Real Life Options for New Construction Evaluation

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ABSTRACT

What do you do when faced with evaluating a New Construction project and you are unable to follow Uniform Methods Project or International Performance Measurement and Verification Protocol recommendations for whole-building simulation?

The use of a whole-building simulation model is frequently recommended for the measurement and verification of new construction measures. These types of projects can be modeled based on design documents, without the need for real-time metering to estimate measure savings. Project evaluation can be completed using a model, but there are several obstacles to completing this approach. The method assumes that actual reliable weather can be easily used in the model and that the operable simulation model is available for modification or that sufficient budget is available for the evaluator to create a model. In the absence of these conditions, evaluators may revert to low rigor evaluation methods, including only verifying installed equipment.

The paper will determine the scope of the issues typical of a calibrated model evaluation approach, and presents a methodology that can be used in situations when these issues become insurmountable. The authors believe that the presented examples offer more rigorous results than commonly applied verification-only evaluations.

Introduction

A common approach to evaluating energy savings for efficiency measures in new construction situations is to use a building simulation model. The reason for this is simple: the building is new, and does not have an actual baseline available for comparison. The energy savings, or the difference in baseline energy use versus post energy use, can only be determined if an acceptable baseline is available. Simulation models work to estimate the heating, cooling, and miscellaneous loads in a theoretical model by allowing parameters based on the predicted occupancy, systems, and process equipment, while simulating the energy used by the HVAC systems to meet building conditioning or process load conditioning requirements.

Simulation models are especially useful because of their ability to capture the interactive effects of different systems and equipment (e.g. the effect of high efficiency lighting reducing lighting <u>and</u> cooling load by reducing the amount of heat introduced into a space). They are also useful in allowing a mechanical engineer to determine the best system to use in a building, or to evaluate the cost effectiveness of improvements over the original design. Models are sometimes used to estimate the savings in prototypical installations, but throughout this paper we discuss models that are used to simulate specific buildings in which energy efficient features were installed.

High-Rigor Building Simulation Calibration Approach Guidance

Two main sources for guidance for measurement and verification (M&V) using building simulations are the International Performance Measurement and Verification Protocol (IPMVP) and the Department of Energy Uniform Methods Project. Within the IPMVP, there are four major approaches for determining savings, Options A through D. These approaches are described in the two most widely used IPMVP documents: IPMVP Core and IPMVP Volume I. In addition, IPMVP Volume III provides more detail on measurement and verification in new construction projects, including using a calibrated building simulation. The following equation is generally applied to determine measure savings using this method:

Energy Savings = Base-year Energy Use - Post-Retrofit Energy Use ± Adjustments

Equation 1: IPMVP Equation to Determine Energy Savings in Calibrated Building Simulations

Per IPMVP, Option D is defined as follows: *Option D involves the use of computer simulation software to predict facility energy use for one or both of the energy use terms in [Equation 1]. Such simulation model must be "calibrated" so that it predicts an energy use and demand pattern that reasonably matches actual utility consumption and demand data from either the [base year] or a post-retrofit year.*[1]

The Uniform Methods Project also describes an approach to evaluating measures in a new construction facility using a calibrated building model. Measures that are appropriate for the New Construction protocol include any that may have either significant interactions with non-measure systems or have seasonal variations in energy use (typically due to weather dependency). New construction measures can fall within three major classifications according to the UMP:

- **Newly Constructed Buildings:** The design and construction of an entirely new structure on a green-field site or wholesale replacement of a structure torn down to the ground.[2]
- **Addition (Expansion) to Existing Buildings:** Significant extensions to an existing structure requiring building permits and triggering compliance with current codes.
- **Major Renovations or Tenant Improvements of Existing Buildings:** Significant reconstruction or "gut-rehab" of an existing structure, requiring building permits and triggering compliance with current codes.

The circumstances listed above may not be the only triggers for using a building simulation approach. Projects where there is difficulty determining savings due to complicated control sequences or equipment interactions (i.e. commercial/industrial refrigeration systems) may also use this method. The UMP NC protocol requires the creation of the following models to allow project savings to be calculated:

Table 1: UMP NC Protocol Models for Determining Energy Savings[3]

Model	*Model Name and Purpose*	*Model Description*
1	As-Built Physical *To calibrate simulations and assess uncertainty.*	Model and Simulate as found during site visit. Use the occupancy and building operation as reflected in billed energy history and sub-metered data. Simulate using actual local weather observations matching the consumption history period.
2	As-Built Design *To estimate typical usage at full occupancy.*	Base on As-Built Physical model. Use full design occupancy and expected “typical” building schedules. Use constructions and equipment efficiencies as found during site visits. Simulate using normalized weather data (e.g., TMY datasets).

