions, climate zones, and years.

Current Refrigerator Auditing Methods

One of the issues in incorporating refrigerator replacements into an energy efficiency program is developing an approach for assessing the energy usage of the existing unit. The three most common refrigerator "audit" methods are: short-term metering, adjusted rated usage, and age-based replacements. Some programs have incorporated more than one approach.

<u>Short-term metering</u> approaches usually involve metering each candidate refrigerator's energy usage for a period of one to three hours and using that measurement to estimate annual usage. Because refrigerator usage is sensitive to the temperature difference across the unit, audits sometimes include a temperature correction factor of 2%-3% per degree Fahrenheit. The high-energy usage associated with defrost cycles is also incorporated into some metering protocols. Some audits attempt to avoid a defrost cycle by adjusting a timer screw while others attempt to at least identify a defrost cycle by monitoring wattage draw or freezer temperatures during the metering. Some vendors also use time-of-day correction factors. In terms of the length of time to meter, most audit protocols require at least two hours of metering and some require three hours based on various research reports and trade press articles (Moore 2001 and Cavallo and Mapp 2001). The *length* of metering has become an issue especially for programs where the existing length of the home visit is shorter than the required metering time.

<u>Adjusted rated usage</u> approach typically involves looking up each model's rated energy usage in a database of values based on DOE rating procedure test results (available from the Association of Home Appliance Manufacturers, AHAM, with some subsets available publicly). The rated usage at time of manufacture is typically adjusted for age-based performance degradation and sometimes other factors such as door style and defrosts type. The primary advantage of the rated usage is approach is that metering is not required and decisions can be made quickly. Some models are not found in the database and then metering is typically done. In addition, some programs allow the auditor to use metering when they believe that the unit is using substantially more energy than the rating (based on condition or occupant reports of continuous operation).

<u>Age-based replacements</u> have been used by at least one program in an effort to reduce audit costs and streamline the decision process. A Wisconsin program replaces all units

manufactured prior to 1990 (when efficiency standards began). In addition, some programs offer incentives to remove any secondary refrigerators, regardless of age or estimated usage.

The five programs run by the three sponsoring utilities in this study, employ three contractors to deliver the programs. Four of the programs are open to any customers requesting participation and one program targets high use households. All three contractors perform a semi-formal pre-screening of each refrigerator that eliminates units that are relatively new (< 10 years old) and appear to be working properly. They also do not audit a refrigerator if the customer isn't interested in replacing the refrigerator. This pre-screening eliminates approximately half of the refrigerators prior to a more detailed audit.

Once a unit has passed the pre-screening, the contractors use a combination of short term metering and adjusted rated usage approaches to determine replacement qualification. Two contractors use their own adjusted rated usage approaches and only employ short-term metering (typically one or two hours) if they are unable to find the model number in the database *or* believe that metering would provide a different result. More than 80% of the units are assessed by the rated usage approaches. Both rated usage approaches include adjustments for age and other proprietary factors. The third contractor uses short-term metering for between one and one and one half hours and a temperature correction that is not consistently applied. One of the main objectives of the research project is to assess the strengths and weaknesses of the differing audit approaches, develop guidelines for an optimal approach and ultimately recommend a single standard assessment tool.

Data Collection

The research plan includes metering electricity usage and room temperatures for 160 existing refrigerators and 30 new replacement units, collecting information about each site's refrigerator and household. Refrigerators were selected from current program production of the five utility programs in the study. The existing program contractors performed meter deployment and site data collection during their regular program operations. The contractors were trained by the evaluators in screening sites, deploying metering equipment, and collecting site data. Refrigerators were selected if the unit was qualified for a refrigerator rebate using the contractor's current audit approach (and included some units that were close to qualifying) and if the customer agreed to allow the metering for approximately three weeks. Customers were provided with a small monetary incentive for participating. The site selection and metering process was planned for five waves over the course of a year to represent different seasons.

