ADDENDA

ANSI/ASHRAE/IBPSA Addendum c to ANSI/ASHRAE Standard 209-2018

Energy Simulation Aided Design for Buildings Except Low-Rise Residential Buildings

Approved by ASHRAE and the American National Standards Institute on July 31, 2024. Approved by the International Building Performance Simulation Association on July 10, 2024.

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FOREWORD

Addendum c adds a new appendix. Informative Appendix XX, "Predictive Energy Modeling," is a discussion on the differences between the typical comparative energy modeling used for code compliance and determining performance beyond code, and a more outcomes-based modeling when a team wants to determine the likely performance of a building. The appendix is informative and is not required for compliance with the standard, but it provides context and things that may require additional attention in performance-based modeling.

Informative Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum c to Standard 209-2018

Modify Section 5.6.4 as shown.

5.6.4 Document the overall project energy performance goal.

Informative Note: See Informative Appendix G.

Add new informative appendix as shown.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX XX
PREDICTIVE ENERGY MODELING

XX1. INTRODUCTION

The goal of predictive energy modeling is to predict the actual energy performance of a building in order to meet a target energy use intensity or to achieve net zero energy use or other specific outcome. Predictive modeling is distinct from the more common comparative energy modeling, where modeling is used to compare two or more options. In comparative modeling, schedules and unregulated loads are often set at a reasonable estimate and have little impact on the comparison because they are applied to both the proposed design and baseline. In predictive modeling, these assumptions will likely significantly impact the outcome. This appendix provides guidance on predictive modeling during the design phase rather than model calibration that happens after a building is occupied and actual weather, occupancy, and metered consumption is available. Additional information on model calibration can be found in ASHRAE Guideline 14[2].

XX2. DEFINING A GOAL

Predictive modeling is typically performed to assess whether a building is on track to meet a specific goal. It is imperative that this goal be clearly defined so that success can clearly and easily be determined based on the results of the energy modeling. Determining an energy performance goal is discussed in Section 5.6, "Energy Performance Goals in OPR." Energy consumption per year goals need to specify if they are site or source. Net zero goals need to specify if they are net zero site energy, source energy, or carbon emissions. If carbon emissions, does that include Scope 1 and Scope 2 only (direct and purchased energy) or also Scope 3 (indirect) emissions[F16] as well or embodied carbon from construction? The project team should specify if the carbon emission goals are based on marginal or average emission factors, calculated hourly, monthly, or annually based on the current grid, or on projected future emissions. The National Renewable Energy Laboratory's Cambium[F29] project is one potential source for long-run marginal emission rates.

XX3. USES FOR PREDICTIVE MODELING

While comparison modeling (and in many cases compliance modeling) tends to focus on relative performance compared to a baseline, predictive modeling usually has the goal of designing a new building or retrofitting an existing building to meet an absolute performance target. These targets, often set by the owner, project team, or an outcome-based code, are specified in terms of energy use intensity in units of kBtu/ft^2·yr, or an absolute limit for CO_2 equivalent emissions. Predictive energy modeling performed during design increases the confidence that these operational targets can be met. The following are common uses of predictive modeling:

a. Net Zero Energy Grants and Utility Incentives: Some programs (e.g., Illinois Clean Energy Community Foundation) require 12 months of utility data demonstrating net zero energy performance to receive financial incentives.
b. Outcome-Based Performance Codes and Certifications: A growing number of codes and certifications (e.g., Energy Star, LEED Zero, Living Building Challenge, International Living Future Initiative's Zero Energy Certification) require actual performance to meet established goals.
c. Accurate Operational Budgeting: Some owners desire accurate predictions of utility consumption and costs for operational budgeting purposes.
d. Grid Interoperability: Estimating how much load a building could shed during a demand response event, modeling techniques to quantity how a building will interact with the electric grid have been developed by the Grid Optimal[F28] program.

Additional information about predictive and comparative energy modeling can be found in *ASHRAE Handbook—Fundamentals*[F7], Chapter 19-, Section 1.5.