[1] 3.4.4 International Performance Measurement and Verification Protocol: Option D - Calibrated Building Simulation.
[2] Uniform Methods Project: Commercial New Construction, page 1. Classifications for new construction measures, or the circumstance that befit them.
[3] http://www.nrel.gov/extranet/ump/pdfs/20130912_ump_commerical_new_construction_draft.pdf, page 9

3	As-Built Expected Design *To estimate difference between original and as-built models.*	Base on As-Built Design model. Use full design occupancy and expected “typical” building schedules. Use assumed (ex-ante) constructions and equipment efficiencies. Simulate using normalized weather data (e.g., TMY datasets).
4	Whole-Building Reference *To estimate savings of the EEMs*	Base on As-Built Design model. Use full design occupancy and expected “typical” building schedules. Apply baseline requirements defined by reference codes or standards. Simulate using normalized weather data (e.g., TMY).
5	Measure Building Reference *To isolate savings claimed by the participant.*	Base on Whole-Building Reference model. Use full design occupancy and expected “typical” building schedules. Apply baseline requirements defined by reference codes or standards. Include ECMs not incentivized by DSM program. Simulate using normalized weather data (e.g., TMY).

The models developed per the table above must then be used to calculate the iterative savings between each change in the model, accounting for project and non-project savings:

Table 2: UMP NC Protocol Calculations for Determining Energy Savings[4]

Savings Component	*Model Subtraction*	*Description*
Expected Measure Savings	n/a	Energy savings expected by the building designers and/or the DSM program application. (Also known as the project’s ex-ante energy savings.)
Rebated Measure Savings	5 – 2	Evaluated (or realized) energy savings for incentivized ECMs, often determined by an independent third-party evaluator. Calculate these savings by subtracting the difference in simulated energy use of the As-Built Design from the Measure Building Reference. (The result is also known as the project’s ex-post savings.)
Non-Rebated Measure Savings	4 – 5	Energy savings resulting from ECMs implemented in the final building design, but not rebated by the DSM program. Calculate these savings by subtracting the difference in simulated energy use of the Measure Building Reference from the Whole Building Reference. (The result is also known as the spillover savings.)
Total Achieved Savings	4 – 2	Evaluated (or realized) energy savings for all implemented ECMs, whether rebated or not. These are often determined using an independent third-party evaluator, and calculated by subtracting the difference in simulated energy use of the As-Built Design from the Whole Building Reference. Some DSM programs report this (rather than Rebated Measure Savings) as the project’s ex-post savings.

While Option D and the UMP accurately define the calculation approach and data that should be collected to comprise an evaluation, including sub-metering and trend data, it is often the case that evaluators are unable to follow this guidance strictly. Faced with no operable model, the evaluation effort is often reduced to verifying equipment capacities and operation of energy savings controls measures (e.g. outside air economizers) without calibrating the model. Calibration may not take place for the reasons listed previously and presented in the following section, so the resulting evaluation can only be considered "verification only," and should not be regarded as a "high-rigor.” In these instances the reported ex-ante

[4] http://www.nrel.gov/extranet/ump/pdfs/20130912_ump_commerical_new_construction_draft.pdf, page 12

savings are passed through, resulting in an ideal realization rate, but without the confidence that should be provided by a full project evaluation.

Typical Modeling Issues

While calibrated simulations models can be a useful tool in evaluating energy savings, there are several issues that can compromise the evaluator's ability to complete a high-rigor evaluation when using this method. These issues may not be typical in programs that have strict documentation requirements for the submission prior to incentive payment, but they have impacted the authors' ability to carry out a calibrated simulation model approach on many occasions.

The key piece of information required for a calibrated model approach is an operable, up-to date copy of the actual model that produced the original savings estimates, either for the application savings or for *ex-ante* savings. These models can come in many forms based on the simulation software used, requiring the modeler/contractor to provide the correct version of the operable model, as well as all of the secondary files required for its execution. Table 3 demonstrates the variety of file types needed for some of the most popular building simulation software packages. If any of the files that are submitted are not in the correct format, or if a needed secondary file was not submitted, a modeler may or may not work with the evaluator to help rectify the issue. There can also be instances where an operable model was never provided with the application and only model outputs were sent. Oftentimes, in these cases an energy modeler will not provides files that they consider proprietary.

