ANSI/ASHRAE/IESNA Addendum *e* to
ANSI/ASHRAE/IESNA Standard 90.1-2001

ASHRAE STANDARD

Energy Standard for Buildings Except Low-Rise Residential Buildings

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FOREWORD

Certain agencies, such as the U.S. Green Building Council, have referenced Section 11, Energy Cost Budget Method, of Standard 90.1 as the benchmark for a performance rating of building designs. These agencies require the use of the Energy Cost Budget (ECB) Method in order to gain credits for certification of a building design.

The ECB Subcommittee and interested parties identified some serious problems with using Section 11 as a benchmark for above-standard design, which is something that a growing number of users are now doing. At the same time, there was a consensus among the participants in the discussion that Section 11 was appropriate, as written, for determining minimum compliance with 90.1.

There is a fundamental tension between these two uses of Section 11: for above-standard ratings and for minimum code compliance. An effective rating procedure needs to recognize the contribution of a broad range of features that can be used to make buildings more energy efficient. In contrast, an alternate path for minimum compliance cannot penalize the use of features that are permitted under the standard or reward the use of features that are outside of its scope and still represent an equivalent path. A number of users of the U.S. Green Buildings Council's LEED rating system, which is based in part on Section 11, have recognized this as a problem and brought it to the attention of members of the ECB Subcommittee.

To meet the needs of the users of Standard 90.1 as a code-compliance tool and as a benchmark for above-standard design, the ECB Subcommittee decided to develop an appendix chapter expressly for use in above-standard ratings. This appendix would be an informative one because it is not to be included as part of the minimum requirements to comply with code. The attempt is to provide a generic method, one that can be referenced by any rating agency. The result, Informative Appendix G (Performance Rating Method), parallels Section 11, on which it is based, but contains some significant differences. The rating method generates a performance benchmark that, while generally equivalent in stringency with Standard 90.1, is more stable because it is based on programmatic requirements of the project rather than on its design. Because the benchmark is more stable, a wider array of measures receive credit, and exemplary buildings will show higher ratings than under Section 11, which will bring the applicable components of the standard in line with the requirements of the various rating agencies. In addition to these changes, we identified a number of ways to clarify and streamline the use of performance methods. We hope to move some of these improvements into Section 11 in the future.

Addendum *e* to 90.1-2001 (I-P and SI editions)

Add the following new definitions to Section 3.2:

baseline building design: a computer representation of a hypothetical design based on the proposed building project. This representation is used as the basis for calculating the *baseline building performance* for rating above-standard design.

baseline building performance: the annual energy cost for a building design intended for use as a baseline for rating above-standard design.

rating authority: the organization or agency that adopts or sanctions use of this rating methodology.

regulated loads: building energy load components that are regulated by this standard. HVAC, lighting, and service water heating are regulated loads; receptacle and most process loads are not.

performance rating method: a calculation procedure that generates an index of merit for the performance of building designs that substantially exceeds the energy efficiency levels required by this standard.

proposed building performance: the annual energy cost calculated for a proposed design.

Revise the following definition in Section 3.2:

energy cost budget: the annual energy cost for the budget building design intended for use in determining minimum compliance with this standard.

Add the following new informative appendix:

(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.)

INFORMATIVE APPENDIX G
PERFORMANCE RATING METHOD

G1 GENERAL

G1.1 Performance Rating Method Scope. This building performance rating method is a modification of the Energy Cost Budget (ECB) Method in Section 11 and is intended for use in rating the energy efficiency of building designs that exceed the requirements of this standard. This section does NOT offer an alternative compliance path for minimum standard compliance; that is the intent of Section 11, Energy Cost Budget Method. Rather, it is provided for those wishing to use the methodology developed for this standard to quantify performance that substantially exceeds the requirements of Standard 90.1. It may be useful for evaluating the performance of all proposed designs, including alterations and additions to existing buildings, except designs with no mechanical systems.

G1.2 Performance Rating

This performance rating method requires conformance with the following provisions:

(a) All requirements of 5.2, 6.2, 7.2, 8.2, 9.2, and 10.2 are met. These sections contain the mandatory provisions of the standard, and are prerequisites for this rating method.

(b) The improved performance of the proposed building design is calculated in accordance with provisions of this appendix using the following formula:

Percentage improvement =
100 × (*Baseline building performance – Proposed building performance*) / *Baseline building performance*

Notes:

1. Both the *proposed building performance* and the *baseline building performance* shall include all end-use load components, such as receptacle and process loads.
2. Neither the *proposed building performance* nor the *baseline building performance* are predictions of actual energy consumption or costs for the *proposed design* after construction. Actual experience will differ from these calculations due to variations such as occupancy, building operation and maintenance, weather, energy use not covered by this procedure, changes in energy rates between design of the building and occupancy, and the precision of the calculation tool.

G1.3 Trade-off Limits. When the proposed modifications apply to less than the whole building, only parameters related to the systems to be modified shall be allowed to vary. Parameters relating to unmodified existing conditions or to future building components shall be identical for determining both the *baseline building performance* and the *proposed building performance*. Future building components shall meet the prescriptive requirements of Sections 5.3, 6.3, 7.3, and 9.3.

G1.4 Documentation Requirements. Simulated performance shall be documented, and documentation shall be submitted to the *rating authority.* The information submitted shall include the following:

(a) Calculated values for the *baseline building performance,* the *proposed building performance*, and the percentage improvement.

(b) A list of the energy-related features that are included in the design and on which the performance rating is based. This list shall document all energy features that differ between the models used in the *baseline building performance* and *proposed building performance* calculations.

(c) Input and output report(s) from the *simulation program* or compliance software including a breakdown of energy usage by at least the following components: lights, internal equipment loads, service water heating equipment, space heating equipment, space cooling and heat rejection equipment, fans, and other HVAC equipment (such as pumps). The output reports shall also show the amount of time any loads are not met by the HVAC system for both the *proposed design* and *baseline building design*.

(d) An explanation of any error messages noted in the *simulation program* output.

