ADDENDA

ANSI/ASHRAE/IBPSA Addendum l 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 August 30, 2024, and by the International Building Performance Simulation Association on August 28, 2024.

This addendum was approved by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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 ISSN 1041-2336

International Building Performance Simulation Association

Approved American National Standard

www.ansi.org

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FOREWORD

Addendum l adds a new Informative Appendix X (final designation TBD) that seeks to provide guidance for evaluating the impact of climate change on building energy consumption and building system design. Changes are proposed to existing Informative Appendix A to avoid overlap between Appendix A and the new appendix.

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 l to Standard 209-2018

Modify Informative Appendix A as shown.

INFORMATIVE APPENDIX A
CLIMATE INFORMATION

This appendix provides information sources for climate data for ~~building~~ *energy modeling*. The basic difference between weather and climate is the period of time used when aggregating the original data. Weather data provide outdoor weather information, such as dry-bulb air temperature, or wind speed, for one representative year. Climate data look at the same outdoor weather variables over a multiyear timeframe to define trends in weather data that can affect a building or its energy simulation.

Climate data are also being reviewed for the effects known as "climate change" or "global warming." Some of the information sources may provide information on these topics. Climate change data can be incorporated into an energy modeling analysis to define the risk associated with predicted climate change effects on building energy use and equipment sizing for peak loads. Refer to Appendix X for more information on future climate analysis.

Note about Typical Meteorological Year (TMY) and Actual Meteorological Year (AMY) Weather Data

A typical meteorological year (TMY) weather file contains typical weather/climate data for a one-year period that has been statistically derived from the past ten to 30 years of actual meteorological year (AMY) weather/climate data. The TMY file is useful for typical baseline weather file input to an energy modeling analysis. However, the actual weather data files are not statistically modified. For example, the AMY files contain actual extremes for a given timeframe. These extremes may not be present in a TMY file due to the data analysis methods that define the TMY file. For climate analysis trends, both weather files can be useful, depending on the judgment of the energy modeler.

1. General information resources
   - 1.1 Crawley, D.B. 1998. Which weather data should you use for energy simulations of commercial buildings? ASHRAE Transactions 104:2:498–515.
   - 1.2 Rocky Mountain Institute (RMI)
     - 1.2.1 Elements—software that can convert weather data file formats, perform statistical analysis, convert actual weather data into a given file format
   - 1.3 Energy Design Resources, UCLA Energy Design Tools Group
     - 1.3.1 Climate consultant software
2. Climate data resources
   - 2.1 National Oceanic and Atmospheric Administration (NOAA), part of the United States (U.S.) Department of Commerce
     - 2.1.1 National Centers for Environmental Information (NCEI)
     - 2.1.2 National Weather Service (NWS) Climate Services—provides climate information for U.S. cities:
       - 2.1.2.1 Past weather
       - 2.1.2.2 Climate Prediction Center (CPC): 6 to 14 days, 30 days, and 90 days predictions
   - 2.2 U.S. Department of Energy (DOE)

2.2.1 EnergyPlus Energy Simulation Software

2.2.1.1 Weather Data Sources—website contains information on worldwide weather data sources that may be applicable for climate data use

2.2.2 National Renewable Energy Laboratory (NREL)

2.2.2.1 System Advisor Model (SAM) weather files

2.3 White Box Technologies (WBT) and ASHRAE

2.4 Climate.OneBuilding.org website contains extensive worldwide weather data sources

2.5 WeatherBank, Inc.

2.6 Weather Source

2.7 American Solar Energy Society (ASES)—primarily solar insolation data

2.8 Rocky Mountain Institute (RMI)

~~3. Climate change/global warming models and information~~

~~3.1 Intergovernmental Panel on Climate Change (IPCC)~~

~~3.2 National Center for Atmospheric Research (NCAR) community climate model~~

~~3.2.1 Community Earth System Model (CESM)~~

~~3.2.2 Whole Atmosphere Community Climate Model (WACCM)~~

~~3.3 National Oceanic and Atmospheric Administration (NOAA) (http://climate.gov)~~

~~3.4 Hadley Centre for Climate Change Prediction and Research at the U.K. Meteorological Office~~

~~3.4.1 HadCM3 model~~

~~3.5 International Energy Agency (IEA)~~

~~3.5.1 Addressing Climate Change Database~~

~~3.6 WeatherShift (http://weather-shift.com)~~

Add new Informative Appendix X (final designation TBD). NOTE: The following text is completely new to the standard. Underline has been omitted to make it easier to read.

