Simplified Performance Rating Method

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ABSTRACT

The Performance Rating Method (PRM) in ASHRAE Standard 90.1 (ASHRAE, 2022) is a simulation ruleset for establishing minimum code compliance and for rating a building's beyond-code performance. Building Performance Modeling (BPM) to comply with the PRM is often expensive and time-consuming due to the complexity of code requirements. Pacific Northwest National Laboratory (PNNL) has developed a simplified PRM (S-PRM) approach for commercial buildings to expand the use of BPM to more commercial buildings by defining a low-cost, simplified approach for creating robust and detailed models for applicable buildings.

This paper will explore the forthcoming S-PRM and its implications for code compliance, utility efficiency programs, and evaluations. Specifically, the paper will detail the use of S-PRM-based modeling in Duke Energy's New Construction Energy Efficiency Design Assistance (NCEEDA) program. Since 2017, Duke Energy has used a simplified modeling approach, based on the PRM on more than 100 projects and has compared the metered consumption to the predicted consumption. This paper will analyze the deviations between the models and meters and the most common reasons for deviation. We will discuss the implications for broader adoption of S-PRM for modeling and savings evaluations using the International Performance Measurement and Verification Protocol (IPMVP) Option D – Calibrated Simulation model approach.

Introduction

Building Performance Modeling Use Case—Code Compliance

Building energy codes and standards include both prescriptive and performance-based compliance paths. Prescriptive paths establish minimum requirements for energy-related characteristics of individual building components such as minimum required R-values of insulation, minimum equipment efficiency thresholds, etc. Performance paths provide greater flexibility, including allowing some design features to be below code as long as the overall performance of the building achieves a specified target. While easy to use and understand, the prescriptive path limits design flexibility and fails to acknowledge individual building characteristics as well as interactive considerations that can optimize a building's energy performance with integrated solutions. Because prescriptive requirements are typically established at an individual component level and limited by cost-effectiveness requirements, the rate of improvement of each subsequent code has decelerated based on economic considerations and limits of technological feasibility.

Because of the limitations discussed above, it is unlikely that energy codes largely dependent on prescriptive compliance will achieve the aggressive savings policy goals espoused by many. The solution championed by the authors relies on a move to performance-based codes that treat the building as a system and encourages creative solutions more likely to lead to deep savings than the prescriptive alternative (Rosenberg et al., 2015). Additionally, a performance-based code allows developers to set and track progress toward clearly defined targets. While there seems to be consensus that performance-based codes are the preferred path going forward, many stakeholders have reservations stemming from the added complexity and cost associated with building performance modeling and the complexity of code requirements (Rosenberg et al., 2020). Simplification of code requirements and simpler modeling workflows are critical for the adoption of performance-based energy codes.

Energy Design Assistance, Utility Incentive Programs, and Guaranteed Energy Savings

In addition to the use case for code compliance, BPM is often used for optimizing the design of new and existing commercial buildings, through a process commonly called Energy Design Assistance (EDA). This process can be used to identify the most cost-effective way to meet code or beyond-code performance goals such as net-zero energy or carbon emissions, or to evaluate the financial or environmental return on investment (ROI) for different efficiency measures. BPM may be driven by the need to demonstrate code compliance, the project team's internal standards, such as an aspiration to meet the American Institute of Architects (AIA) 2030 Challenge (AIA, 2023) which sets a requirement for all new buildings to be net-zero energy by 2030, by owner for an ROI analysis, or by the utility to encourage efficiency as a less expensive way to meet energy demand rather than increasing electricity generation capacity. BPM-based utility efficiency programs can provide more targeted incentives based on the energy savings for a specific building and offer greater accuracy than the practice of using prototypical savings for prototypical commercial buildings in the same climate zone. The 2020 DOE Building Technologies Office (BTO) Innovations in Building Energy Modeling: Research and Development Opportunities Report for Emerging Technologies estimates that BPM can reduce energy use intensity by 20% compared to prescriptive design (USDOE, 2020)

Why Simplified Building Performance Modeling?

Gap In Market

Over 80% of commercial buildings are <25,000 ft2 (CBECS, 2012), and the complexity and cost associated with BPM can be a big deterrent for performance-based compliance or design assistance for this sub-sector, limiting opportunities for optimization of building design to achieve highest possible savings at the lowest cost (Barbour et al., 2016). Simplification of the energy modeling process for this subset of small or simple buildings can greatly reduce the barrier to whole-building energy modeling and allow design optimization for code compliance or design assistance.

Several simplified BPM applications exist in the industry (Tillou et al., 2021). Simplified BPM allows a user to specify a proposed building with a limited number of inputs and calculate the energy savings compared to a baseline. The inputs are limited to the key variables that have the greatest impact on the energy use in a building. The applications do this by extrapolating and interpreting the key inputs into appropriate simulation engine inputs to create a valid input file for the proposed design and automatically generate the input file for the baseline design. Willdan found, in an internal comparison, a 75% reduction in modeling time using a simplified BPM tool with automated baseline generation compared to a detailed model. An Energy Trust of Oregon S-PRM pilot that PNNL was involved in found a 40% time savings, even without baseline automation. The HVAC System Performance tool (Goel et al 2021) which implements a simplified whole building modeling approach, as well as baseline automation for compliance with the HVAC system performance approach in Washington State Energy Code (WSEC 2018), has resulted in more than a 60% reduction in modeling time. Simplified models take 2-10 hours to develop, depending on the complexity of the model.