XX4. PREDICTIVE MODELING CONSIDERATIONS

XX4.1 Weather. Selecting a weather file should be carefully considered for predictive modeling. Projects should choose weather from nearby stations with similar microclimates (such as elevation or proximity to large bodies of water). Projects with a goal for the first year's energy consumption can use current typical meteorological year weather files. Projects that want to predict energy use further into the future should consider using predictive weather files based on climate change models for the desired time frame and emission scenario and warming percentile. Projects should further consider modeling with several different weather years to determine the sensitivity to weather. Further discussion on future weather can be found in Appendix YY.

XX4.2 Occupant Behavior. Comparative energy modeling often uses typical schedules for the major building uses. This approach may have all private offices set to 10% occupancy during a specific time period, when a more nuanced schedule would have one out of every ten private offices occupied. Similarly for conference rooms, the building's energy consumption may be different if two conference rooms are occupied at 25% versus one conference room at 50% and the other at 0%. As much as feasible, projects performing predictive modeling should build schedules that reflect the variation in occupancy across different spaces.

Projects should use schedules based on real survey data or security badge logging, ideally for that organization, when possible. Different organizations use their buildings in unique ways, and predictive modeling should strive to reflect that. If the organization has other buildings with similar programs, they should be evaluated and used as a basis for the loads and schedules in the modeled building. If no peer building is available, *ASHRAE Handbook*, standards and guidelines, DOE reference buildings, and simulation guides such as COMNET can be used. Further discussion on occupant behavior in modeling can be found in *ASHRAE Handbook—Fundamentals*[F7], Section 19.14.

XX4.3 Uncertain Loads. Some loads are challenging to predict during modeling. Plug loads may vary as staff change their workstation setups, infiltration depends on the details and rigor of the installation methods, and HVAC equipment may be improperly installed or commissioned.

Due diligence to estimate uncertain loads includes discussions with the owner, occupants, and operators about how they anticipate using the new building and how they currently use similar existing facilities. Assumptions should be documented and shared with the rest of the design team and owner. For projects with absolute energy goals, assumptions regarding occupant loads and behaviors should be provided to the owner and occupant as energy budgets/allowances, preferably with sensitivity analysis showing the impact of varying from those assumptions. These allowances can inform how the building is operated and highlight if the building use is driving a deviation from the predicted energy consumption. Infiltration rates can be specified as a maximum allowable infiltration required for the contractor to meet, and testing should be performed to ensure the allowable maximum rate has been achieved. Plug loads can be prescribed as a maximum watt-hour allowance per workstation.

XX4.4 Overlooked Loads. Energy modeling for compliance can sometimes overlook loads that are not regulated by energy codes such as ANS/ASHRAE/IES Standard 90.1 but fall within the energy boundary of interest. Predictive energy modeling needs to account for all expected thermal loads in the operation of the building site and all energy loads on the building meter to produce an accurate prediction. Commonly overlooked loads that may be on the building meter include

- Exterior lighting
- Engine block heaters (cold climates)
- Heat trace (cold climates)
- Landscaping features
- Process loads
- Kitchen loads
- Guard shacks
- Personal space heaters
- Duct and piping losses
- Heat loss in service hot-water circulation
- Transformers
- Vehicle charging
- Vertical transportation including escalators and elevators
- Parking garage exhaust
- After-hour cleaning equipment
- Water features
- Electric or gas fireplaces

If an owner has a similar facility to the one being designed, a detailed survey of all energy-consuming devices should be taken, or a peer facility should be identified to determine typical actual loads in a building of that type.

XX4.5 Sensitivity Analysis. While for some applications of building energy modeling (e.g., code compliance) it is convenient to yield consistent deterministic results, there are applications (see Section XX3, “Uses of Predictive Modeling”) where it is desirable to predict building energy performance in probabilistic terms, either using a range or the mean and standard deviation of predicted annual energy. A sensitivity analysis can be used for this purpose.

A sensitivity analysis is useful in comparative energy modeling to determine which design parameters have the greatest impact on building energy performance. However, in design-phase predictive energy modeling, a sensitivity analysis is also useful in determining the probable range of performance outcomes due to the uncertainty in the construction and operation of the building and its systems. It also provides the building operator with a list of parameters to monitor closely.