G2 SIMULATION GENERAL REQUIREMENTS

G2.1 *Simulation Program.* The *simulation program* shall be a computer-based program for the analysis of energy consumption in buildings (a program such as, but not limited to, DOE-2, BLAST, or EnergyPlus). The *simulation program* shall include calculation methodologies for the building components being modeled. For components that cannot be modeled by the simulation program, the exceptional calculation methods requirements in Section G5 may be used.

G2.1.1 The *simulation program* shall be approved by the *rating authority* and shall, at a minimum, have the ability to explicitly model all of the following:

(a) 8,760 hours per year;

(b) hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation, defined separately for each day of the week and holidays;

(c) thermal mass effects;

(d) ten or more thermal zones;

(e) part-load performance curves for mechanical equipment;

(f) capacity and efficiency correction curves for mechanical heating and cooling equipment;

(g) air-side economizers with integrated control;

(h) *baseline building design* characteristics specified in G4.

G2.1.2 The *simulation program* shall have the ability to either (1) directly determine the *proposed building performance* and *baseline building performance* or (2) produce hourly reports of energy use by an energy source suitable for determining the *proposed building performance* and *baseline building performance* using a separate calculation engine.

G2.1.3 The *simulation program* shall be capable of performing design load calculations to determine required HVAC equipment capacities and air and water flow rates in accordance with generally accepted engineering standards and handbooks (for example, *ASHRAE Handbook—Fundamentals*) for both the *proposed design* and *baseline building design*.

G2.2 Climate Data. The *simulation program* shall perform the simulation using hourly values of climate data, such as temperature and humidity from representative climate data, for the site in which the *proposed design* is to be located. For cities or urban regions with several climate data entries, and for locations where weather data are not available, the designer shall select available weather data that best represents the climate at the construction site. The selected weather data shall be approved by the *rating authority.*

G2.3 Energy Rates. Annual energy costs shall be determined using either actual rates for purchased energy or state average energy prices published by DOE's Energy Information Administration (EIA) for commercial building customers, but rates from different sources may not be mixed in the same project.

Note: The above provision allows users to gain credit for features that yield load management benefits. Where such features are not present, users can simply use state average unit prices from EIA, which are updated annually and readily available on EIA's web site (http://www.eia.doe.gov/).

Exception to G2.3: On-site renewable energy sources or site-recovered energy shall not be considered to be purchased energy and shall not be included in the *proposed building performance*. Where on-site renewable or site-recovered sources are used, the *baseline building performance* shall be based on the energy source used as the back-up energy source or on the use of electricity if no back-up energy source has been specified.

G2.4 Performance Calculations. The *proposed building performance* and *baseline building performance* shall be calculated using the following:

(a) the same *simulation program,*

(b) the same weather data, and

(c) the same energy rates.

G3 CALCULATION OF THE *PROPOSED BUILDING PERFORMANCE*

G3.1 Proposed Design Model. The simulation model of the *proposed design* shall be consistent with the design documents, including proper accounting of fenestration and opaque envelope types and areas; interior lighting power and controls; HVAC system types, sizes, and controls; and service water heating systems and controls. All end-use load components within and associated with the building shall be modeled, including, but not limited to, exhaust fans, parking garage ventilation fans, snow-melt and freeze-protection equipment, facade lighting, swimming pool heaters and pumps, elevators and escalators, refrigeration, and cooking.

G3.2 Space Use Classification. Usage shall be specified using the building type or space type lighting classifications in accordance with 9.3.1.1 or 9.3.1.2. The user shall specify the space use classifications using either the building type or space type categories but shall not combine the two types of categories. More than one building type category may be used in a building if it is a mixed-use facility. If space type categories are used, the user may simplify the placement of the various space types within the building model, provided that building-total areas for each space type are accurate.

G3.3 Buildings with Incomplete Energy System Designs. When the *performance rating* method is applied to buildings in which energy-related features have not yet been designed (e.g., a lighting system), those yet-to-be-designed features shall be described in the *proposed design* exactly as they are defined in the *baseline building design.* Where the space classification for a space is not known, the space shall be categorized as an office space.

G3.4 Requirement for Both Heating and Cooling. All *conditioned spaces* in the *proposed design* shall be simulated as being both heated and cooled even if no heating or cooling system is to be installed, and temperature and humidity control setpoints and schedules shall be the same for *proposed* and *baseline building designs*.

G3.5 HVAC Systems. The HVAC system type and all related performance parameters in the *proposed design*, such as equipment capacities and efficiencies, shall be determined as follows:

(a) Where a complete HVAC system exists, the model shall reflect the actual system type using actual component capacities and efficiencies.

(b) Where an HVAC system has been designed, the HVAC model shall be consistent with design documents. Mechanical equipment efficiencies shall be adjusted from actual design conditions to the standard rating conditions specified in 6.2.1 if required by the simulation model.

(c) Where no heating system exists or no heating system has been specified, the heating system classification shall be assumed to be electric, and the system characteristics shall be identical to the system modeled in the *baseline building design.*

(d) Where no cooling system exists or no cooling system has been specified, the cooling system shall be identical to the system modeled in the *baseline building design.*

G3.6 Building Envelope. All components of the *building envelope* in the *proposed design* shall be modeled as shown on architectural drawings or as built for existing building envelopes.

Exceptions to G3.6: The following building elements are permitted to differ from architectural drawings.

(a) All uninsulated assemblies (e.g., projecting balconies, perimeter edges of intermediate floor stabs, concrete floor beams over parking garages) shall be separately modeled. Any other envelope assembly that covers less than 5% of the total area of that assembly type (e.g., exterior walls) need not be separately described provided that it is similar to an assembly being modeled. If not separately described, the area of an envelope assembly shall be added to the area of an assembly of that same type with the same orientation and thermal properties.

(b) Exterior surfaces whose azimuth orientation and tilt differ by less than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers.