Electricity usage was metered using a data-logging true power meter that employed adaptive time resolution -- the recorded metering interval would double in length every one thousand readings, leading to a time resolution of approximately one half hour (34 minutes) for site metered less than 23 days and one hour (68 minutes) for sites metered for 23 to 46 days. Room temperatures were recorded on an hourly basis using a self-contained temperature logger.

As of the writing of this paper, three waves of metering have been completed including a total of 95 existing refrigerators and 13 new replacement units.

Refrigerator and Site Information

The average existing refrigerator was 20 years old and 21 cubic feet. Eighty percent of the units had a top freezer and 18% had a side-by-side door configuration. Thirteen percent of the refrigerators were located in unheated basements and 1 percent (1 unit) was located on a semi-conditioned porch. Icemakers were present in 16% of the units – 11% through the door and 5% internal. Only 20% of the units were located in air-conditioned spaces and occupants reported a typical winter thermostat setting of 68°F. Only 2 units had manual defrost and one unit had partial automatic defrost. Antisweat heater switches (designed to reduce door edge condensation in older units but at the cost of approximately 10%-20% additional energy usage) were present in 64% of the units and were found in the on position 46% of the time -- 52% in the summer metering and 37% in the winter metering. The average household had 2.8 occupants and the vast majority of households reported never adjusting the temperature controls or antisweat switch on their refrigerator.

Results

The analysis plan includes four primary tasks: model the energy usage for each unit based on temperatures; develop a model of average annual temperature for each unit; analyze the accuracy and cost effectiveness of each audit method; develop an improved audit method based on rated usage; and analyze refrigerator energy savings and load shapes.

Analysis of Energy Usage / Temperature Relationships

The first task in the analysis was to estimate the annual usage for each unit based on the 2-4 weeks of metered usage and temperature data. The analysis plan involved modeling of refrigerator usage as a function of temperature and then using this model to estimate two versions of annual usage: a temperature-adjusted annual usage for each unit at a standard temperature of 70°F, and an estimate of the annual usage at the average temperature each unit experiences (based on an annual temperature model).

An initial analysis found that time-of-day effects could bias the estimated usage/temperature relationship if the data were analyzed using periods shorter than one day because occupant loadings are correlated with indoor temperatures. The selected analysis approach employed a “random coefficients” regression model to estimate the temperature dependence of each unit based on daily average usage and temperature (see Hildreth and Houck, 1968). This modeling approach essentially estimates the temperature dependence of each unit based on a weighted average of that unit’s data and the overall average temperature effect across all units with the weighting related to the relative uncertainty in each. This approach provides more reasonable temperature effect estimates for units that experienced a relatively narrow range of temperatures or otherwise exhibited large uncertainty in the temperature effect estimate.

The analysis found that refrigerator usage varied by about 2.7% per °F (from 70°F). This impact is consistent with a typical temperature difference across the unit of 37°F (ignoring non-linearities in the refrigeration cycle and defrost frequency). An effect of 2.7% may seem small, but the monitored temperature data found that hourly indoor temperatures varied over a range of about 16°F on average within each house and even daily average temperatures varied by 10°F in the summer and 8°F in the winter on average.

The data analysis also found 7 apparently malfunctioning units -- 6 with “flat” usage and 1 with a major usage shift in the middle of metering. The flat usage units are refrigerators that run continuously due to some type of malfunction. These units were kept in the analysis as they represent a real phenomenon in the population.

Modeling of Indoor Temperatures

We used the monitored indoor temperature data to develop a model of indoor temperatures as a function of outdoor temperatures; occupant reported thermostat settings, and the presence of air conditioning. Unheated basements were modeled separately.

We fit a regression model of winter temperatures as a function of reported thermostat settings and heating degree days (base 60°F). We modeled mild weather temperatures as simply the mean of the indoor temperatures when the outdoor temperatures were between 60°F and 70°F. We modeled summer temperatures as a function of cooling degree days (base 70°F) and cooling degree-days interacted with the presence of air conditioning in the room. For unheated basements, we modeled winter temperatures as a function of heating degree-days. For all basements, we modeled summer temperatures as a function of cooling degree-days.