This analysis typically starts with a proposed energy model, typically using standardized or as-designed inputs. One or more sets of simulations are executed that provide information about the sensitivity of annual building energy use to specific design or operational parameters. These parameters can be properties or sets of properties relating to building design or operation that can vary continuously or discretely over a range of values. Possible parameters are

- Weather data
- Plug loads
- Degradation of equipment performance (such as lighting or HVAC control failure)
- HVAC and lighting control set points and schedules
- Occupants and occupied schedules
- Diversity factors
- Internal loads during unoccupied hours
- Operation of movable shading devices
- Infiltration rate

Sensitivity is the change in building energy use per change in the given parameter; for instance, a 10% increase in plug loads may produce a 1% increase in site energy, and responses may not be linear across the range of inputs.

Tools and techniques for sensitivity analysis for building energy modeling are still being developed, and sensitivity analysis is not yet widely used. One approach is to perform several simulation runs over a range of parameter values. The building energy use can then be extrapolated and interpolated to be plotted as a function of the given parameter. The resulting curve gives an idea of the relationship between the parameter and energy use.

A less rigorous approach to sensitivity analysis that may require fewer simulation runs is to compare the baseline energy use to only two additional data points. The two simulations bracket the original parameter value by increasing it by a fixed value (e.g., 50%) in one run and decreasing it by the same value in the other run. The slope between the two extremes provides a measure of the sensitivity. This slope can be used to interpolate the energy savings for intermediate parameter values. In either of the two approaches to sensitivity analysis, caution should be exercised when selecting the endpoints of the range and the intermediate values to test, as the relationship between a parameter and energy use may not be linear over a broad range.

Once the parameters having a high level of sensitivity and uncertainty are identified, one or more simulation runs should be performed using a combination of different values for these parameters across their probable ranges. The number of runs and the values of each parameter within each run may be determined through automated/scripted batch processing of all possible combinations or a smaller set of simulation runs in which the value of each parameter is randomly selected within its probable range. The results of these simulations will provide a range of predicted building performance and should be shared with the owner/occupants.

Further discussion of sensitivity analysis can be found in *A Handbook for Planning and Conducting Charrettes for High-Performance Projects.*[F30]

XX4.6 Documenting Existing Conditions. Retrofits of existing buildings present numerous challenges, especially in documenting existing conditions. Nearly all energy modeling inputs that are existing to remain will need to be investigated, taking more time than in new buildings where envelope and equipment characteristics can be read on design documents.

Envelope properties can be investigated with older drawings, thermal imaging, and sometimes with minor exploratory demolition to determine construction and levels of insulation. Glazing and framing properties are especially important if they are to be reused. Many older buildings lack insulation or air barriers in some places, so multiple areas of the building should be investigated before concluding that a certain U-factor exists. Blower door tests can be used to establish existing infiltration rates.

Reusing equipment requires meeting an assumed standard of good working order and maintenance that should be documented and reviewed with the owner. When feasible, actual operating efficiencies should be measured and used in the energy model across a range of load conditions.

Many unexpected conditions are found during demolition and construction on existing buildings, meaning an allowance is needed for adjusting the energy model during or after construction so it reflects actual conditions more closely.

XX4.7 Calculation Uncertainty. Beyond the uncertainty of input values discussed previously, there is also uncertainty due to the algorithms used by the simulation engines not perfectly matching real-world performance. A full discussion of calculation uncertainty is beyond the scope of this appendix. Modelers should be familiar with the simulation tool they are using and investigate its limitations. ASHRAE Standard 140 sets criteria for testing simulation engine algorithms. Standard 140 is in the process of adding empirical test results with which to compare simulation engines[F13], and modelers should use tools that meet Standard 140. The ability for well calibrated models to closely match a building's hourly energy consumption demonstrates that the majority of uncertainty is due to uncertain building inputs rather than algorithms, but for newer technologies, or technologies not directly modeled by the simulation engine, there may be greater algorithm-driven uncertainty. Further discussion on modeling uncertainty can be found in *ASHRAE Handbook—Fundamentals*[F7], Chapter 19, Section 1.6.