A common concern stated while debating simplified versus detailed energy modeling relates to the potential for intentional and unintentional errors introduced due to simplification of the modeling process. However, even with current practice using complex tools, there is substantial personal judgement that goes into creating an energy simulation of a building. One study found that when 12 professional energy modelers analyzed the same building, the modeled predicted electricity consumption varied from -11% to +104% and gas consumption varied from -61% to +1535% (Berkeley, Haves, & Kolderup, 2015). In the DOE BTO Multi-Year Plan, they stated:

> *Inconsistency across tools pale in comparison to inconsistencies across modelers. Energy modelers are sparsely distributed, under-trained, and often poorly supported. Few architecture and mechanical engineering programs include energy modeling in their curricula and do not produce professionals with adequate building physics and modeling knowledge. Although advances have recently been made, the infrastructure for training is sparse, and few modelers seek professional certification. Further, basic modeling procedures are not documented, and best practices are slow to spread to practitioners.* (USDOE, 2016)

In 2006, AIA adopted the 2030 Commitment with the aspiration that all new buildings be net-zero energy by 2030 with ambitious efficiency goals in the interim (AIA, 2023). This voluntary challenge has been adopted by 1.7% of U.S. architecture firms, who report annually on their progress towards that goal. Even among this self-selected sample of firms most interested in sustainability, only 59.7% of their projects are using BPM. The DOE BTO Building Energy Modeling Roadmap estimated that 20% of commercial buildings received energy modeling (Barbour et al., 2016).

Simplified BPM has the potential to overcome several of these barriers to widespread adoption of energy modeling and can increase consistency between modelers by requiring less engineering judgement and automating the baseline. It can reduce the need for training, automate the use of best practices, and produce more consistent results. Reviewing simplified BPMs is also much simpler than current detailed models.

How Simplified Energy Modeling Could Bridge the Gap

Several simplified BPM tools exist; however, each tool provides varying levels of simplifications and simulation results can be vastly different based on the inputs available to users and values provided for the input fields. Standardization of the minimum level of detail for building input simplification methodologies could reduce the varying interpretations and approaches adopted by simplified BPM tools. This would result in a higher level of confidence in simulation results and the use of the simplified BPM tool. To support this objective, the authors have developed the Simplified Performance Rating Method (S-PRM) approach, which is a simplified BPM approach based on the PRM, to simplify and lower the cost of the energy modeling process in a controlled and documented manner. Consequentially, this can increase the use of BPM and its effectiveness in the design, retrofit, and operation of commercial buildings. The S-PRM approach specifies simplified modeling rules which could be integrated into software tools to provide a simplified BPM and code-compliance interface. The S-PRM approach would be initially applicable to simple commercial buildings of standard use types (office, retail, warehouse, etc.) with relatively simple HVAC systems and typical geometries. S-PRM would create a standard that could be used consistently across the industry. Simplified whole-building performance modeling approaches are currently being used in 18 programs implemented by Willdan, by Slipstream for ComEd, and has been piloted by the New York City and Energy Trust of Oregon.

Simplified Energy Modeling Has Increased the Use of Modeling

In the last decade, several firms have developed simplified BPM tools or modes in their detailed modeling tools (Tillou, Goel, Rosenberg, 2020). Simplified BPM tools have been used as part of state-regulated utility energy efficiency programs since 2013. These programs are subject to third-party review of the savings claims by Evaluation, Measurement, and Verification (EM&V) consultants. In 2016, Xcel Energy's Minnesota EDA program adopted simplified BPM and grew participation 58% in the subsequent four years from 110 projects per year to 174. Simplified BPM allowed smaller buildings to be enrolled in the program and receive BPM because of the lower cost to provide the modeling. Similarly, in 2016, Duke Energy added a simplified BPM-based path to their New Construction Energy Efficiency Design Assistance (NCEEDA) program and went from 16 projects to over 140 in a year. The programs are not just enrolling more projects, but the 17 utility efficiency programs using simplified BPM are also delivering 2.2 times the verified energy savings per project (ESource, 2024) while maintaining realization rates (third-party verified savings divided by claimed savings) above 95%. Fewer required inputs for simplified BPM allow modeling to happen earlier in the design, giving the opportunity for greater influence on the design without the delays or costs of redesigning a project. The Duke Energy NCEEDA program is discussed in further detail below.

Simplified Performance Rating Method

The S-PRM ruleset has well-defined requirements to provide a standard approach for simplified BPM capabilities. It clearly outlines the permitted level of detail for defining building parameters including building geometry, envelope properties, HVAC systems etc., and it includes a default set of schedules and loads which could be used if project specific schedules and loads are not defined.

Applicability

Simplified BPM is not appropriate for all buildings such as large buildings with complex HVAC systems. Neither are mission-critical use types, such as hospitals and data centers, nor those with complex requirements for pressurization or ventilation.

Simplifications

The S-PRM ruleset attempts to strike a balance between simplifications and appropriate level of detail to ensure models developed in accordance with this ruleset are representative of the building being analyzed. The section below identifies some of the key simplifications that are required by the ruleset.

- **Geometry and Thermal Zoning:** Building geometry is one of the most challenging and time-consuming aspects of developing a building performance model. The S-PRM ruleset defines the permitted variation between the actual and simplified building footprint area, exterior surface area, orientation, building volume, and fenestration area. It codifies the concept of a thermal block which is a collection of zones with the same use type and served by the same type of HVAC system and prescribes a simplified perimeter and core zoning requirement with weighted average schedules, loads, and HVAC system characteristics.
- **Building Classification:** S-PRM ruleset requires the use of building area types instead of individual space types for defining a building.
- **Building Envelope:** The S-PRM ruleset requires the user to model opaque surfaces through an assembly U-factor. Layer-by-layer specification of opaque construction assemblies is not required. Fenestration surfaces are allowed to be modeled as a single surface on the center of the façade or roof.
- **Lighting Systems:** The S-PRM ruleset requires the lighting power density to be entered as a weighted average value at a thermal block level. It does not give credit for lighting controls which go beyond the mandatory code minimum.
- **HVAC Systems:** The ruleset explicitly identifies the HVAC system types that are permitted to be analyzed using this approach. For the permitted HVAC systems, the ruleset identifies the permitted input parameters for HVAC system definition as well as the assumptions for default system parameters that are not user inputs. It also defines the methodology for calculating weighted average values for efficiency, fan power etc. for all the HVAC systems serving a thermal block.