We estimated the annual temperature as the average temperatures during these three seasonal regimes, weighting each regime by its frequency in a typical weather year. We assigned each unit to either the Boston or Worcester weather station for analyzing the data and calculating the weighted annual averages. The temperature model resulted in average projected indoor temperatures of 70.4°F in the living space (ranging from 66°F-75°F) and 64.2°F in unheated basements (ranging from 63.8°F to 64.5°F). One slightly unexpected finding was the relative unimportance of air conditioning because of how few hours per year are affected by it in the moderate New England climate. The temperature model will be further refined using data from the remaining sites in the project.

Usage Analysis Results

We used the analysis results to provide two estimates of annual usage for each unit: usage at a "standard" 70°F and usage at the estimated annual average indoor temperature for each unit. The results of this analysis and comparisons to rated usage are summarized in Table 1.

Table 1. Annual Refrigerator Usage – Averages and Comparisons to Rated

			Usage @ 70°F		Usage @ estimated average T-in	
	N	Rated kWh	Annual kWh	% rated	Annual kWh	% rated
Existing Refrigerators:						
All Units	93		1421		1411	
Units with known rated usage	89	1238	1420	115%	1412	114%
- Side-by-Side units	17	1398	1679	120%	1663	119%
- Top Freezer units	70	1191	1362	114%	1354	114%
New Refrigerators:						
All	13	495	451	91%	437	88%
- Side-by-Side	4	619	600	97%	593	96%
- Top-Freezer	7	429	333	78%	316	74%

The annual usage for the 93 existing units with results averaged 1421 kWh/yr at 70°F and 1411 kWh/yr at the site-specific temperature estimate. For units with rated usage values, the average annual usage was about 15% greater than the original rated value. Based on the limited sample size available, it appears that units with side-by-side doors tended to have greater usage relative to their rating than units with top freezers.

For the 13 new replacement refrigerators, annualized usage averaged about 10% less than rated. Preliminary breakouts suggest that units with top freezers use substantially less than rated while other door styles have usage about equal to rated. The sample sizes are too small to draw any firm conclusions, but these patterns will be examined more closely once data from all 30 new units in the study are collected.

Accuracy of Audit Approaches

We assessed the accuracy of each of the auditing approaches by comparing their usage estimates to the "best" estimates developed by the detailed model. We summarized the mean error (i.e. bias), the mean absolute error, and the root mean square error. These values provide insight into the direction and size of the discrepancies but do not directly indicate how often the audit estimate is close or far from the true value. To summarize the distribution of errors, we classified the accuracy of audit usage estimates as either very good (within 10% of true value), OK (within 10%-20%), not good (20%-40% off) and poor (more than 40% off).

Initial analysis of the contractor usage estimates found that one contractor's estimate based on rated usage was consistently much higher than the other's. This contractor's algorithm was based on published research from a study of refrigerators in New York public housing (Pratt and Miller, 1998) that contained an embedded assumption of 79°F indoor temperatures (the apartments were often over-heated). The contractor had not incorporated a temperature correction factor mentioned in that study, leading to erroneously high usage estimates. We also found that neither contractor's algorithm contained any adjustment for the estimated temperature in the space. The short-term metering audits employed software that allowed for temperature corrections but this feature was often not used. As an initial improved version of the contractors' audit figures, we created temperature-adjusted versions of their usage estimates assuming a 2.5% usage impact per degree F, based on a pre-project estimate. We also assessed the accuracy of short-term metering using the full metered dataset by calculating temperature-corrected short-term metered estimates for all potential audit times (assumed to be weekdays from 7AM to 7PM) with metering period lengths ranging from ½ hour through 2 hours (actually, 34 minutes through 136 minutes).