XX4.8 Project Process and Team Member Implications. With aggressive efficiency targets, early and regular energy analysis is critical to determining a cost-effective path to achieving the project's performance target. Prerequisites in Standard 209, such as an early energy charrette, are important.

Frequent meetings between the architects, mechanical designers, and energy analysts (and other stakeholders as needed) are useful to coordinate project inputs and inform the design process as the design evolves from project inception through the design development phase. The energy modeler will play a key role providing feedback to keep the project within its energy budget, similar to how a cost estimator provides feedback to keep a project within its financial budget.

Predictive modeling requires that team members get reasonable and justified estimates for uncertain and overlooked loads, and many of these require owner and architect input or confirmation; often some of these require an additional study outside the expected scope. This can include plug load surveys of existing spaces, review of equipment purchasing policies, analysis of existing hours of operation, or other studies.

Early predictions will evolve as new information is added, leading to discrepancies with later results. This can be handled by providing conservative estimates, showing uncertainty or ranges in results, and by benchmarking against existing projects with actual energy use to ensure results are reasonable. Documenting and reviewing the important modeling inputs/assumptions with the owner and architect at project phases will alleviate some of the changes in predicted energy use, as the changes will be made often due to changes in inputs/assumptions.

XX5. RENEWABLE ENERGY

Projects with goals that include offsetting their energy consumption with renewable energy should determine a list of potential renewable energy sources available on their site. Sources may include solar photovoltaic, solar thermal, wind, hydro, geothermal, and biofuels.

For the majority of projects, solar photovoltaic (PV) will be the most likely candidate to incorporate into a project. With proper infrastructure considerations, solar PV can be installed on a roof, over parking, or in open fields.

When incorporating renewable energy into a predictive modeling cycle, it is important to understand the project goals. The following are some of the reasons to incorporate renewable energy.

- Site EUI reduction
- Points toward a sustainability certification
- Utility demand reduction
- Source energy reduction
- Carbon neutrality
- Return on investment
- Proof of concept/example project
- Code requirement

Each of the reasons above requires a different level of effort to successfully predict the energy impact. The level of effort and granularity of analysis can range from rule-of-thumb measurements to a detailed layout with equipment specified and utilizing an hour-by-hour solar weather file to match building electricity use to solar generation.

XX6. STORAGE

Energy storage provides resilience, demand response, and better base loading and can help reduce the source energy impact of the building.

Energy storage is predominantly focused on batteries and thermal energy storage. Batteries can be charged with grid-purchased or solar PV generated electricity to store energy when building loads are low and release that energy either to assist peak reduction goals or further reduce energy consumption when building consumption is greater than PV generation. Batteries will not lower the building's energy use but can highly impact the amount of electricity imported and exported across an electric meter at particular times. The financial impact of charging and discharging a battery will depend on the utility rate structure, particularly the demand charges. Different utility net metering regulations and demand charges can make it a complex task to fully model the financial impact as well as the source carbon impact if using time of day and seasonal emissions factors.

Thermal energy storage can provide additional capacity during daily cooling and heating swings. In this way, cooling and heating can be generated during periods of low utility energy rates and released during peak times. When incorporating thermal energy storage into an energy model, it is important to understand the capabilities of the energy modeling software. Multiple means may be needed to fully understand and model the impacts.

XX7. DEMAND RESPONSE

Although most building energy simulations do not currently account for it, demand response will likely become a more important aspect of building design as the electric grid continues its transition to variable energy sources such as wind and solar. Demand response allows buildings to adjust their energy consumption, thereby reducing the strain on the electric grid at peak times and responding to energy prices.

Demand response can be estimated by determining the likely time of peak grid load and modeling the building with demand response measures engaged and not engaged. Demand response measures may include

- Lower lighting levels
- Relaxing thermal set points
- Precooling or preheating a space
- Cycling HVAC equipment
- Adjusting service hot-water temperatures (within a safe operating range)
- Reducing industrial production

- Energy storage

New Building Institute's GridOptimal project [F28] has developed grid loads for each state that can be used to determine likely peak demand times. Demand response can be implemented to lower a building's peak demand charges, to respond to utility-declared grid events as a revenue source, or to optimize energy costs or carbon emissions.

Modify Informative Appendix F as shown.

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ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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