Table 3: Building Simulation Software File Types

Software	*Required Executable Files*
Carrier HAP	.E3A (archive needed to transfer to new server)
Trane Trace 700	.TAF
eQUEST	.inp, .prd, .pd2

In the event that an operable model was submitted, and the secondary files are all accounted for, the evaluator is still constrained by other factors that limit the effectiveness of this approach. Depending on the project, the number of measures and systems involved can be numerous. It falls on the evaluator to determine how to compare what was modeled to what exists in the actual building. The most common verification techniques involve comparing the modeled post-installation equipment to the as-built drawings and installed equipment nameplates. Other parameters in the model may not be able to be verified at all in the field, such as building envelope. After construction, the walls and roof cross-section are not typically available for inspection. Construction specifications, as built drawings, and shop drawing submittals become the sole source for this information.

Evaluators may not have any executable files, they could be limited by not having access to the appropriate software, the installed measures may not have been correctly modeled, or the technology that comprises the measure cannot be accurately modeled using available software versions. Additionally, the evaluator must have sufficient experience or expertise in the software to make modifications based on survey or site visit data.

The effectiveness (or availability) of a calibrated simulation approach in a project verification should be determined by the available information from the customer or their contractor. The approach can also depend on whether the supplied model was properly constructed, if the model is calibrated, and whether or not sufficient post-occupancy utility data are available, among other considerations.

Developing an Approach

The table below outlines the initial steps that can be used to determine if a calibrated simulation approach is feasible with available data, if additional information from the customer would make it feasible, or if calibrating an operable model is not possible:

Table 4: Steps to Determine an Approach

Steps or Data Available	*Action(s) Taken*
1) Is the executable model available?	If **YES**, then use the UMP New-Construction protocol. If **NO**, continue to next step.
2) Is there sufficient budget available to construct a model?	If **YES**, then use the UMP New-Construction protocol If **NO**, continue to next step
3) Plot the actual monthly data against actual weather, and modeled monthly data against modeled weather.	Is there reasonable (>6 months) of utility data available? If **YES**, plot monthly. If **NO**, plot daily average kWh for modeled and actual vs. weather for each.
4) Do the models show similar load profiles? Is the post-installation model versus actual reasonably calibrated and do the CDD/HDD dependencies make sense for the modeled systems?	If **YES**, the project is verified! If **NO**, an alternative approach is needed to verify savings.

The presented approach to verifying measure savings can be used in the event that the evaluator passes through the above decision matrix and cannot perform an evaluation using the UMP new-construction protocol. The model outputs that were used to document the application or *ex-ante* savings are critical to making any corrections to the savings. Ideally, these outputs are available as they would comprise the minimally accepted amount of data for an initial savings estimate.

New Construction Evaluation Method: First Steps

There are two main elements to new construction evaluation in the event that a building calibration model approach is presented but may not be possible: 1) a recommended method for assessing the adequacy of the ex-ante model, and 2) a systematic approach to adjusting ex-ante savings.

After following the steps in Table 4 and determining that an alternative approach is necessary, the following steps provide a general guideline to the authors' method:

Table 5: New Construction Evaluation Method General Guideline Steps

Step	*Notes*
1) View the post-installation model results by end-use.	Often the energy savings are available per system or measure, which leads to the baseline and post-installation energy use by system or measure to be available.
2) Compare the model outputs to the utility bills to identify likely errors.	Much can be discerned by looking at either the time series of monthly energy use, or comparing energy use versus ambient conditions, including energy dependence on ambient conditions or time of year (e.g. schools).
3) Field inspect equipment and collect any available trend data.	The findings from the field inspection and analysis of trends can verify whether measures were installed as anticipated or if the project was not fully implemented.
4) Make end-use-level or measure-level adjustments to model outputs.	Take information from the previous step and use to make adjustments to the model results (e.g. realization rate adjustments to equipment savings based on average actual kW versus modeled average kW).

The key step is to create a plot constructed with data that is available in nearly every evaluation: simulation outputs that show the modeled monthly energy use of the building. If the type of weather that was used in the model is known (actual or TMY), the data can be analyzed to characterize the energy use versus the ambient weather conditions (degree days or average temperature) for each modeled month. By plotting modeled monthly usage against modeled weather, insight is gained into the temperature dependence of the model. This plot is more meaningful than the standard time series plot. The figures in the following section show the results of this type of data presentation and the conclusions that can be reached by analyzing them.