Table 1 summarizes the accuracy of the audit-predicted usage values including the "as is" contractor estimates, the temperature-corrected versions of these estimates, and the results of the all possible short-term metering.

The table shows that the current contractor audit approaches are not very accurate. Both types of audits over-estimated usage by greater than 20% and had average errors greater than 30%. The rated usage approach estimates were more than 40% in error ("Poor" column) about half the time, primarily because of the problem with one contractor's algorithm. Temperature adjustments to current approaches led to substantial improvements, especially in reducing bias and the proportion of cases with poor accuracy.

Table 2. Accuracy of Audit-Predicted Usage (compared to best estimate at T-in)

		Mean Usage kWh/yr.		Mean Error (% of true)			% Cases with Accuracy*		
Audit Method	**N**	**Audit**	**True**	**Bias**	**Absolute**	**RMSE**	**V Good**	**OK**	**Poor**
Contractor:									
Rated	76	1713	1368	25%	38%	47%	16%	14%	51%
Metered	17	1969	1604	23%	34%	42%	12%	18%	29%
T Adjusted:									
Rated	76	1521	1368	11%	29%	36%	18%	26%	32%
Metered	17	1725	1604	8%	25%	37%	35%	24%	24%
All Possible Meter:	**# tests**								
Meter ½ hour (n=61)	17,687	1366	1388	-2%	27%	36%	25%	23%	22%
Meter 1 hour (n=89)	14,807	1402	1415	-1%	21%	30%	33%	28%	13%
Meter 1½ hour (n=61)	5,923	1373	1388	-1%	19%	27%	34%	29%	11%
Meter 2 hour (n=89)	7,515	1418	1422	0%	17%	26%	38%	30%	9%

Note: Accuracy categories are defined as Very Good <10% error; OK 10%-20% error; Poor >40% error

The analysis of all potential short-term metered results found that metering for just ½ hour is more accurate than the temperature-adjusted rated usage approaches. Accuracy improves substantially when metering is extended from one half hour to one hour but does not improve as much when extended further to two hours – the average error declines from 27% for one half hour metering to 21% for one hour metering to 17% for two hour metering.

Although accuracy is certainly a worthwhile way to compare auditing approaches, the practical issue is how each approach affects the decisions made – how many refrigerators are replaced that don't qualify (mistaken replacements) and how many qualifying refrigerators are missed (missed opportunities)? Even a tabulation of auditing decision accuracy does not capture the full impact of an auditing strategy since a missed opportunity is not much of a loss if the unit only qualified marginally. Similarly, a mistaken replacement does not impose much net loss if a unit just barely missed qualifying. The core issue is how the auditing approach affects the overall program benefits and costs.

We approached the issue of audit cost-effectiveness by calculating the net benefit that would be derived from replacing each refrigerator. We used program planning assumptions from the utilities that indicated that each kWh in annual savings is worth \$0.31 and that the cost for each replacement unit should be valued at 35.3% of the full replacement price (to reflect non-energy customer value). We used data from the replacement refrigerators in the project to estimate the replacement costs and new unit usage based on size (split at 19 cubic feet), which resulted in an average assignable program cost of \$285 per unit and an average new unit usage of 414 kWh. We calculated the energy savings from replacing each refrigerator as the best estimate of annual usage (at the site-specific temperature) minus the estimated usage for the new unit. We then multiplied these savings by \$0.31/kWh to calculate the energy benefits. We then subtracted the assignable program cost for a replacement unit from these energy benefits to calculate the net benefits for replacing that refrigerator. For some units, the net benefits are negative, indicating that replacement is not cost effective based on the program criteria. We used these calculated net benefits to assess any potential audit strategy by calculating the average net benefits per audit if that audit approach had been used to select units for replacement (and counting unselected units as zero benefit). For comparative purposes, we also calculated the maximum possible net benefit per audit if all decisions had been made with "perfect" knowledge (i.e., based on the best estimate of annual usage at the annual average temperature from our site-specific modeling).