INFORMATIVE APPENDIX X
FUTURE CLIMATE ANALYSIS

Climate change underscores the critical need to assess and enhance building energy and resilience performance against evolving future weather conditions. This appendix offers comprehensive information and guidance on integrating future weather data into building performance simulation practices. Included are climate modeling and downscaling techniques, future weather data types, application scenarios, and publicly available sources for such data. It is important to note that data sources are dynamic and continually evolving; updates can be found on data.ashrae.org, as this document is a living resource. A general overview of climate information used in building performance simulations can be found in Informative Appendix A.

X1. OVERVIEW OF CLIMATE MODELING TECHNIQUES

X1.1 The Representative Concentration Pathway—Shared Socioeconomic Pathway (RCP-SSP) Framework. In climate research, scenarios are alternative descriptions of how the future might evolve and are an important tool for analyzing how driving forces may influence future emission outcomes and for assessing the associated uncertainties (Nakićenović and Swart 2000). Currently, the most widely adopted emissions scenario framework is the RCP-SSP framework, which combines the SSPs and the RCPs in a matrix architecture, where the radiative forcing levels and socioeconomic assumptions form the two axes, and each cell represents a comprehensive scenario. These scenarios are not predictions or policy recommendations but rather represent a broad range of possible future outcomes that can aid in understanding uncertainties in climate change projections (Moss et al. 2010).

The radiative forcing axis is represented by the RCPs. The RCPs are specific emission scenarios selected to be representative of the full range of emission scenarios in the literature. The RCPs are named according to the expected radiative forcing level for 2100. A total of four radiative forcing levels were chosen, including one mitigation scenario leading to a very low forcing level (RCP2.6), two medium stabilization scenarios (RCP4.5/RCP6), and one very high *baseline* emission scenario (RCP8.5) (van Vuuren et al. 2011). The socioeconomic assumptions axis is described in SSPs. The SSPs are a set of five socioeconomic pathways consisting of qualitative narratives and quantitative projections for population, education, urbanization, and economic development. They are characterized by sustainability with low challenges to mitigation and adaptation (SSP1); middle of the road with medium challenges to mitigation and adaptation (SSP2); regional rivalry with high challenges to mitigation and adaptation (SSP3); inequality with low challenges to mitigation, high challenges to adaptation (SSP4); and fossil-fueled development with high challenges to mitigation, low challenges to adaptation (SSP5), respectively (Riahi et al. 2017).

In the Sixth Assessment Report (AR6) of the IPCC published in 2021 (Bamdad et al. 2021), a new set of five illustrative scenarios based on the SSPs (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5) are adopted to replace the four RCPs used in the Fifth Assessment Report (AR5) of the IPCC. These scenarios cover a broader range of greenhouse gas and air pollutant futures than the RCPs do.

X1.2 Projection of Future Climate. General circulation models (GCMs) are used as the primary tool to project the evolution of climate. They simulate the movement of mass and energy in the atmosphere and the ocean by using a system of mathematical equations discretized on three-dimensional grids. While some equations are derived from fundamental laws of physics, many physical processes have to be parameterized using empirical relationships based on observations (Intergovernmental Panel on Climate Change 2021). Early GCMs only contain mathematical descriptions of atmospheric circulation (Randall 2000). As research progressed, representations of three-dimensional ocean circulation, cryosphere, and land use were added to form coupled atmosphere-ocean GCMs (AOGCMs) (Intergovernmental Panel on Climate Change 2021). Today, Earth system models (ESMs, also known as coupled carbon-cycle climate models) have been developed to incorporate the biosphere and the carbon cycle (Flato 2011). Apart from new components, the GCMs have been continuously improved by adopting more realistic parameterizations and finer resolutions, which has lead to significantly better performance in terms of reproducing the observed climates (Reichler and Kim 2008). Some of the most well-known GCMs in the world include the Community Earth System Model Version 2 (CESM2) whose development is led by the National Center for Atmospheric Research (NCAR) in the U.S. (Danabasoglu et al. 2020); the HadCM3 developed by the Hadley Centre of the Meteorological Office in the U.K. (Hadley Centre for Climate Prediction and Research 2016); and the GFDL Earth System Model Version 4.1 (GFDL-ESM 4.1) developed by the Geophysical Fluid Dynamics Laboratory (GFDL) in the National Oceanic and Atmospheric Administration (NOAA) of the U.S. (Dunne et al. 2020).