Using regressions of modeled energy use to TMY weather, and by comparing actual energy use to actual weather, the evaluator can observe major deficiencies in the simulation. In cases where there are only minimal post-retrofit utility data available, the average daily kWh for the modeled and actual energy use should provide the source for the regressions, along with the daily weather (outside air dry-bulb temperature, heating degree days, cooling degree days, or some combination thereof). The model still provides approximately 12 points of data for this regression while allowing the actual data, if limited to only a few weeks, to provide more points than would be available if monthly usage and weather were used. In the event that a large amount of actual utility data is available, the monthly usage and weather (heating degree days or cooling degree days) may provide more suitable variables for the regression.

There are several reasons that the amount of post-retrofit data may be limited. If the evaluation is scheduled to be completed before an ideal amount of billing data can be generated, or if other measure installations not involved with the incentivized measures took place shortly before and/or after the subject project, the impact of those measures will show up in the utility bills. Unless that impact can be easily accounted for (e.g. 24/7 lighting retrofits where an easily calculated base load is removed), the billing or interval utility data may not accurately reflect the impact of the subject measures.

After these regressions are created, comparisons can be made between the actual and modeled monthly energy use. The reasonableness of the model is determined based on the deviation of the modeled results from the actual use, both monthly and yearly. Some programs may have tools used to verify whether a model is sufficiently calibrated, such as the New Jersey Pay for Performance (NJ P4P) program. Others may not have any calibration requirements or rely on requirements set out by governing bodies, such as ASHRAE Guideline 14, 6.3.3.4.1 Calibrate to Monthly Utility Bills and Spot Measurements (ASHRAE 2002, 38):

"Acceptable tolerances for this comparison shall range from ±10% for MBE (mean bias error) to ±30% for CV (coefficient of variation) (RMSE – root mean squared error) of the bill's represented energy use and/or demand quantity when using hourly data or 5% to 15% using monthly data (see section 6.3.3.4.2.2 for additional information).[5]"

Proper calibration requires the model and actual utility data to be compared using the same weather, which can usually be done by performing a regression for both sets of monthly data against monthly CDD or HDD used in the simulation and actual weather coinciding with the billing months used, then applying those regressions to typical annual weather data (e.g. TMY3).

If the submitted model falls within the calibration requirements set out by the program, or within generally accepted limits, and the equipment/controls are visibly confirmed as having been installed, the project may be considered verified. Projects that do not meet the necessary criteria for an Option D analysis must find another solution.

New Construction Evaluation Method: Analyze the Model Outputs

The first step is to view the baseline and post model monthly results by end use. Do the results make sense based on the system types? Was the baseline system appropriately modeled for the building type, size, and location?

The next step is to compare the monthly results to actual billing data. This step was previously used to determine whether the model was calibrated already, but a more in-depth understanding of the relationships between energy use and building occupancy or seasonal temperature variations can help determine where any uncertainty lies. Did the model account for changes in occupancy (e.g. school year versus summer)?

A field inspection allows the evaluator to collect additional data that may not have been available in the originally submitted project documentation and allows for direct verification of installed equipment and controls. While an executable model may not have been made available, the evaluator should still compare the listed application measures to the actual building systems and operations. Any deviations from the application (or other sources provided with the project) may need to be accounted for. Examples of deviations would be equipment that was modeled and not installed, control strategies that were not fully implemented, or air flow reductions that could not be fully realized due to unforeseen system requirements. If available, trend data or metering can be useful in helping to determine the equipment operations.

When sufficient data are collected, through a combination of inspections, trends, and metering, the evaluator can make adjustments to the model results to account for deviations. These adjustments should explain some of the difference between modeled post-installation energy use and actual energy use.

[5] Section 6.3.3.4.1 Calibrate to Monthly Utility Bills and Spot Measurements, ASHRAE Guideline 14 - 2002

Example 1: Manufacturing Facility

The first example involved the conversion of existing constant volume single-zone (CVSZ) HVAC systems to variable volume single-zone (VAVSZ) systems in an existing building. While generally the issues described in this paper apply to new construction measures, they can also apply to retrofit installations. In this example, the design consultant needed to use simulation software to model the proposed measures because of the interactive effects of the project. The project involved installing variable speed drives on supply and exhaust/return fans with the associated controls to allow for variable operation, as well as re-commissioning the units. The customer submitted a Trace 700 energy model with the monthly outputs for the baseline and post-installation cases.