S-PRM Validation

To evaluate the impact of the simplifications proposed by S-PRM and validate the approach, PNNL evaluated three prototype buildings with each of the S-PRM simplifications analyzed individually and cumulatively. The intent of this validation test was to identify the extent of variation introduced by the simplifications when compared to the detailed PRM model. Since prototypes are prototypical models, they don't always represent all potential design variations. Hence, these validation tests are meant to be indicative of the expected impact of each simplification rather than deterministic on the actual impact of the simplification.

For a more detailed comparison of the S-PRM and PRM, actual projects with more complex zoning and design were also analyzed and are discussed in the sections below.

Prototype Buildings

PNNL modified a retail strip mall, midrise multifamily and small office prototypes to develop S-PRM-compliant versions of the same. The most impactful simplifications were:

- Simplified thermal zoning

- Infiltration
- Use of default schedules and loads

Simplified Thermal Zoning: The impact of the simplified thermal zoning was most significantly seen in the retail strip mall prototypes where the 10 individual retail zones were combined into a thermal block level perimeter and core zoning configuration, as shown in Figure 1. The annual energy savings impact of this simplification is shown in Figure 1.

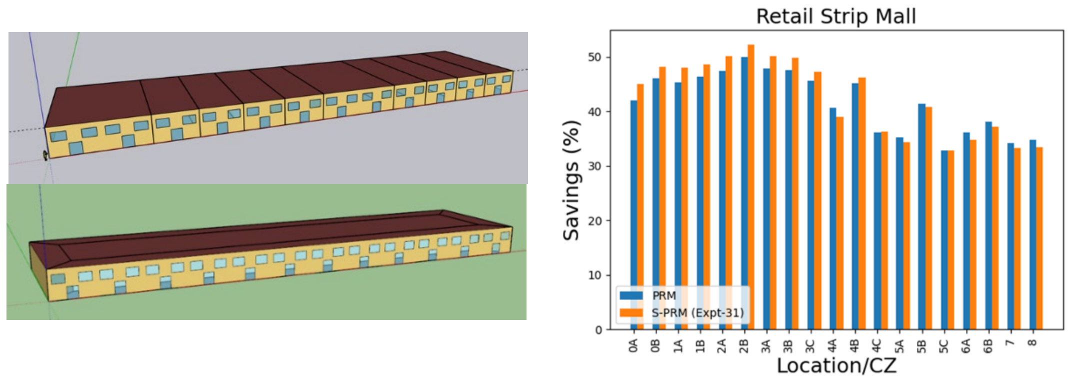

Figure 1. Detailed and Simplified Zoning and Corresponding Energy Savings

Use of Default Schedules and Loads. Despite the significant time savings possible through prescribed schedules and loads, the extent of variation in the as-designed may necessitate customization. Figure 2 shows a comparison of the as-designed schedules against the default schedules for lighting when the defaults do not align with as-designed expectations. Schedules and loads are therefore not prescribed, but defaults are provided for use if detailed information is unknown or unavailable.

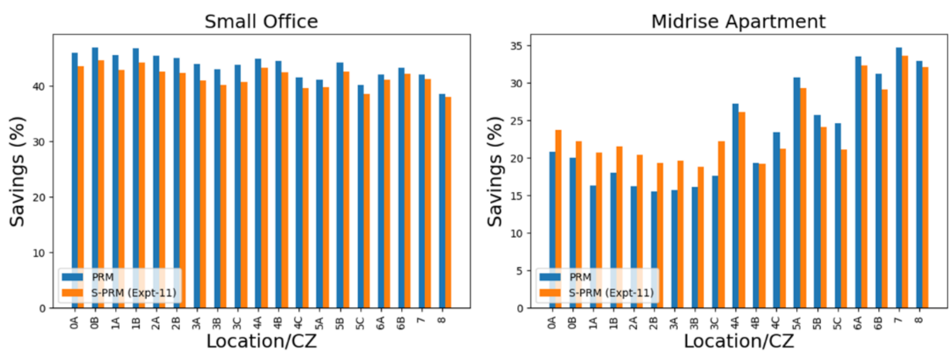

Figure 2. Savings Impacts of Default Compared to Custom Load Schedules

Simplified BPM Use in Duke Energy's NCEEDA Program

Duke Energy (Duke), a Fortune 150 company headquartered in Charlotte, North Carolina, is one of the largest energy holding companies in the U.S. Duke Energy electric utilities serve 8.2 million customers in North Carolina, South Carolina, Florida, Indiana, Ohio, and Kentucky, and collectively own 50,000 megawatts (MW) of energy capacity. Their natural gas serves 1.6 million customers in North Carolina, South Carolina, Tennessee, Ohio, and Kentucky. Duke Energy has provided incentive programs since 2009 in their North Carolina, South Carolina, and Indiana service territories. In 2016, Duke added a simplified BPM path to the NCEEDA program serving commercial and multifamily new construction and major renovation projects. This path was implemented by Willdan (The Weidt Group) using Willdan's Net Energy Optimizer® (NEO). Launching the simplified BPM path increased participation by nearly 10 times. Simplified BPM is currently used for 94.9% of participants and detailed modeling is used for 5.1% of participants with complex building types or mechanical systems such as hospitals, laboratories, or buildings with water-to-water heat pumps. Simplified BPM allowed modeling to move from construction documents to the earlier schematic design and design development phases. Willdan's internal review of projects found projects that enroll and receive energy modeling earlier in the design average 60% more savings than those that enroll later.