(c) For exterior roofs, the roof surface may be modeled with a reflectance of 0.45 if the reflectance of the *proposed design* roof is greater than 0.70 and its emittance is greater than 0.75. Reflectance values shall be based on testing in accordance with ASTM E903, ASTM E1175, or ASTM E1918, and the emittance values shall be based on testing in accordance with ASTM C835, ASTM C1371, or ASTM E408. All other roof surfaces shall be modeled with a reflectance of 0.30.

(d) Manual fenestration shading devices such as blinds or shades shall not be modeled. Automatically controlled fenestration shades or blinds may be modeled. Permanent shading devices such as fins, overhangs, and light shelves may be modeled.

G3.7 Service Hot Water Systems. The service hot water system type and all related performance parameters, such as equipment capacities and efficiencies, in the *proposed design* shall be determined as follows:

(a) Where a complete service hot water system exists, the *proposed design* shall reflect the actual system type using actual component capacities and efficiencies.
(b) Where a service hot water system has been specified, the service hot water model shall be consistent with design documents.
(c) Where no service hot water system exists or has been specified but the building will have service hot water loads, a service hot water system shall be modeled that matches the system in the *baseline building design* and serves the same hot water loads.
(d) For buildings that will have no service hot water loads, no service hot water system shall be modeled.

G3.8 Lighting. Lighting power in the *proposed design* shall be determined as follows:
(a) Where a complete lighting system exists, the actual lighting power shall be used in the model.
(b) Where a lighting system has been designed, lighting power shall be determined in accordance with 9.2.4 and 9.2.5.
(c) Where lighting neither exists nor is specified, lighting power shall be determined in accordance with the building area method for the appropriate building type.
(d) Lighting system power shall include all lighting system components shown or provided for on the plans (including lamps and ballasts and task and furniture-mounted fixtures).

Exception to G3.8 (d): For multifamily living units, hotel/motel guest rooms, and other spaces in which lighting systems are connected via receptacles and are not shown or provided for on building plans, assume identical lighting power for the *proposed* and *baseline building designs* in the simulations, but exclude these loads when calculating the *baseline building performance* and *proposed building performance*.

(e) Lighting power for parking garages and building facades shall be modeled.
(f) Credit may be taken for the use of automatic controls for daylight utilization but only if their operation is either modeled directly in the building simulation or modeled in the building simulation through schedule adjustments determined by a separate daylighting analysis approved by the *rating authority.*
(g) For automatic lighting controls in addition to those required for minimum code compliance under 9.2, credit may be taken for automatically controlled systems by reducing the connected lighting power by the applicable percentages listed in Table G3.8. Alternatively, credit may be taken for these devices by modifying the lighting schedules used for the *proposed design,* provided that credible technical documentation for the modifications are provided to the *rating authority.*

G3.9 Receptacle Loads. Receptacle and process loads, such as those for office and other equipment, shall be estimated based on the building type or space type category and shall be assumed to be identical in the *proposed* and *baseline building designs*, except as specifically authorized by the *rating authority.* These loads shall be included in simulations of the building and shall be included when calculating the *baseline building performance* and *proposed building performance*.

G3.10 Further Modeling Limitations and Exceptions

G3.10.1 Limitations to the *Simulation Program*. If the *simulation program* cannot model a component or system included in the *proposed design* explicitly, substitute a thermodynamically similar component model that can approximate the expected performance of the component that cannot be modeled explicitly.

G3.10.2 Alterations and Additions. It is acceptable to demonstrate compliance using building models that exclude parts of the existing building provided that all of the following conditions are met:
(a) Work to be performed in excluded parts of the building shall meet the requirements of Sections 5 through 10.
(b) Excluded parts of the building are served by *HVAC systems* that are entirely separate from those serving parts of the building that are included in the building model.
(c) Design space temperature and HVAC system operating setpoints and schedules on either side of the boundary between included and excluded parts of the building are essentially the same.
(d) If a declining block or similar utility rate is being used in the analysis and the excluded and included parts of the building are on the same utility meter, the rate shall reflect the utility block or rate for the building plus the addition.

G3.11 Schedules. Schedules capable of modeling hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation shall be used. The schedules shall be typical of the proposed building type as determined by the designer and approved by the *rating authority.* Schedules shall be identical for the *proposed design* and *baseline building design.*

TABLE G3.8
Power Adjustment Percentages for Automatic Lighting Controls

Automatic Control Devices(s)	Non 24 h & <=5,000 ft^2 (460 m^2)	All Other
(1) Programmable timing control	10%	0%
(2) Occupancy sensor	15%	10%
(3) Occupancy sensor and programmable timing control	15%	10%

Notes: The 5,000 ft^2 (460 m^2) condition pertains to the total conditioned floor area of the building.

Exception to G3.11: Schedules may be allowed to differ between *proposed design* and *baseline building design* when necessary to model nonstandard efficiency measures, provided that the revised schedules have the approval of the *rating authority.* Measures that may warrant use of different schedules include, but are not limited to, lighting controls, natural ventilation, demand control ventilation, and measures that reduce service water heating loads.

G3.11.1 HVAC Fan Schedules. Schedules for HVAC fans shall run continuously whenever spaces are occupied and shall be cycled on and off to meet heating and cooling loads during unoccupied hours.

Exception to G3.11.1: Where no heating and/or cooling system is to be installed and a heating or cooling system is being simulated only to meet the requirements described in Section G3.4, heating and/or cooling system fans shall not be simulated as running continuously during occupied hours but shall be cycled on and off to meet heating and cooling loads during all hours.

G3.12 Thermal Blocks

G3.12.1 *HVAC Zones* Designed. Where *HVAC zones* are defined on HVAC design drawings, each HVAC zone shall be modeled as a separate *thermal block*.

Exception to G3.12.1: Different *HVAC zones* may be combined to create a single *thermal block* or identical *thermal blocks* to which multipliers are applied, provided that all of the following conditions are met:

(a) The space use classification is the same throughout the *thermal block.*
(b) All HVAC zones in the thermal block that are adjacent to glazed exterior walls face the same orientation or their orientations vary by less than 45 degrees.
(c) All of the zones are served by the same *HVAC system* or by the same kind of *HVAC system*.