X1.3 Downscaling. GCMs have a typical spatial resolution of 62 to 124 mi (100 to 200 km) to stay within the computational limits of modern supercomputers. Physical processes at a scale finer than the grid size cannot be explicitly resolved and must be parameterized. Additionally, topographic features such as orography and land-sea contrasts within a cell are poorly represented, impeding the simulation of local features such as orographic precipitation and temperature variation with altitude (Ekström et al. 2015). Therefore, the outputs of GCMs must be spatially downscaled before they can be applied to impact studies such as building and *energy modeling*. On the other hand, the outputs of GCMs are often stored on a daily or monthly basis due to the massive storage capacity required (Meehl et al. 2007). Building and *energy modeling* generally require hourly or even smaller-interval weather data as input, necessitating temporal downscaling of the outputs of GCMs. The downscaling techniques can be categorized into two types: dynamical downscaling and statistical downscaling. The dynamical downscaling approach utilizes physics-based climate models similar to GCMs that operate at finer horizontal resolutions, typically in the range of 6 to 19 mi (10 to 30 km) (Yang 2015). These models can only be run for limited areas instead of the entire globe, making them known as regional climate models (RCMs) (Laprise 2008). Statistical downscaling techniques use empirical relationships between local-scale variables and large-scale atmospheric variables (Ekström et al. 2015). At present, most of the future weather data used in *energy modeling* are generated using two statistical downscaling techniques—morphing (Belcher et al. 2005) and stochastic weather generators (Wilby and Wigley 1997).

X1.4 Different Types of Future Weather Data

X1.4.1 Typical Weather Data. Due to the natural variability of climate systems, the weather of a location exhibits significant interannual variations (Intergovernmental Panel on Climate Change 2021). This variability makes it difficult to select a single arbitrary year's weather data for analysis without introducing significant biases (Guan 2009). To overcome this challenge, a popular approach is to select 12 representative months from several decades of chronological weather data and combine them into a typical meteorological year (TMY) that accurately reflects the longterm average characteristics of the local climate. This method was first developed by Sandia National Laboratories in 1978 (Hall et al. 1978). Since then, the Sandia method has been widely modified to create various TMY-type weather datasets, such as the International Weather for Energy Calculations Version 2 for 3012 international locations (Huang et al. 2014) and the Test Reference Year for the U.K. (Levermore and Parkinson 2006).

The most widely adopted approach to developing future typical weather data is to directly morph present TMY-type weather data using climate change trends projected by GCMs (Belcher et al. 2005). This method is popular due to its simplicity, requiring only personal computers and publicly available weather data. Another approach involves using modified Sandia methods to select representative months from future chronological weather data (Qian et al. 2023).

X1.4.2 Extreme Weather Data. Due to the exclusion of extreme weather events, simulations using typical weather data will underestimate the peak heating and cooling demand (Crawley 1998) and the degree of overheating or overcooling in extreme conditions, which calls for the development of extreme weather data. Extreme weather data can be constructed based on event-wise, monthly, seasonal, or annual metrics. Event-wise extreme weather data can be classified into two types: climatic design conditions and extreme weather events. Climatic design conditions represent the values of dry-bulb, dew-point, and wet-bulb temperature and wind speed that are exceeded on average by a certain percentage of hourly values in a year. By using these values, full design-day weather data can be generated, which are used by BEM programs for zone design loads calculation and heating, ventilating, and air conditioning (HVAC) equipment sizing (ASHRAE 2013). Extreme weather events are periods of weather data extracted from the chronological dataset that represent a certain type of extreme weather event, such as a heat wave or a cold spell.