An example may help clarify the approach. If the unit cost effectiveness calculations indicated that the net benefits of replacement were $300, $75, and -$100 for 3 refrigerators, then the maximum possible net benefit per audit would be $125 (the two units with positive benefits would be replaced, yielding $375 total benefits, equal to $125 per audit). If an audit strategy selected all three for replacement, the net benefits per audit would drop to $93, calculated as ($300+$75-$100)/3. If another audit strategy only identified the one unit with the greatest benefits, the net benefits per audit would be $100 ($300/3). This latter audit strategy would be $7 more cost effective per audit than the one that replaced all three units, but it would miss a cost-effective replacement opportunity.

Table 2 summarizes the decision-making, the estimated savings realization rate and the net benefits per unit audited for each auditing strategy.

Table 3. Decision Reliability, Savings, & Net Value of Audit Methods

		Qualifying %		Decision Errors		Savings Realization		Net Benefit $ per audit	
Audit Method	**N**	**Audit**	**True**	**Missed**	**Mistake**	**Predict**	**Realize**	**Actual**	**Possible**
Contractor "as is"									
Rated	76	57%	97%	0%	42%	1318	74%	11	67
Metered	17	76%	100%	0%	24%	1560	77%	97	111
T Adjusted									
Rated	76	57%	80%	7%	34%	1222	86%	29	67
Metered	17	76%	100%	0%	24%	1316	91%	97	111
All Meter									
w/ ½ hr data:									
Meter ½ hour	61	59%	60%	17%	18%	1350	89%	57	72
Meter 1 hour	61	59%	62%	12%	16%	1298	94%	61	72
Meter 1½ hour	61	59%	62%	11%	15%	1287	95%	63	72
Meter 2 hour	61	59%	63%	9%	15%	1274	95%	62	72
w/ 1 hr data:									
Meter 1 hour	89	58%	61%	12%	15%	1355	93%	65	75
Meter 2 hour	89	58%	62%	9%	14%	1334	95%	67	75
w/ Rated & Meter									
Rated: as is	72	54%	93%	0%	42%	1337	74%	12	67
Rated: T adjust	72	54%	82%	3%	36%	1200	88%	28	67
Meter 1 hour	72	54%	56%	13%	16%	1372	91%	55	67
Meter 2 hour	72	54%	57%	11%	15%	1356	93%	57	67

The columns labeled “Qualifying %” show the percentage of units meeting the replacement incentive threshold of 1,175 kWh/yr. (the value used in the most common program) based on the audit method and the “true” percentage based on the site specific full dataset analysis. The “Decision Errors” columns show the percent of truly qualified units not qualified by audit (“Missed”) and the % of units qualified by audit that shouldn’t have (“Mistake”). The Savings Realization columns show the predicted savings per unit based on the audit and the percentage of those savings that would be realized based on the site-specific analyses. The “Net Benefit” columns show the results of the cost-effectiveness calculations, which indicates the net value to the program of the audit strategy. The value in the “Actual” column is the result for the specific audit method, the value in the “Possible” column shows the maximum value if the “true” usage results were known. For the “All Meter” analyses, we based the results on the proportion of the periods each unit appeared qualified and summarized these values across units. The table shows that:

- Current rated usage based audit strategies qualify far more units for rebates than is cost-effective – 42% of the units offered rebates should not have qualified – and only capture \$11 of the potential \$67 in net benefits per audit;
- Temperature-adjusted rated usage methods improve decision making somewhat, increase net benefits to \$29 per audit, and improve the savings realization rate (mostly due to lower savings estimates);
- Short-term metering by the contractors tended to occur in higher use refrigerators, yielding high net benefits that may not replicate if performed on more marginal units (this higher usage may be due to inter-program differences as well as a potential association between usage and the availability of rated usage data) ;
- Based on the “all possible” meter results, short-term metering of just ½ hour would reduce the rate of mistaken replacements dramatically but increase the proportion of missed opportunities by ten percentage points compared to the rated usage approaches;
- Based on the 61 units with ½ hour metered data, net benefits from short-term metering only increase by \$4 when extending the metering from ½ hour to 1 hour and only increase \$1 more from extending the metering to 2 hours.
- Based on the 72 units with both rated usage estimates and all possible metering estimates, metering for one hour provides \$27 in incremental net benefits per audit to the program compared to the temperature-adjusted rated usage approaches but extending the metering to 2 hours only provides an additional \$2 in benefits.