G3.12.2 *HVAC Zones* Not Designed. Where the *HVAC zones* and systems have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and space temperature schedules, and in combination with the following guidelines:

(a) separate *thermal blocks* shall be assumed for interior and perimeter spaces. Interior spaces shall be those located greater than 15 ft (5 m) from an exterior wall. Perimeter spaces shall be those located within 15 ft (5 m) of an exterior wall.
(b) separate *thermal blocks* shall be assumed for spaces adjacent to glazed exterior walls; a separate zone shall be provided for each orientation, except that orientations that differ by less than 45 degrees may be considered to be the same orientation. Each zone shall include all floor area that is 15 ft (5 m) or less from a glazed perimeter wall, except that floor area within 15 ft (5 m) of glazed perimeter walls having more than one orientation shall be divided proportionately between zones.
(c) separate *thermal blocks* shall be assumed for spaces having floors that are in contact with the ground or exposed to ambient conditions from zones that do not share these features.
(d) separate *thermal blocks* shall be assumed for spaces having exterior ceiling or roof assemblies from zones that do not share these features.

G3.12.3 *Thermal Blocks* in Multifamily Residential Buildings. *Residential spaces* shall be modeled using at least one *thermal block* per living unit, except that those units facing the same orientations may be combined into one *thermal block*. Corner units and units with roof or floor loads shall only be combined with units sharing these features.

G4 CALCULATION OF THE *BASELINE BUILDING PERFORMANCE*

G4.1 *Baseline Building* Envelope. The *baseline building design* shall be modeled with the same number of floors and identical conditioned floor area as the *proposed design*. Equivalent dimensions shall be assumed for each exterior envelope component type as in the *proposed design*; i.e., the total gross area of exterior walls shall be the same in the *proposed* and *baseline building designs.* The same shall be true for the areas of roofs, floors, and doors, and the exposed perimeters of concrete slabs on grade shall also be the same in the *proposed* and *baseline building designs.* The following additional requirements shall apply to the modeling of the *baseline building design*:

(a) *Orientation.* The baseline building performance shall be generated by simulating the building with its actual orientation and again after rotating the entire building 90, 180, 270 degrees, then averaging the results. The building shall be modeled so that it does not shade itself.
(b) *Opaque Assemblies.* Opaque assemblies used for new buildings or additions shall conform with the following common, light-weight assembly types and shall match the appropriate assembly maximum U-factors in Tables B-1 through B-26:
    - Roofs—Insulation Entirely above Deck
    - Above-grade walls—Steel Framed
    - Floors—Steel Joist
    - Opaque door types shall match the proposed design and conform to the U-factor requirements from the same tables.
    - Slab-on-grade floors shall match the F-factor for unheated slabs from the same tables.

    Opaque assemblies used for alterations shall conform to 4.1.2.2.1.
(c) *Vertical Fenestration*. *Vertical fenestration* areas for new buildings and additions shall equal that in the *proposed design* or 40% of gross above-grade wall area, whichever is smaller, and shall be distributed uniformly in horizontal bands across the four orientations. Fenestration U-factors shall match the appropriate requirements in Tables B-1 through B-26 for the applicable vertical glazing percentage for U_{fixed}. Fenestration solar heat gain coefficient (SHGC) shall match the appropriate requirements in Tables B-1 through B-26 using the value for $SHGC_{all}$ for the applicable vertical glazing percentage. All vertical glazing shall be modeled as fixed and shall be assumed to

be flush with the exterior wall, and no shading projections shall be modeled. Manual window shading devices such as blinds or shades shall not be modeled. The fenestration areas for envelope alterations shall reflect the limitations on area, U-factor, and SHGC as described in 4.1.2.2.1.

(d) *Skylights and Glazed Smoke Vents*. Skylight area shall be equal to that in the proposed building design or 5% of the gross roof area that is part of the building envelope, whichever is smaller. If the skylight area of the proposed building design is greater than 5% of the gross roof area, baseline skylight area shall be decreased by an identical percentage in all roof components in which skylights are located to reach the 5% skylight-to-roof ratio. Skylight orientation and tilt shall be the same as in the proposed building design. Skylight U-factor and SHGC properties shall match the appropriate requirements in Tables B-1 through B-26.

(e) *Roof Albedo*. All roof surfaces shall be modeled with a reflectivity of 0.30.

(f) *Existing Buildings*. For existing building envelopes, the *baseline building design* shall reflect existing conditions prior to any revisions that are part of the scope of work being evaluated.

G4.2 *Baseline* HVAC Systems. The HVAC system(s) in the *baseline building design* shall be of the type and description specified in G4.2.1, shall meet the general HVAC system requirements specified in G4.2.2, and shall meet any system-specific requirements in G4.2.3 that are applicable to the *baseline* HVAC system type(s).

G4.2.1 *Baseline* HVAC System Type and Description. HVAC systems in the *baseline building design* shall be based on usage, number of floors, conditioned floor area, and heating source, as specified in Table G4.2.1A, and shall conform with the system descriptions in Table G4.2.1B.

TABLE G4.2.1A
***Baseline* HVAC System Types**

Heating Source	Residential	Nonresidential & Three Floors or Less & <75,000 ft^2 (7,000 m^2)	Nonresidential & Four or Five Floors & <75,000 ft^2 (7,000 m^2) or Five Floors or Less & 75,000 ft^2 (7,000 m^2) to 150,000 ft^2 (14,000 m^2)	Nonresidential & More than Five Floors or >150,000 ft^2 (14,000 m^2)
Fossil Fuel, Fossil/Electric Hybrid & Purchased Heat	Sys. 1—PTAC	Sys. 3—PSZ-AC	Sys. 5—Packaged VAV w/ Reheat	Sys. 7—VAV w/Reheat
Electric and Other	Sys. 2—PTHP	Sys. 4—PSZ-HP	Sys. 6—Packaged VAV w/ PFP Boxes	Sys. 8—VAV w/PFP Boxes

Notes:
1. Residential building types include dormitory, hotel, motel, and multifamily. Residential space types include guest rooms, living quarters, private living space, and sleeping quarters. Other building and space types are considered nonresidential.
2. Where no heating system is to be provided or no heating energy source is specified, use the "Electric and Other" heating source classification.
3. Where attributes make a building eligible for more than one *baseline* system type, use the predominant condition to determine the system type for the entire building.