A monthly method of constructing extreme weather data is similar to the Sandia method, the difference being that instead of selecting the month whose cumulative density function (CDF) is the closest to that of the chronological dataset, the month whose CDF is the most different from that of the chronological dataset is selected. The month with the greatest positive temperature difference is selected as the extreme cold month, while the month with the greatest negative temperature difference is selected as the extreme hot month (Nik 2016). The 12 selected months are then concatenated into a complete year just like in the Sandia method. Another method is to select the extreme months on a three-month or six-month basis. This is the so-called seasonal method (Crawley and Lawrie 2019). Annual extreme weather data is a complete extreme year selected from multiyear datasets, the most well-known example of which is the Design Summer Year adopted in the U.K. (Levermore and Parkinson 2006).

X2. APPLICATION SCENARIOS OF FUTURE WEATHER DATA

The whole-building analysis that considers future weather conditions is essential for building owners and facility managers to make informed decisions. A detailed analysis can help identify opportunities for investment in new energy-efficient technologies and solutions, create financial strategies, and reduce longterm maintenance and operational costs. In addition to providing environmental and financial benefits, considering future weather conditions in the whole-building analysis can also improve the building's resilience and safety.

Whole-building analysis can reveal potential opportunities for future-proofing buildings through investments in adaptive technologies, such as sensors and automation systems, that can help buildings adapt to changing weather patterns. Buildings that are resilient to extreme weather conditions can include backup power systems, renewable energy, energy storage systems, or microgrids that help maintain operations during power outages. Future weather data can be applied in a wide range of scenarios:

a. Building Design: Many building owners and architects now use future weather data to inform design decisions, including consideration of factors such as temperature extremes, precipitation patterns, and wind speeds to optimize the building envelope, *HVAC systems*, and other building components.
    1. Energy use and cost: Using future climate models to anticipate building changes in energy use and cost provides the owner and/or tenant additional information to use in capital planning and operations budgeting. If they see a building has a risk of substantial increases to energy costs in the building's lifetime, they may prioritize further energy conservation or demand response measures to mitigate the risk.
    2. HVAC load: Future climate analysis can indicate that sizing *HVAC systems* based on historic TMY files may result in systems undersized to handle future conditions. Increasing the day-one size of an *HVAC system* requires careful coordination from the HVAC engineer to determine the implications for day-one operation (i.e., AHU will spend more time at lower operating conditions). In the U.S., in compliance with its Climate Change Risk Management Plan to have its buildings be climate-ready, the General Services Administration (GSA) requires review of climate vulnerabilities including the HVAC loads of buildings in design (GSA 2021).
    3. Thermal comfort: The use of future weather scenarios can assist planners and designers to mitigate future weather impacts on people in and around buildings. This may result in shading strategies, fenestration changes, insulation adjustments for walls and roofs and more or less indoor space communication with the outdoors, and better design of outdoor spaces to be comfortable in future weather scenarios.
    4. Water consumption of cooling towers: If using water-cooled equipment, future loads as well as future humidity shifts will impact cooling tower efficiency and overall consumption. If using water reuse strategies or otherwise accounting for water in the overall building performance analysis, Future TMY and Extreme Warm Year and Extreme Cold Year scenarios should be tested to determine possible impacts.

5. Water generation of condensate: Changes to future weather conditions may impact the humidity level and patterns for a particular site. If considering air-conditioner condensate reuse, the average condensate captured per year may shift significantly. In addition, locations with stable humidity patterns may enter into more frequent and prolonged patterns of extreme humidity shifts resulting in changes to reuse strategy effectiveness and return on investment.