The NCEEDA program was launched before S-PRM was developed and has several deviations from S-PRM. Current deviations include allowing more building types and mechanical systems, and allowing additional customizations such as ventilation rates. Since incorporating simplified BPM, NCEEDA has had 480+ projects. Figure 3 shows the distribution of building types in the population of verified projects and the sample of projects that received third-party EM&V.

For each of these projects, typically during the schematic design phase, a trained energy modeler collaborates with design teams and owners to gain details about the building including basic geometry, functional usage, operational usage, ventilation, thermostat settings, water usage, other space loads, and HVAC systems. Additionally, beyond energy code efficiency improvements are documented and modeled to predict the savings relative to a building that just meets minimum code requirements.

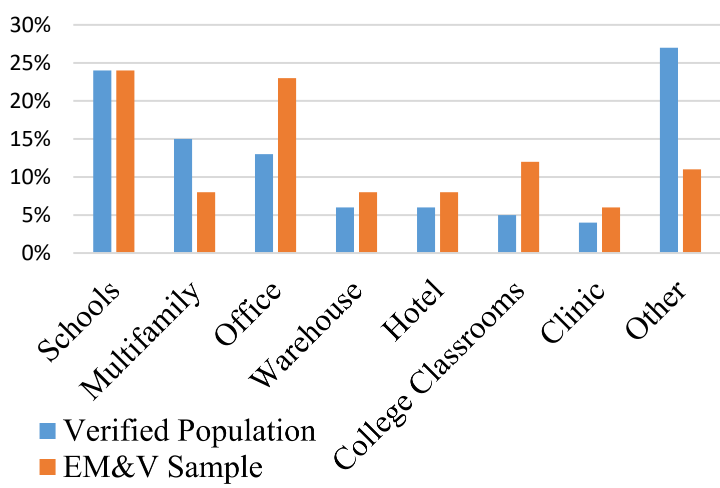

Figure 3. NCEEDA Verified Projects Population Compared to EM&V Sample

The intent of the Duke Energy NCEEDA whole-building modeling is to capture the best representation of how the building is intended to be used including expected occupancy, loads, and usage. The model predicts energy use and savings, which need to be closely realized at the meter. After the initial creation of the energy models, the Duke Energy models are revisited at construction completion to create an "as-verified" model that reflects the final completed building. These models and results will be referenced as predictive models.

A focus of the Duke Energy program has been to ensure that these predictive savings and results are realized at the meter. A representative sample of 67 projects were selected by a third-party evaluator covering the period of January 1, 2020 through December 31, 2021 (Figure 3); a limited number of multifamily projects were reviewed as energy is mostly unregulated in dwellings and aggregation of all tenant and owner meters added complexity. The projects were to be compared to at least 12 months of electric meter data. This model is referenced as calibrated. The calibration consisted of in-depth reviews, virtual, or phone interviews with program participants, collecting trend data, utility consumption data, and building automation system/energy management system (BAS/EMS) data. Acceptable tolerances were set as defined by the Uniform Methods Project (Keates, 2017) looking at monthly consumption within +/-5% normalized mean bias error (NMBE) and +/-15% coefficient of variation of the root mean square error (CVRMSE).

The study by the third-party evaluator found the predictive model results ranged between 68% and 256% relative to the calibrated model, with the overall energy realization rate for the new construction projects within the sample at 99.5%.

Monthly Comparison of Eight Projects

Eight of the 67 projects were chosen at random for detailed analysis in this study. They include four offices and four schools in North Carolina.

When it comes to comparing any energy model to monthly aggregated electric meter data, there are things that expectedly vary. Energy models use project customized schedules for lighting, occupancy, and plug load use and assume proper operation of HVAC systems using typical control sequences. Weather also varies from the predictive model that uses typical meteorological year versus the actual weather. Real buildings have unique daily usage, human occupant interaction, and actual HVAC controls. Capturing trends of usage and separating the baseload from the weather-dependent load are therefore desirable to best create a predictive model. The billed_kwh represents the meter readings from the utility (meter readings were not adjusted, the month was chosen that covered the bulk of meter reading dates). The simulated_kwh represents the calibrated model results from the third-party evaluator at the same interval as the metered data. The model was run using Typical Meteorological Year (TMY3) weather files. Additionally for this paper, the EM&V calibrated energy model files were also run using Actual Meteorological Year (AMY) data to show any potential weather impacts for the particular year of metered data.

Specific details of the offices and schools are hidden to protect the privacy of the client data.