A separate project took place at the facility a few weeks after the installation of the project measures, limiting the amount of post-installation utility data to only a few weeks. Luckily, hourly interval data was available from the utility instead of the typical monthly data. There was some variability in the outside air temperatures during that time. The lack of post-installation data necessitated comparison of shorter term kWh data (average kW instead of monthly kWh). The following graph demonstrates the average kW versus the average daily dry-bulb temperature from the modeled outputs and from actual utility data (baseline and post-installation):

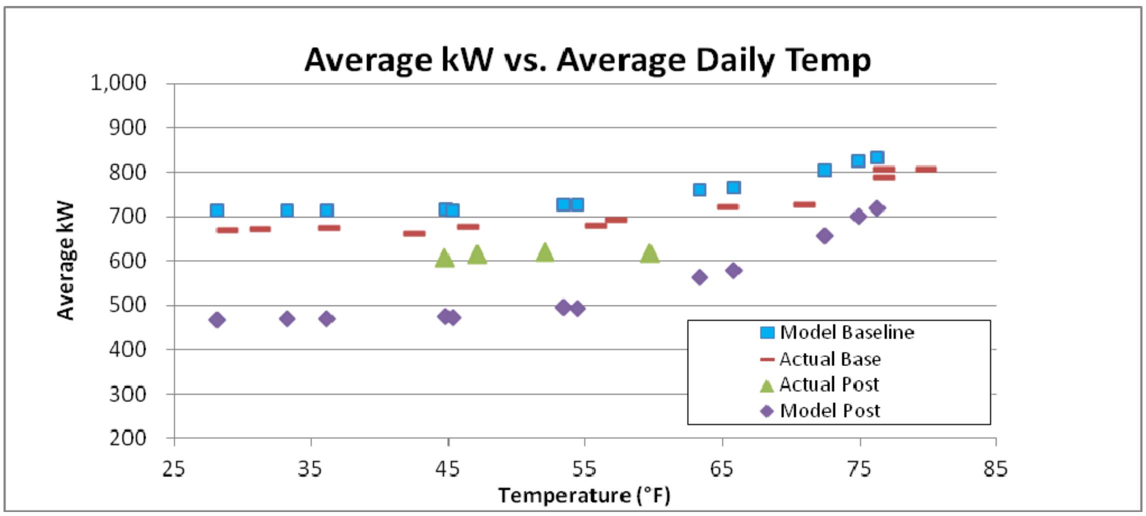

Figure 1: Manufacturing Facility Modeled and Actual Average kW vs. Outside Air Temperature

From the comparison of the results and the actual operations, it can be concluded that the equipment was modeled using the correct load profile, if not the same magnitude. The baseline modeled kW was relatively similar to the actual baseline kW. The modeled baseline use was slightly higher than the actual use, but the weather dependence was captured properly. The actual post-installation kW was much higher than the modeled. There was a lack of warmer weather post-installation data because of the issues with the site. Because of this, the actual post-installation kW dependence on warm weather was assumed to behave the same as the baseline, with increased use during warmer weather. The evaluator determined that the modeled savings were not accurate, since the baseline energy use was slightly overestimated while the post-installation energy use was significantly underestimated.

The evaluator did not have access to the operable model, so another approach was needed to determine the verified savings for the project. The specific adjustments made to the outputs will be presented in the next section.

Example 2: Middle School

The second example involved a new construction project. The submitted application savings were taken from an energy model created by the customer's design consultant. The measures included the installation of geothermal heat pumps and energy recovery units with performance greater than ASHRAE 90.1-2007 Appendix G minimum performance. There were also improvements in lighting power density and envelope construction over Code minimums.

Several issues arose during the initial file review that required the attention of the evaluator. The weather used in the model did not reflect the actual weather conditions, making a direct comparison of usage to utility data not possible. The site also had natural gas available for heating and cooking. The modeler had used a VAV system with electric reheat[6] as the baseline for project savings. According to the ASHRAE 90.1-2007 Appendix G, in buildings with fossil fuel availability the appropriate baseline would be the system based on square footage and usage with a hot-water fossil fuel boiler for space heating. By using an electric resistance heating baseline, the customer incorrectly modeled the baseline for savings. The model also included 10 energy recovery units, though only 9 were installed as part of the project. Finally, the simulation had only one schedule for occupancy and temperature setbacks, though the school was essentially unoccupied during the summer months.