Based on this analysis, it appears that employing a temperature-adjusted version of the current rated usage approaches would only be preferable to one hour metering if it reduced program costs by at least \$27 per audit. Extending metering time to two hours is certainly worthwhile if there is no incremental cost (e.g., if the home visit would last longer than two hours anyway) but is only worth about \$2 more to the program per audit than 1 hour metering.

Our results concerning length of metering are generally at odds with other published recommendations and most program rules. The primary reason for this discrepancy is that most of the research and recommendations have focused on the accuracy of metering for different lengths of time without regard to how it affects the decision making in the field and particularly the net benefits to the program. Refrigerator replacement programs tend to get a large proportion of their overall net benefits from replacing a relatively small fraction of units that have very high usage. The decision to replace these units is generally not affected by errors of 20%-30% or more because their usage is far above the replacement threshold. Therefore, even very short-term metering is likely to identify them. In contrast, the refrigerators where moderate gains in the accuracy of the usage estimate affect the replacement decision tend to have usage rates near the replacement threshold, making the net impact of a wrong decision fairly small.

The conclusions drawn from the results in Table 2 may not fully apply to other programs, particularly programs with very different replacement thresholds and designs. For example, a program with a usage threshold that leads to a low replacement rate may find few units with very large net benefits (which tend to be captured by almost any audit approach) making small changes in usage estimation accuracy more important. The impact of differing usage thresholds and cost effectiveness assumptions will be explored in the final project report.

Developing an Improved Audit Method

One of our project objectives is to investigate the possibility of developing an improved rated usage based audit method to improve the accuracy of field decisions made with current rated usage approaches and to reduce program costs associated with metering for contractors. The new audit method is still under development, but preliminary analysis has found some adjustment factors that can improve current methods. The modeling process is focused on predicting the ratio of actual usage to rated usage, so explanatory factors are multiplicative.

Refrigerators with icemakers use about 15% more electricity relative to their rated usage than units without icemakers. This difference is at least partially due to the fact that the rated usage test procedure has the icemaker turned off. There may be some other refrigerator features associated with icemakers, such as door style, that are responsible for some of this incremental usage, but the addition of door style to the model did not improve the fit. Usage also increases with the number of occupants (by about 2% per occupant) and decreases if the unit is not the primary refrigerator (by about 6% to 10%). Modeling thus far has not found that the age of the unit is a very significant factor in predicting the ratio of actual to rated usage, but the weak relationship could be due in part to the fact that virtually all units in the sample are more than 10 years old.

Although the new audit method is still under development, we assessed its performance using the same analyses used on the current audit methods. This analysis will likely be somewhat biased in favor of the new audit approach since the approach was developed using the same data it is being tested on. Given this caveat, the analysis found that the new audit performed considerably better than the existing rated usage approaches, but fell short of the performance of short term metering. For the 76 units with projected usage from both audit methods, the new audit produced net benefits of $45 per audit (out of a possible $67) compared to $29 per audit for the temperature-corrected rated usage approaches. For the 89 units with metered results, the new audit produced net benefits of $48 per audit (out of $74 possible) compared to the $65 for one hour metering and $67 for two hour metering. These results indicate that metering is still a better approach if the cost of metering is less than $17 for one hour metering or $19 for two hour metering. Once all project metering is complete, we plan to develop a rated usage approach that comes closer to capturing the available benefits.

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