Comparison of Model to Meter of Offices

Table 1. Calibrated Model Results Compared to Metered Results for Offices

Building	Office A	Office B	Office C	Office D
Size (sf)	350,000	100,000	750,000	250,000
Electric Consumption Deviation from Meter				
TMY Annual kwh	7%	8%	200%	-2%
AMY Annual kwh	3%	6%	198%	-3%
Average monthly kwh	5%	6%	226%	-1%
Monthly Variability	18%	10%	123%	11%
NMBE	2%	7%	233%	4%
CVRMSE	18%	13%	218%	16%

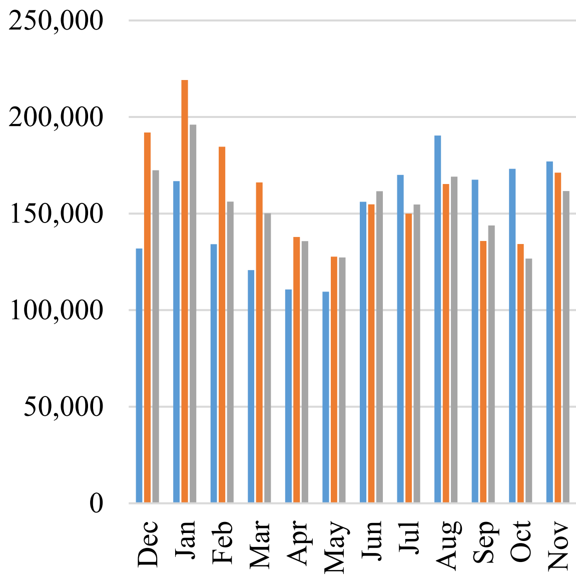

Figure 4. Office A Model to Meter Comparison, VAV with Water-Cooled Chiller and Boiler

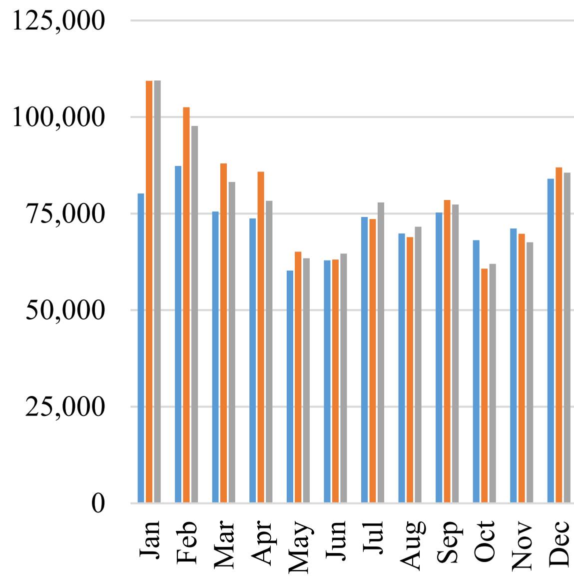

Figure 5. Office B Model to Meter Comparison, VAV with DX Cooling and Electric Heat

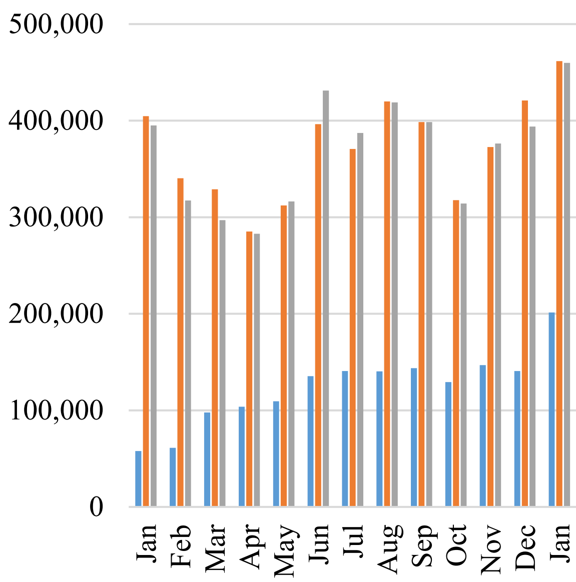

Figure 6. Office C Model to Meter Comparison, Self-Contained Water-Cooled DX with Electric Heat

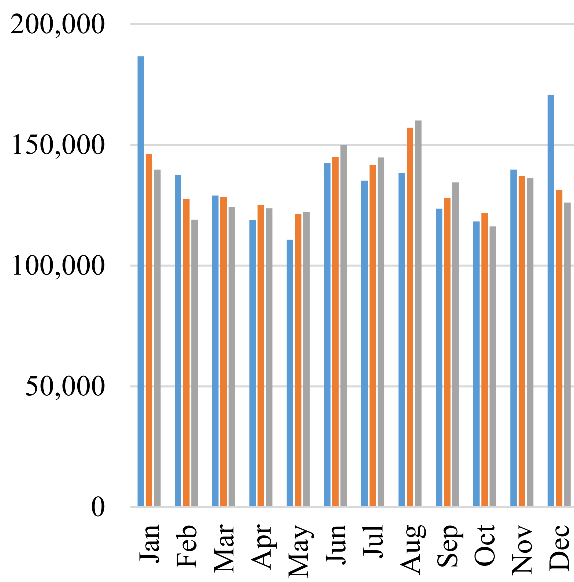

Figure 7. Office D Model to Meter Comparison, Self-Contained Water-Cooled DX with Electric Heat

Offices A, B, and D visually show that the overall shape of the electric consumption is quite similar between the metered data and the modeled data.

Office A

Office A is a 350,000 sf multiuse tenant building including retail, office, and parking served primarily with a multizone variable air volume system with chilled and hot water served by a water-cooled chiller and gas boiler, respectively. The fuel usage from the gas boiler is not analyzed. See Figure 4 for meter to model monthly electric consumption. When the weather was altered to represent the actual weather, the results trended more closely. Of note, one of the tenants has since been confirmed to be a restaurant instead of the modeled retail which impacts the equipment, occupancy, and overall schedule for a portion of the building. Tenant buildings will naturally show more tendency for variation since the occupant and use-type of the spaces are unknown.