TABLE G4.2.1B
***Baseline* System Descriptions**

	System 1 – PTAC	System 3 – PSZ – AC	System 5 – Packaged VAV w/ Reheat	System 7 – VAV w/Reheat
System Type	Packaged terminal air conditioner	Packaged rooftop air conditioner	Packaged rooftop variable air volume with reheat	Variable air volume with reheat
Fan Control	Constant Volume	Constant Volume	VAV	VAV
Cooling Type	Direct Expansion	Direct Expansion	Direct Expansion	Chilled Water
Heating Type	Hot Water Fossil Fuel Boiler	Fossil Fuel Furnace	Hot Water Fossil Fuel Boiler	Hot Water Fossil Fuel Boiler

	System 2 – PTHP	System 4 – PSZ – HP	System 6 – Packaged VAV w/ PFP Boxes	System 8 – VAV w/ PFP Boxes
System Type	Packaged terminal heat pump	Packaged rooftop heat pump	Packaged rooftop variable air volume with reheat	Variable air volume with reheat
Fan Control	Constant Volume	Constant Volume	VAV	VAV
Cooling Type	Direct Expansion	Direct Expansion	Direct Expansion	Chilled Water
Heating Type	Electric Heat Pump	Electric Heat Pump	Electric Resistance	Electric Resistance

Exceptions to G4.2.1:

(a) Use additional system type(s) for nonpredominant conditions (i.e., residential/nonresidential or heating source) if those conditions apply to more than 20,000 ft^2 (1900 m^2) of conditioned floor area.

(b) If the *baseline* HVAC system type is 5, 6, 7, or 8, use separate single-zone systems conforming with the requirements of System 3 or System 4 (depending on building heating source) for any spaces that have occupancy or process loads or schedules that differ significantly from the rest of the building. Peak thermal loads that differ by 10 Btu/h·ft^2 (31.2 W/m^2) or more from the average of other spaces served by the system or schedules that differ by more than 40 equivalent full-load hours per week from other spaces served by the system are considered to differ significantly. Examples where this exception may be applicable include, but are not limited to, computer server rooms, natatoriums, and continually occupied security areas.

(c) If the *baseline* HVAC system type is 5, 6, 7, or 8, use separate single-zone systems conforming with the requirements of System 3 or System 4 (depending on building heat source) for any zones having special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates.

G4.2.1.1 Purchased Heat. For systems using purchased hot water or steam, hot water or steam costs shall be based on actual utility rates, and on-site boilers shall not be modeled in the *baseline building design*.

G4.2.2 General *Baseline* HVAC System Requirements. HVAC Systems in the *baseline building design* shall conform with the general provisions in this section.

G4.2.2.1 Equipment Efficiencies. All HVAC equipment in the *baseline building design* shall be modeled at the minimum efficiency levels—both part load and full load—in accordance with Section 6.2. Where efficiency ratings, such as EER and COP, include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately.

G4.2.2.2 Equipment Capacities. The equipment capacities for the *baseline building design* shall be based on sizing runs for each orientation (per Section G4.1a) and shall be oversized by 15% for cooling and 25% for heating; i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be 1.15 for cooling and 1.25 for heating. Unmet load hours for the *proposed design* or *baseline building designs* shall not exceed 300 (of the 8,760 hours simulated), and unmet load hours for the *proposed design* shall not exceed the number of unmet load hours for the *baseline building design* by more than 50. If unmet load hours in the *proposed design* exceed the unmet load hours in the *baseline building* by more than 50, simulated capacities in the *baseline building* shall be decreased incrementally, and the building resimulated until the unmet load hours are within 50 of the unmet load hours of the *proposed design*. If unmet load hours for the *proposed design* or *baseline building design* exceed 300, simulated capacities shall be increased incrementally, and the building with unmet loads resimulated until unmet load hours are reduced to 300 or less. Alternatively, unmet load hours exceeding these limits may be accepted at the discretion of the *rating authority* provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads.

G4.2.2.2.1 Sizing Runs. Weather conditions used in sizing runs to determine *baseline* equipment capacities may be based either on hourly historical weather files containing typical peak conditions or on design days developed using 99.6% heating design temperatures and 1% dry-bulb and 1% wet-bulb cooling design temperatures.

G4.2.2.3 Preheat Coils. If the HVAC system in the *proposed design* has a preheat coil, and a preheat coil can be modeled in the *baseline* system, the *baseline* system shall be modeled with a preheat coil controlled in the same manner as the *proposed design*.

G4.2.2.4 Fan System Operation. Supply and return fans shall operate continuously whenever spaces are occupied and shall be cycled to meet heating and cooling loads during unoccupied hours. If the supply fan is modeled as cycling and fan energy is included in the energy-efficiency rating of the equipment, fan energy shall not be modeled explicitly.

G4.2.2.5 Ventilation. Minimum outdoor air ventilation rates shall be the same for the *proposed* and *baseline building designs.*

Exception to G4.2.2.5: When modeling demand-control ventilation in the *proposed design* when its use is not required by 6.2.3.8.

G4.2.2.6 Economizers. Outside air economizers shall not be included in *baseline* HVAC Systems 1 and 2. Outside air economizers shall be included in *baseline* HVAC System 3 and 4 as specified in Table G4.2.2.6A based on building-conditioned floor area, whether the zone served is an interior or perimeter zone, and climate. Outside air economizers shall be included in *baseline* HVAC Systems 5 through 8 based on climate as specified in Table G4.2.2.6B. Any zone having more than half of its floor area more than 15 ft (5 m) from a glazed exterior wall is considered an interior zone for purposes of applying Tables G4.2.2.6A and G4.2.2.6B.