Typically, these issues could only be addressed through corrections to the submitted energy model. Since the model was not available, the evaluator could only use the available output reports to determine the verified savings. The school had been occupied for the previous 12 months, so sufficient utility data were available to compare to the modeled results. The following figure shows the modeled average daily kWh for the baseline and post-installation periods, as well as the average daily kWh from the utility data, plotted against average daily dry-bulb temperature:

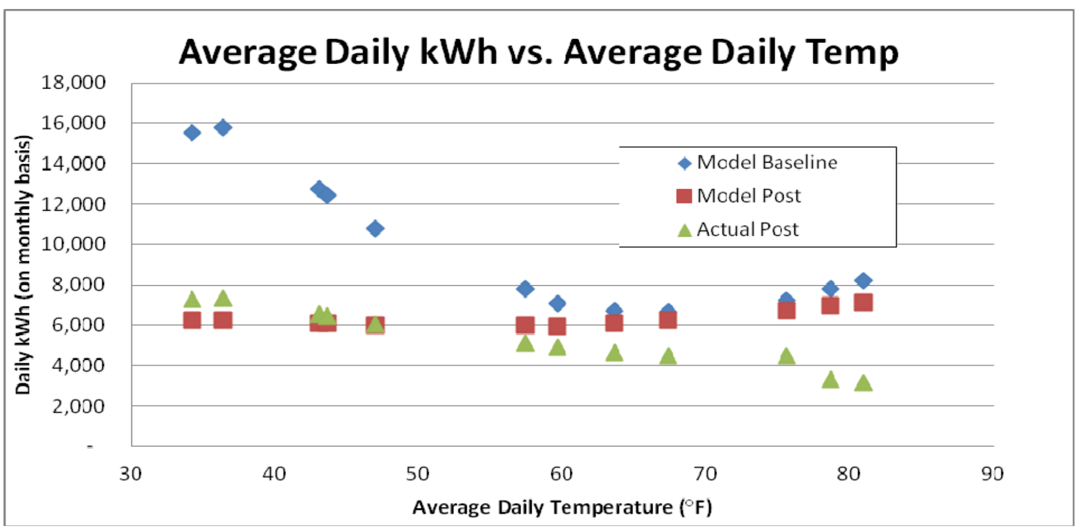

Figure 2: Middle School Modeled and Actual Average Daily kWh vs. Outside Air

The figure comparing the model results to the actual building operation showed a significant departure during summer months, presumably reflecting the difference in summer occupancy. The effect of the modeled electric resistance heating can be seen in the large difference between the modeled cold weather electrical usages from baseline to post-installation.

[6] System Type 8 per Table G3.1.1B, ASHRAE 90.1-2007 Appendix G

Again, for this project the evaluator did not have access to an operable model, so adjustments to account for issues found by the evaluator needed to be made directly to the model outputs. These adjustments are described in detail in the next section.

New Construction Evaluation Method: Adjust the Model Outputs

Example 1: Manufacturing Facility

For this project, neither the baseline nor as-designed models were well calibrated to actual historical usage. There was a difference between the modeled and actual average kW for both baseline and post-installation cases. The model relied on post-installation assumptions from design drawings. The modeled maximum and minimum CFM values for the air handlers, as well as the estimated motor kW, were taken directly from mechanical schedules. During the site visit, these assumptions were compared to actual readings from the motor drives and short-term trending the customer provided. The actual motor energy use as viewed during the post-installation inspection was generally higher than stated in the design documentation. The testing and balancing reports were reviewed after the visit, when it was discovered that the actual CFM reductions were only 42% of the expected reductions. Thus, the model simulated a reduced airflow that was not fully realized upon project completion. Without the ability to alter the model, another option to produce verified savings was to adjust the model outputs directly.

Since the energy savings from the model were primarily driven by the reduced airflow, an adjustment to the outputs could be made based on engineering fundamentals. The baseline and post-installation energy use for each affected HVAC fan was fortunately included in the customer submitted model output reports. The following table shows the design (max) CFM used in the baseline and post models, the actual post maximum air flow, and the differences (saved CFM) between the modeled and verified air flow reductions:

	Modeled (Ex-Ante)				Observed (Ex-Post)		
Unit	Ex-Ante Baseline Design CFM	Ex-Ante Post Design CFM	Post Average CFM (60% of Design)	Ex-Ante Average CFM Saved	Actual Observed CFM	Ex-Ante Baseline Design CFM - Actual Observed CFM	Difference between Ex-Ante Post Design CFM and Actual Observed CFM
AHU-1 SF	14,000	6,386	3,832	10,168	11,160	2,840	(4,774)
AHU-2 SF	23,700	15,449	9,269	14,431	10,000	13,700	5,449
AHU-3 SF	18,450	8,048	4,829	13,621	10,100	8,350	(2,052)
AHU-4 SF	11,500	5,783	3,470	8,030	8,300	3,200	(2,517)
AHU-5 SF	12,950	8,625	5,175	7,775	12,583	367	(3,958)
AHU-6 SF	17,000	7,970	4,782	12,218	11,140	5,860	(3,170)
AHU-7 SF	2,650	3,497	2,098	552	2,650	-	847
AHU-8 SF	16,950	7,710	4,626	12,324	11,750	5,200	(4,040)
AHU-9 SF	18,500	7,710	4,626	13,874	12,000	6,500	(4,290)
AHU-10 SF	7,200	2,816	1,690	5,510	6,500	700	(3,684)
AHU-11 SF	7,200	5,600	3,360	3,840	7,400	(200)	(1,800)
AHU-12 SF	6,500	6,500	3,900	2,600	12,200	(5,700)	(5,700)
AHU-13 SF	16,850	5,142	3,085	13,765	9,200	7,650	(4,058)
AHU-14 SF	16,850	5,142	3,085	13,765	8,400	8,450	(3,258)
AHU-15 SF	16,850	5,142	3,085	13,765	11,400	5,450	(6,258)
AHU-16 SF	16,850	5,142	3,085	13,765	12,100	4,750	(6,958)
Sum	224,000	106,661	63,997	160,003	156,883	67,117	(50,222)

Figure 3: Manufacturing Facility Air Flow Reductions (Note: AHU-11 and AHU-12 actual observed post-installation airflows were higher than the assumed baseline modeled CFM)

The ex-ante modeled fan kW was adjusted by the evaluator to match the actual baseline, corrected for weather. The resulting decrease in the baseline model energy resulted in the calibrated baseline model outputs being approximately 94% of the ex-ante modeled baseline. Furthermore, the difference in actual CFM reduction to modeled CFM reduction and the associated power using DOE-2 curves for fans operated by VFDs were used to determine a ratio for actual reduction in fan energy. This corrected ratio for fan energy savings was applied to the baseline fan energy use to determine the savings attributed to the reduction in airflow.

Unit	Ex-Ante Max Base kW	Ex-Ante Max Post kW	Ex-Ante Average Post kW	Ex-Ante kW Saved at Average Post kW	Ex-Ante kW Saved at Design CFM	Observed kW	Corrected Baseline kW	Corrected Baseline - Observed kW (Ex-Post Saved kW)	Ex-Post Saved kW / Ex-Ante Saved kW
AHU-1 SF	14.9	14.9	2.1	12.8	0.0	9.5	14.1	4.5	35%
AHU-2 SF	18.6	4.0	2.6	16.0	14.6	9.2	17.6	8.4	52%
AHU-3 SF	22.4	22.4	3.2	19.2	0.0	11.3	21.1	9.8	51%
AHU-4 SF	18.6	18.6	2.7	16.0	0.0	9.2	17.6	8.4	53%
AHU-5 SF	18.6	15.9	2.6	16.0	2.7	18.1	17.6	-0.5	-3%
AHU-6 SF	18.6	18.6	2.7	16.0	0.0	9.9	17.6	7.7	48%
AHU-7 SF	11.2	11.2	1.6	9.6	0.0	5.7	10.6	4.9	51%
AHU-8 SF	22.4	22.4	3.2	19.2	0.0	11.5	21.1	9.6	50%
AHU-9 SF	22.4	22.4	3.2	19.2	0.0	11.3	21.1	9.8	51%
AHU-10 SF	11.2	9.3	1.6	9.6	1.9	8.6	10.6	1.9	20%
AHU-11 SF	11.2	1.7	1.6	9.6	9.5	9.4	10.6	1.2	12%
AHU-12 SF	14.9	2.1	2.1	12.8	12.8	12.9	14.1	1.2	9%
AHU-13 SF	18.6	3.0	3.0	15.6	15.6	7.9	17.6	9.7	62%
AHU-14 SF	18.6	3.0	3.0	15.6	15.6	9.0	17.6	8.6	55%
AHU-15 SF	18.6	3.0	3.0	15.6	15.6	14.8	17.6	2.7	18%
AHU-16 SF	18.6	3.0	3.0	15.6	15.6	12.0	17.6	5.6	36%
Sum	**279.6**	**175.5**	**41.2**	**238.4**	**104.1**	**170.3**	**263.8**	**93.5**	**39%**

Figure 4: Manufacturing Facility Fan kW

The realization rate of ex-post fan kW saved over ex-ante fan kW saved, based on the average modeled fan kW and the observed actual kW, was then applied to the fan savings to account for the higher than anticipated post-installation fan usage (39%).