Office B

Office B is a 100,000 sf owner-occupied office using a multizone variable air volume system with direct expansion (DX) cooling and electric resistance heating. See Figure 5 for meter to model monthly electric consumption. The owner-occupied building results trended among the best of those sampled. It is likely a result that the usage of the building is more well-defined and controlled versus a tenant building where less is known about the short- and long-term usage. Of note, is that the months that the electric use diverges the most are heating months. More investigation should be completed to determine why the winter months diverge, which may or may not be a result of the simplified HVAC zoning. This building is also one of the two out of the 8 buildings studied that have a building and HVAC system type that are allowed through the S-PRM

Office C

Office C is a 750,000 sf speculative office building served by self-contained units that use water-cooled DX connected to a cooling tower and electric resistance on a floor-by-floor tenant basis. See Figure 6 for meter to model monthly electric consumption. This building exhibited an extreme difference, we expect because the model assumed full occupancy, and the building is only partially occupied presently. The energy usage of this building continues to increase as more tenants sign leases. The year-over-year January usage doubled as more tenants filled the building.

Office D

Office D is a 250,000 sf core and shell office building with some integral parking served by self-contained units that use water-cooled DX connected to a cooling tower and electric resistance on a floor-by-floor tenant basis. See Figure 7 for meter to model monthly electric consumption. This office building is core and shell, but occupants are somewhat typical office occupancy. The months that the electric use diverges the most are heating months. More investigation should be completed to determine why the winter months diverge, which may or may not be a result of the simplified HVAC zoning or variations in tenant usage that are difficult to account for.

Comparison of Model to Meter of Schools

Table 2. Calibrated Model Results Compared to Metered Results for Schools

Building	School A	School B	School C	School D
Size	100,000	350,000	100,000	100,000
Electric Consumption Deviation from Meter				
TMY Annual kwh	6%	-4%	-16%	20%
AMY Annual kwh	10%	2%	-10%	23%
Average monthly kwh	8%	1%	-13%	22%
Monthly Variability	14%	10%	10%	18%
NMBE	11%	8%	11%	25%
CVRMSE	17%	16%	16%	32%

All schools visually show that the overall shape of the electric consumption is quite similar between the metered data and the modeled data. A clear trend among the evaluated schools is that appropriately understanding the summer usage is extremely important to accurately model summer break electric consumption.

billed_kwh calibrated_kwh weather_calibrated_kwh

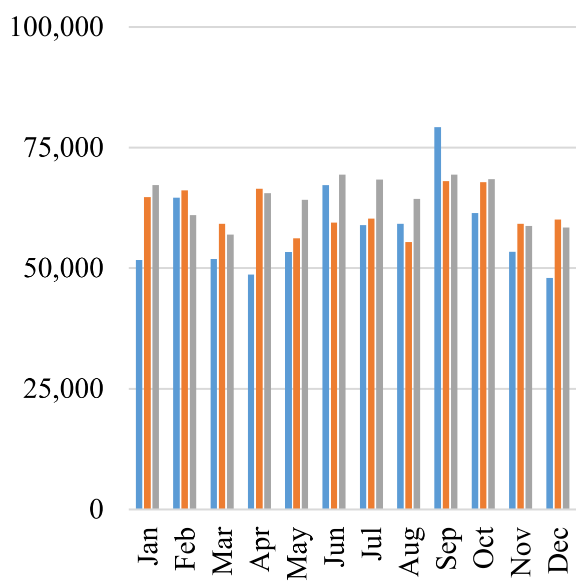

Figure 8. School A Model to Meter Comparison,
Ground-Source Heat Pump

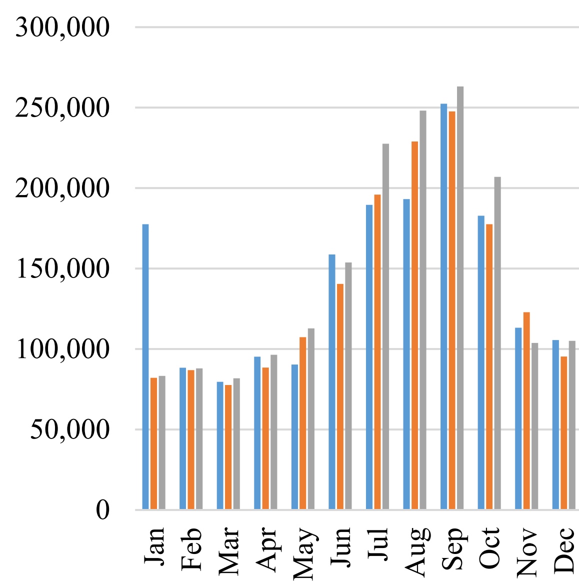

Figure 9. School B Model to Meter Comparison, VAV with Air-Cooled and Gas Boiler

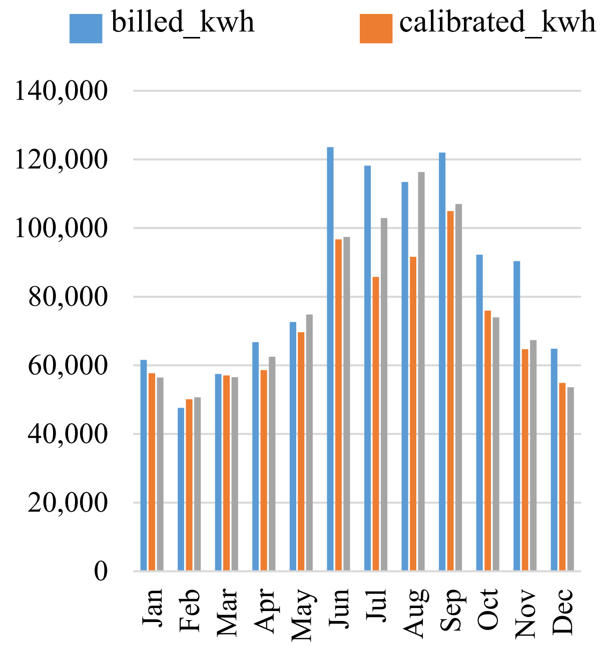

Figure 10. School C Model to Meter Comparison, Four Pipe Fan Coil with Air-Cooled Chiller and Gas Boiler