Exceptions to G4.2.2.6: Economizers shall not be included for systems meeting one or more of the exceptions listed below.

(a) Systems that include gas phase air cleaning to meet the requirements of 6.1.2 of ANSI/ASHRAE Standard 62. This exception shall be used only if the system in the *proposed design* does not match *building design*.

(b) Where the use of outdoor air for cooling will affect supermarket open refrigerated casework systems. This exception shall only be used if the system in the proposed design does not use an economizer. If the exception is used, an economizer shall not be included in the *baseline building design*.

TABLE G4.2.2.6A (I-P)
Minimum Building-Conditioned Floor Areas at which Economizers are Included for Baseline Systems 3 and 4

No. of Hours Between 8 a.m. and 4 p.m. with 55°F < T_{db} < 69°F	Minimum Building-Conditioned Floor Area (ft^2) at which Economizers are Included					
	1% Cooling Design Wet-Bulb Temperature					
	T_{wb} < 69°F		69°F ≤ T_{wb} ≤ 73°F		T_{wb} > 73°F	
Type of Zone	**Interior**	**Perimeter**	**Interior**	**Perimeter**	**Interior**	**Perimeter**
0-199	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200-599	15,000	N.R.	N.R.	N.R.	N.R.	N.R.
600-799	10,000	25,000	15,000	N.R.	N.R.	N.R.
800-999	10,000	25,000	15,000	N.R.	15,000	N.R.
1000-1199	10,000	25,000	10,000	25,000	15,000	N.R.
>1199	10,000	25,000	10,000	25,000	10,000	25,000
High-Limit Dry-Bulb Shutoff	75°F		70°F		65°F	

T_{db} = 1% cooling design dry-bulb temperature.
T_{wb} = 1% cooling design wet-bulb temperature.
N.R. means that there is no conditioned building floor area for which economizers are included for the type of zone and climate.

TABLE G4.2.2.6A (SI)
Minimum Building-Conditioned Floor Areas at which Economizers are Included for Baseline Systems 3 and 4

No. of Hours Between 8 a.m. and 4 p.m. with 13°C < T_{db} < 21°C	Minimum Building-Conditioned Floor Area (m^2) at which Economizers are Included					
	1% Cooling Design Wet-Bulb Temperature					
	T_{wb} < 21°C		21°F ≤ T_{wb} ≤ 23°C		T_{wb} > 23°C	
Type of Zone	**Interior**	**Perimeter**	**Interior**	**Perimeter**	**Interior**	**Perimeter**
0-199	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
200-599	1,400	N.R.	N.R.	N.R.	N.R.	N.R.
600-799	900	2,300	1,400	N.R.	N.R.	N.R.
800-999	900	2,300	1,400	N.R.	1,400	N.R.
1000-1199	900	2,300	900	2,300	1,400	N.R
>1199	900	2,300	900	2,300	900	2,300
High-Limit Dry-Bulb Shutoff	24°C		21°C		18°C	

T_{db} = 1% cooling design dry-bulb temperature.
T_{wb} = 1% cooling design wet-bulb temperature.
N.R. means that there is no conditioned building floor area for which economizers are included for the type of zone and climate.

TABLE G4.2.2.6B (I-P)
Climate Conditions Under which Economizers are Included for Baseline Systems 5 through 8

No. of Hours Between 8 a.m. and 4 p.m. with 55°F < T_{db} < 69°F	1% Cooling Design Wet-Bulb Temperature		
	T_{wb} < 69°F	69°F ≤ T_{wb} ≤ 73°F	T_{wb} > 73°F
0-199	N.R.	N.R.	N.R.
200-599	Economizer Included	N.R.	N.R.
600-799	Economizer Included	Economizer Included	N.R.
>800	Economizer Included	Economizer Included	Economizer Included
High-Limit Dry-Bulb Shutoff	75°F	70°F	65°F

T_{db} = 1% cooling design dry-bulb temperature.
T_{wb} = 1% cooling design wet-bulb temperature.
N.R. means that economizers are not included for these climates.

TABLE G4.2.2.6B (SI)
Climate Conditions Under which Economizers are Included for Baseline Systems 5 through 8

No. of Hours Between 8 a.m. and 4 p.m. with 13°C < T_{db} < 21°C	1% Cooling Design Wet-Bulb Temperature		
	T_{wb} < 21°C	21°C ≤ T_{wb} ≤ 23°C	T_{wb} > 23°C
0-199	N.R.	N.R.	N.R.
200-599	Economizer Included	N.R.	N.R.
600-799	Economizer Included	Economizer Included	N.R.
>800	Economizer Included	Economizer Included	Economizer Included
High-Limit Dry-Bulb Shutoff	24°C	21°C	18°C

T_{db} = 1% cooling design dry-bulb temperature.
T_{wb} = 1% cooling design wet-bulb temperature.
N.R. means that economizers are not included for these climates.

TABLE G4.2.2.9
***Baseline* Fan Brake Horsepower**

Supply Air Volume	*Baseline* Fan Motor Brake Horsepower	
	Constant Volume Systems 1 – 4	Variable Volume Systems 5 – 6
< 20,000 cfm (9400 L/s)	17.25 + (cfm – 20000) × 0.0008625	24 + (cfm – 20000) × 0.0012
>= 20,000 cfm (9400 L/s)	17.25 + (cfm – 20000) × 0.000825	24 + (cfm – 20000) × 0.001125

G4.2.2.7 Economizer High-Limit Shutoff. The high-limit shutoff shall be a dry-bulb switch with setpoint temperatures in accordance with the values listed at the bottom of Tables G4.2.2.6A and G4.2.2.6B.

G4.2.2.8 Design Airflow Rates. System design supply airflow rates for the *baseline building design* shall be based on a supply-air-to-room-air temperature difference of 20°F (11°C). If return or relief fans are specified in the *proposed design*, the *baseline building design* shall also be modeled with fans serving the same functions and sized for the *baseline* system supply fan air quantity less the minimum outdoor air, or 90% of the supply fan air quantity, whichever is larger.