In addition to the building industry, practitioners in other fields including infrastructure planning, emergency response, and energy production companies can use future weather data to inform planning and design decisions in optimizing and creating more resilient engineering solutions.

b. Infrastructure planning: Future weather data can be used to inform planning and design decisions for roads, bridges, water treatment plants, and other critical infrastructure. By considering future climate projections, engineers can design infrastructure that is resilient to future weather patterns and natural disasters.
c. Emergency response: Emergency response teams can use future weather data to help prepare for and respond to natural disasters, including by planning evacuation routes, identifying at-risk areas, and prepositioning resources such as food, water, and medical supplies.
d. Energy production: Energy companies can use future weather data to optimize energy production and distribution, including by predicting wind speeds and solar radiation to optimize wind and solar energy production and predicting temperature and precipitation patterns to anticipate energy demand.

X3. SOURCES OF FUTURE WEATHER DATA

Future weather data in building performance simulation can be used for annual simulations or design-days HVAC equipment sizing. Data used for annual simulations come typically under the form of a TMY-kind weather file.

There are future weather data generator tools that have data for locations throughout the world. Most tools use statistical downscaling based on the morphing method or on the stochastic weather generation method. A few tools use the dynamic downscaling method. Emission scenarios considered include RCP 2.6, RCP 4.5, RCP 8.5, AR3 CMIP2, AR5 CMIP5, etc. The future weather files come mostly in the EnergyPlus weather (EPW) file format. It is recommended that the choice of future time period be based on the design life of the building being simulated.

In addition to the global weather generators, there are sources of local data in different countries: e.g., Oak Ridge National Laboratory (ORNL) in the U.S. and Pacific Climate Impacts Consortium (PCIC) in Canada.

Sources of data for future weather analysis are hosted at data.ashrae.org.

X4. INTERPRETATION OF RESULTS

With any analysis using future weather conditions, it is important to recognize that the weather input file is based on potential scenarios of future conditions that undergo different techniques to provide a practitioner with a weather file usable for energy simulations. There are four significant sources of uncertainty to factor in any analysis. These include the actual radiative forcing that will occur over time, the climate's response to that radiative forcing, climate variability at a particular site, and the downscaling technique used to turn the output of GCMs into weather files used in *building energy simulations* (Zeng et al. 2023). Because the scenarios are not intended to be accurate future weather predictions, only a broad range of possible outcomes, using future climate weather files for energy analysis introduces uncertainty at the outset. While climate models continue to advance in accuracy, due to computational needs requiring simplification and inability to factor every variable, they contain uncertainty. Downscaling global models to a specific site may not accurately reflect local topology or other differences. The process should be used to analyze the order of magnitude impact between current and future climate on the building analyzed.

As the future weather is unknown—hence the multiple RCP options—it is important to test the sensitivity of the building model against different scenarios if using for capital planning, resiliency measures, or human impacts. If there is low sensitivity to the parameter being analyzed (peak load, annual energy use, rainwater reuse, etc.), there is a greater degree of certainty that the proposed mitigation strategy or bundle of strategies will be successful both now and in the future. However, if the parameter is highly sensitive to the RCP used or extreme weather files, it could lead to additional strategies being required to mitigate the risk that the parameter will deviate from the owner project requirements over the life of the building.

Add the following to Informative Appendix F, "Informative References," as shown.

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POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

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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About ASHRAE

Founded in 1894, ASHRAE is a global professional society committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields.

As an industry leader in research, standards writing, publishing, certification, and continuing education, ASHRAE and its members are dedicated to promoting a healthy and sustainable built environment for all, through strategic partnerships with organizations in the HVAC&R community and across related industries.

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ASHRAE offers its Standards and Guidelines in print, as immediately downloadable PDFs, and via ASHRAE Digital Collections, which provides online access with automatic updates as well as historical versions of publications. Selected Standards and Guidelines are also offered in redline versions that indicate the changes made between the active Standard or Guideline and its previous version. For more information, visit the Standards and Guidelines section of the ASHRAE Bookstore at www.ashrae.org/bookstore.

IMPORTANT NOTICES ABOUT THIS STANDARD

To ensure that you have all of the approved addenda, errata, and interpretations for this Standard, visit www.ashrae.org/standards to download them free of charge.

Addenda, errata, and interpretations for ASHRAE Standards and Guidelines are no longer distributed with copies of the Standards and Guidelines. ASHRAE provides these addenda, errata, and interpretations only in electronic form to promote more sustainable use of resources.

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