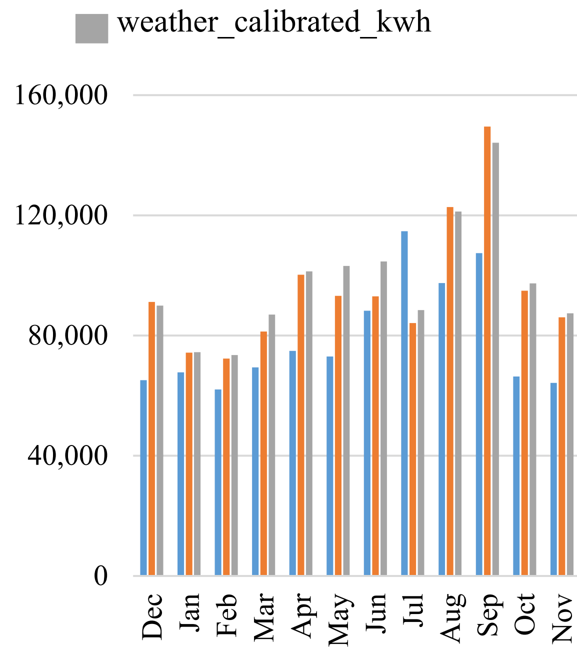

Figure 11. School D Model to Meter Comparison, VAV with Air-Cooled Chiller and Gas Boiler

School A

School A is a 100,000 sf elementary school served primarily with zonal ground source heat pumps, where heating is supplied by electricity and accounted for in the results. See Figure 8 for meter to model monthly electric consumption. The winter usage showed a higher overall variation on a monthly basis. This could potentially be attributed to a number of school calendar days where the school is unoccupied. The summer usage was customized to partial usage and appears to have been characterized fairly accurately. This building is also one of the two out of the 8 buildings studied that have a building and HVAC system type that are allowed through the S-PRM.

School B

School B is a 350,000 sf high school served primarily with multizone variable air volume systems with hot water and chilled water served by an air-cooled chiller and gas boiler. See Figure 9 for meter to model monthly electric consumption. Heating was supplied by natural gas and is not included in this analysis. The first month of meter data for January appears to be an outlier or an error in the meter readings. The winter energy use otherwise trended extremely closely, noting that the model likely captured the baseload well as the heating energy was not included since it is natural gas based. The summer months of July and August overestimate the overall energy use relative to the meter, likely attributed to the modeled results assuming a year-round schedule instead of a partial schedule for reduced summer use.

School C

School C is a 100,000 sf elementary school served primarily with zonal four pipe fan coil systems with hot water and chilled water served by an air-cooled chiller and gas boiler. See Figure 10 for meter to model monthly electric consumption. The winter energy use trended extremely closely, noting that the model likely captured the baseload well as the natural gas heating energy was not evaluated. The modeled summer months of July and August underestimate the overall energy use relative to the meter, likely attributed to the modeled results assuming an overly reduced summer use, though the results trended much closer in the summer when the actual weather was used to simulate, indicating somewhat of a more extreme summer weather than typical.

School D

School D is a 100,000 sf elementary school served primarily with multizone variable air volume system with hot water and chilled water served by an air-cooled chiller and gas boiler. See Figure 11 for meter to model monthly electric consumption. Heating was supplied by natural gas and is not included in this analysis. Overall modeled energy use appears to be overestimated in the model, likely attributed to either scheduling or overestimation of the baseload energy use. A tighter calibration could likely have been achieved by the evaluator.

Model-to-Model Comparisons in the Duke Energy NCEEDA Program

Based on the model-to-meter data comparison, it can be concluded that the calibrated models are a good representation of the billed meter data. Given this, the predictive model estimates can be evaluated for how well they estimate the metered data and realized savings due to energy efficiency. For the 67 project sample size, the total modeled electric savings was found to be 94% of the metered savings. The representativeness of the predictive model to the realized savings at the meter showed some trends.

Only six building types had enough samples to be statistically significant. The buildings showed an average of 89% to 110% of the realized savings with deviations within the sample size ranging from 7%-24% (Figure 12). Hotels showed the least deviation and college classrooms showed the most, likely due to the variety in usage of the college classrooms from standard lecture halls to science classrooms.

By S-PRM applicability, which is based on building and system type, the buildings showed an average of electricity savings 100% realization rate for the sample that fits the criteria of S-PRM and a lower overall variability of 22%. For buildings and systems beyond the S-PRM criteria, the overall savings are 105% of the verified with a higher variability of 25% (removing the outlier of the partially occupied spec office building).

When analyzing the reliability and variability of results by the cooling plant type, there was very little difference when a plant was present versus a DX based cooling system. Air-cooled chillers average 110% modeled savings relative to meter, with district cooling averaging 95% modeled savings relative to the meter. Water-cooled chillers and DX fell in between at 98% and 101%, respectively. The variability for any particular project from the average ranged from 22% for DX systems to 28% for air-cooled chillers (Figure 13). These results support that a simplified model can model chillers, district cooling, and DX systems with similar accuracy.