Equipment	Baseline	Post-Installation	Ex-Ante Savings	Ex-Post Savings
System	kWh	kWh	kWh	kWh
1. Warehouse (AHU-13 to AHU-16)	653,235	105,036	548,199	213,798
5. AHU-1	130,647	18,523	112,124	43,728
6. AHU-2	163,309	23,154	140,155	54,661
7. AHU-3	195,971	27,784	168,186	65,593
8. AHU-4	163,309	23,445	139,864	54,547
9. AHU-5	163,309	23,154	140,155	54,661
10. AHU-6	163,309	23,270	140,039	54,615
11. AHU-7	97,985	14,051	83,935	32,735
12. AHU-8	195,971	28,134	167,837	65,456
13. AHU-9	195,971	28,134	167,837	65,456
14. AHU-10	97,985	13,892	84,093	32,796
15. AHU-11	97,985	13,892	84,093	32,796
16. AHU-12	130,647	18,523	112,124	43,728

Figure 5: Manufacturing Facility Ex-Ante vs. Ex-Post kWh Savings

With the adjustments made to the baseline, coupled with the increase in post fan energy usage, the final kWh realization rate was approximately 25% (other measures that were corrected and affected the final realization rate are not shown for the sake of brevity). This represented a significant departure from the savings used to calculate the incentive. The main source of discrepancy was basing the ex-ante savings on an uncorrected simulation model that was submitted prior to calibration to actual conditions.

An Option A or B approach would have been suitable for this project, but the lack of available trending data, reluctance by the customer to allow meters to be installed, and the effects of additional energy savings projects outside of the subject measures limited the options available to the evaluator.

Example 2: Middle School – New Construction

This plot of monthly usage against weather demonstrates the large amount of electrical energy predicted in the submitted baseline model to provide heat using an electric resistance heating baseline. The evaluator had to adjust the model outputs to remove the electrical heat usage from the modeled baseline, resulting in a net electrical penalty for the heating system. The site had fossil fuel available prior to construction, and even had a natural gas-fired boiler to provide supplemental heat to the geothermal heat pump water loop. Appendix G clearly calls for use of a natural gas heating system in this instance. Alternatively, the designer could argue that a Code minimum efficiency heat pump system could be the baseline. This baseline would have resulted in small to slightly positive savings, but still far less than the ex-ante value.

Based on an Appendix G baseline, the verified savings resulted in a net electrical penalty but an overall energy savings due to the large amount of natural gas saved. There were still significant savings when strictly considering energy use (BTUh baseline vs. BTUh post-installation), but the program was designed to reduce the electrical load on the grid. This project had the opposite effect (fuel-switching).

	Ex-post Base	Ex-post Post	Ex-post Savings	Ex-Ante Savings	Phone Ver. Savings
Enduse	kWh	kWh	kWh	kWh	kWh
Int Lgt	387,772	317,614	70,158	108,292	108,292
Misc	397,866	397,866	0	0	0
Main Fans	535,152	656,022	-120,871	-167,018	-167,018
Pumps	186,928	237,273	-50,346	34,034	34,034
Clg	102,946	113,475	-10,529	-20,571	-20,571
Htg	0	396,279	-396,279	960,212	-177,519
Supplemental	assume = exante		898	898	898
Ext Lighting	assume = exante		3,531	3,531	3,531
Total	1,610,663	2,118,530	-503,438	919,378	-218,353
Therms	assume = exante		49,156		49,156

Figure 6: Middle School Ex-Post Analysis Results

Conclusion

The Uniform Methods Project New Construction Protocol and Option D from the IPMVP provide a reasonable approach to determining energy savings for new construction, expansion, and gut rehab building energy efficiency measures. However, in practice there can be numerous obstacles that prevent an evaluator from verifying the savings using a calibrated simulation approach.

In cases where these obstacles are present and no other appropriate M&V approach is feasible, evaluators are tempted to perform a "verification only" analysis.

Even in instances where there is seemingly little information available, good engineering and intuition for comparing the modeled results to billing data, even when that data is limited, can provide sufficient information to allow the completion of a more rigorous approach.

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