G4.2.2.9 Supply Fan Power. System fan electrical power for supply, return, exhaust, and relief (excluding power to fan-powered VAV boxes) shall be calculated using the following formulas:

$$P_{fan} = 746 / (1 - \exp[-0.2437839 \times \ln(\text{bhp}) - 1.685541]) \times \text{bhp}$$

where

P_{fan} = electric power to fan motor (watts)

bhp = brake horsepower of *baseline* fan motor from Table G4.2.2.9

where

cfm = design supply flow rate.

Exception to 4.2.2.9. If systems in the *proposed design* require air filtering systems with pressure drops in excess of 1 in.w.c. when filters are clean, the allowable fan system power in the *baseline design* system serving the same space may be increased using the following pressure credit:

$$\text{Pressure Credit (Watts)} = CFM_{filter} * (Sp_{filter} - 1)/4.984$$

where

CFM_{filter} = supply air volume of the proposed system with air filtration system in excess on 1 in.w.c.

Sp_{filter} = air pressure drop of the filtering system in w.g. when the filters are clean.

G4.2.2.10 Exhaust Air Energy Recovery. Individual fan systems that have both a design supply air capacity of 5000 cfm (2400 L/s) or greater and have a minimum outside air supply of 70% or greater of the design supply air quantity shall have an energy recovery system with at least 50% recovery effectiveness. Fifty percent energy recovery effectiveness shall mean a change in the enthalpy of the outdoor air supply equal to 50% of the difference between the outdoor air and return air at design conditions. Provision shall be made to bypass or control the heat-recovery system to permit air economizer operation, where applicable.

Exceptions to G4.2.2.10: If any of these exceptions apply, exhaust air energy recovery shall not be included in the *baseline building design.*

(a) Systems serving spaces that are not cooled and that are heated to less than 60°F (16°C).

(b) Systems exhausting toxic, flammable, or corrosive fumes or paint or dust. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.

(c) Commercial kitchen hoods (grease) classified as Type 1 by NFPA 96. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.

(d) Heating systems in climates with less than 3600 HDD65 (2000 HDD18).

(e) Cooling systems in climates with a 1% cooling design wet-bulb temperature less than 64°F (18°C).

(f) Where the largest exhaust source is less than 75% of the design outdoor airflow. This exception shall be used only if exhaust air energy recovery is not used in the *proposed design*.

(g) Systems requiring dehumidification that employ series-style energy recovery coils wrapped around the cooling coil. This exception shall be used only if exhaust air energy recovery and series-style energy recovery coils are not modeled in the *proposed design*.

G4.2.3 System-Specific *Baseline* HVAC System Requirements. *Baseline* HVAC systems shall conform with provisions in this section, where applicable, to the specified *baseline* system types as indicated in section headings.

G4.2.3.1 Heat Pumps (Systems 2 and 4). Electric air-source heat pumps shall be modeled with electric auxiliary heat. The systems shall be controlled with multi-stage space thermostats and an outdoor air thermostat wired to energize auxiliary heat only on the last thermostat stage and when outside air temperature is less than 40°F (4°C).

G4.2.3.2 Type and Number of Boilers (Systems 1, 5, and 7). The boiler plant shall use the same fuel as the *proposed design* and shall be natural draft, except as noted under G4.2.1.1. The *baseline building design* boiler plant shall be modeled as having a single boiler if the *baseline building design* plant serves a conditioned floor area of 15,000 ft^2 (1,400 m^2) or less and as having two equally sized boilers for plants serving more than 15,000 ft^2 (1,400 m^2). Boilers shall be staged as required by the load.

G4.2.3.3 Hot Water Supply Temperature (Systems 1, 5, and 7). Hot water design supply temperature shall be modeled as 180°F (82°C), and design return temperature as 130°F (54°C).

G4.2.3.4 Hot Water Supply Temperature Reset (Systems 1, 5, and 7). Hot water supply temperature shall be reset based on outside dry-bulb temperature using the following schedule: 180°F @ 20°F (82°C @ –7°C) and below, 150°F @ 50°F (66°C @ 10°C) and above, and ramped linearly between 180°F (82°C) and 150°F (66°C) at temperatures between 20°F (–7°C) and 50°F (10°C).

G4.2.3.5 Hot Water Pumps (Systems 1, 5, and 7). The *baseline building design* hot water pump power shall be 19 W/gpm (301 kW/1000 L/s). The pumping system shall be modeled as primary-only with continuous variable flow. Hot water systems serving 120,000 ft^2 (11,148 m^2) or more shall be modeled with variable-speed drives, and systems serving less than 120,000 ft^2 (11,148 m^2) shall be modeled as riding the pump curve.

G4.2.3.6 Piping Losses (Systems 1, 5, 7, and 8). Piping losses shall not be modeled in either the *proposed or baseline building designs* for hot water, chilled water, or steam piping.

G4.2.3.7 Type and Number of Chillers (Systems 7 and 8). Electric chillers shall be used in the *baseline building design* regardless of the cooling energy source; e.g., direct-fired absorption, absorption from purchased steam, or purchased chilled water. The *baseline building design's* chiller plant shall be modeled with chillers having the number and type as indicated in Table G4.2.3.7 as a function of building conditioned floor area.

G4.2.3.8 Chilled Water Design Supply Temperature (Systems 7 and 8). Chilled water design supply temperature shall be modeled at 44°F (6.7°C), and return water temperature at 56°F (13°C).

G4.2.3.9 Chilled Water Supply Temperature Reset (Systems 7 and 8). Chilled water supply temperature shall be reset based on outside dry-bulb temperature using the following schedule: 44°F @ 80°F (7°C @ 27°C) and above, 54°F @ 60°F (12°C @ 16°C) and below, and ramped linearly between 44°F (7°C) and 54°F (12°C) at temperatures between 80°F (27°C) and 60°F (16°C).