When analyzing the reliability and variability of results by system types that had more than four projects, the outcome of savings across projects align closely with the savings found at the meter with ground source heat pumps at 96% of modeled savings relative to meter verified to 107% with four pipe fan coils. Single zone units, variable air volume, and variable refrigerant flow fell in between at 100%, 106%, and 99%, respectively. Overall variability among an individual project ranged between 6% for VRF and 29% for VAV. The minimum sample size of VRF likely contributes to the small variability. 31 projects on the VAV system support that VAV systems can be modeled in a simple BPM, but with the simplified zoning, may result in more variability than systems that serve single zones.

Conclusion

The complexity and expense of BPM are a barrier to its use in projects, especially buildings under 25,000 square feet that make up 80% of the commercial building market (CBECS, 2018). According to AIA, even among the 1.7% of firms that are voluntarily and publicly reporting their use of energy modeling, only 59.7% of their projects are modeled. Further, modeling results can vary widely by practitioner. S-PRM could standardize simplified BPMs and increase the adoption of modeling. This report has shown that simplified BPMs can provide accurate energy predictions compared to the metered energy consumption for the Duke Energy NCEEDA population of buildings. Providing a simplified performance approach that reduces the time to create the BPM by up to 75% will provide more projects access to project-specific analysis of their efficiency options. This provides a lower cost and more consistent approach to modeling for energy code compliance, EDA, and utility efficiency programs. Simulation-based optimization can identify more efficient options for the same or lower construction cost than prescriptive-based

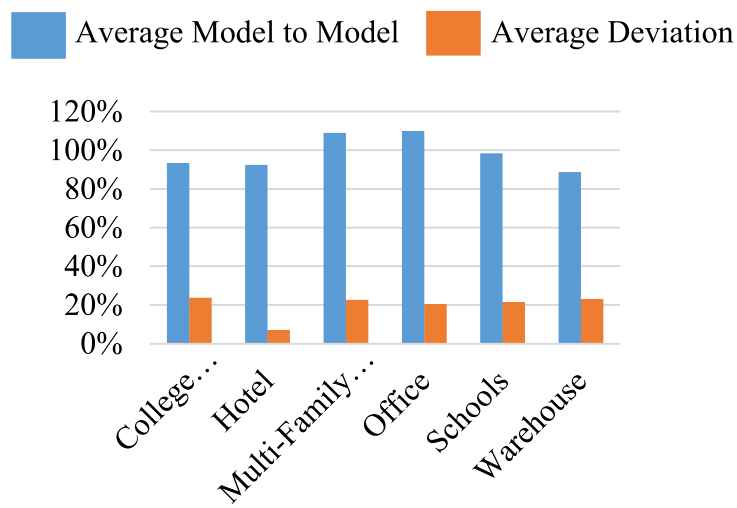

Figure 12. Variability by Building Type

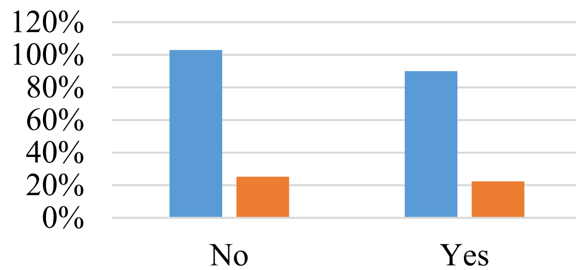

Figure 13. Variability by S-PRM Eligibility

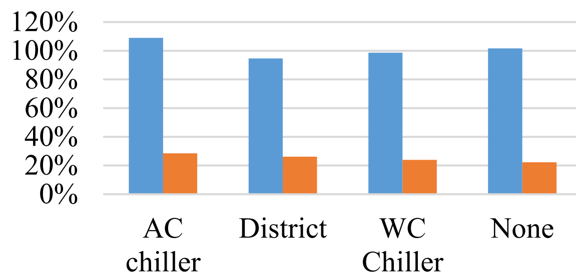

Figure 14. Results Variability by Cooling Plant

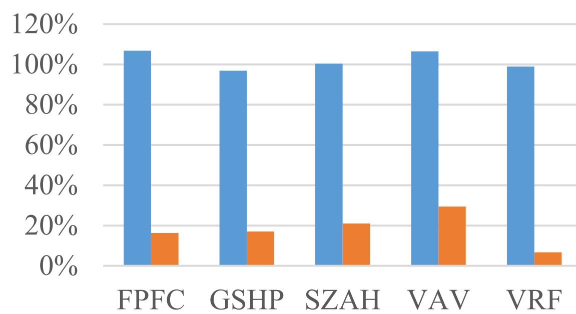

Figure 15. Results Variability by System Type

compliance. Simplified BPMs have also been demonstrated to increase the uptake of modeling rather than simply replacing detailed modeling as discussed above for both the Xcel Energy and Duke Energy commercial new construction programs.

Simplified BPM allows modeling to be used earlier in the design process, hence informing design decisions and supporting design optimization. In Willdan's experience in utility efficiency programs, earlier modeling has been demonstrated to provide 60% more savings per project than when modeling is started later in design.

Adopting a simplified performance rating method into energy codes such as ASHRAE 90.1 and the International Energy Conservation Code (IECC) can enable more cost-effective energy efficiency.

Evaluations

To achieve the cost savings potential of simplified BPM, the industry will need to update their approach to third-party evaluations of the savings. The IPMVP only allows for calibrated simulations (Option C – Whole Facility) for claiming savings for new construction projects. Calibrated models require detailed inputs often not available to simplified BPM. Creating a fully calibrated model can easily cost as much or more than creating the initial design model, negating the cost savings of a simplified approach.

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