G4.2.3.10 Chilled Water Pumps (Systems 7 and 8). The *baseline building design* pump power shall be 22 W/gpm (349 kW/1000 L/s). Chilled water systems serving 120,000 ft^2 (11,148 m^2) or more shall be modeled as primary/secondary systems with variable-speed drives on the secondary pumping loop. Chilled water pumps in systems serving less than 120,000 ft^2 (11,148 m^2) shall be modeled as a primary/secondary system with secondary pump riding the pump curve.

G4.2.3.11 Heat Rejection (Systems 7 and 8). The heat rejection device shall be an axial fan cooling tower with two-speed fans. Condenser water design supply temperature shall be 85°F (29°C) or 10°F (5.6°C) approach to design wet-bulb temperature, whichever is lower, with a design temperature rise of 10°F (5.6°C). The tower shall be controlled to maintain a 70°F (21°C) leaving water temperature where weather permits, floating up to leaving water temperature at design conditions. The *baseline building design* condenser water pump power shall be 19 W/gpm (301 kW/1000 L/s). Each chiller shall be modeled with separate condenser water and chilled water pumps interlocked to operate with the associated chiller.

TABLE G4.2.3.7
Type and Number of Chillers

Building-Conditioned Floor Area	Number and Type of Chiller(s)
≤120,000 ft^2 (≤11,148 m^2)	1 screw chiller
>120,000 ft^2, <240,000 ft^2 (>11,148 m^2, <22,296 m^2)	2 screw chillers sized equally
≥240,000 ft^2 (≥22,296 m^2)	2 centrifugal chillers minimum with chillers added so that no chiller is larger than 800 tons (2813 kW), all sized equally

TABLE G4.2.3.15
Part-Load Performance for VAV Fan Systems

Method 1—Part-Load Fan Power Data	
Fan Part-Load Ratio	**Fraction of Full-Load Power**
0.00	0.00
0.10	0.03
0.20	0.07
0.30	0.13
0.40	0.21
0.50	0.30
0.60	0.41
0.70	0.54
0.80	0.68
0.90	0.83
1.00	1.00
Method 2—Part-Load Fan Power Equation	
$P_{fan} = 0.0013 + 0.1470 \times PLR_{fan} + 0.9506 \times (PLR_{fan})^2 - 0.0998 \times (PLR_{fan})^3$ where P_{fan} = fraction of full-load fan power; and PLR_{fan} = fan part-load ratio (current cfm/design cfm).	

G4.2.3.12 Supply Air Temperature Reset (Systems 5 through 8). Supply air temperature shall be reset based on zone demand from the design temperature difference to a 10°F (5.6°C) temperature difference under minimum load conditions. Design airflow rates shall be sized for the reset supply air temperature; i.e., a 10°F (5.6°C) temperature difference.

G4.2.3.13 VAV Minimum Flow Setpoints (System 5 and 7). Minimum volume setpoints for VAV reheat boxes shall be 0.4 cfm/ft^2 (2.15 L/s·m^2) of floor area served.

G4.2.3.14 Fan Power (System 6 and 8). Fans in parallel VAV fan-powered boxes shall be sized for 50% of the peak design flow rate and shall be modeled with 0.35 W/cfm (0.74 W per L/s) fan power. Minimum volume setpoints for fan-powered boxes shall be equal to 30% of peak design flow rate or the rate required to meet the minimum outside air ventilation requirement, whichever is larger. The supply air temperature setpoint shall be constant at the design condition.

G4.2.3.15 VAV Fan Part-Load Performance (Systems 5 through 8). VAV systems supply fans shall have variable-speed drives, and their part-load performance characteristics shall be modeled using either Method 1 or Method 2 specified in Table G4.2.3.15.

G4.3 *Baseline* Service Hot Water Systems. The service hot water system in the *baseline building design* shall use the same energy source as the corresponding system in the *proposed design* and shall conform with the following conditions:

(a) Where a complete service hot water system exists, the *baseline building design* shall reflect the actual system type using actual component capacities and efficiencies.

(b) Where a new service hot water system has been specified, the equipment shall match the minimum efficiency requirements in Section 7.2. Where the energy source is electricity, the heating method shall be electrical resistance.

(c) Where no service hot water system exists or has been specified but the building will have service hot water loads, a service water system(s) using electrical-resistance heat and matching minimum efficiency requirements of Section 7.2 shall be assumed and modeled identically in the *proposed* and *baseline building designs*.

(d) For buildings that will have no service hot water loads, no service hot water heating shall be modeled.

(e) Where a combined system has been specified to meet both space heating and service water heating loads, the *baseline building system* shall use separate systems meeting the minimum efficiency requirements applicable to each system individually.

G4.3.1 Heat Recovery for Service Water Heating. For large, 24-hour per day facilities that meet the prescriptive criteria for use of condenser heat recovery systems described in Section 6.3.6.2, a system meeting the requirements of that section shall be included in the *baseline building design* regardless of the exceptions to 6.3.6.2.

Exception to G4.3.1: If a condenser heat recovery system meeting the requirements described in Section 6.3.6.2 cannot be modeled, the requirement for including such a system in the actual building shall be met as a prescriptive requirement in accordance with 6.3.6.2, and no heat-recovery system shall be included in the *proposed* or *baseline building designs*.

G4.4 *Baseline* Lighting Systems. Lighting power in the *baseline building design* shall be determined using the same categorization procedure (Building Area or Space Function)

and categories as the proposed design with lighting power set equal to the maximum allowed for the corresponding method and category in 9.3. No automatic lighting controls (e.g., programmable controls or automatic controls for daylight utilization) shall be modeled in the *baseline building design* because the lighting schedules used are understood to reflect the mandatory control requirements in this standard.

G4.5 Other *Baseline* Systems. Other systems, such as motors covered by Section 10, and miscellaneous loads shall be modeled as identical to those in the *proposed design*. Where there are specific efficiency requirements in Section 10, these systems or components shall be modeled as having the lowest efficiency allowed by those requirements.

G5 EXCEPTIONAL CALCULATION METHODS

Where no *simulation program* is available that adequately models a design, material, or device, the *rating authority* may approve an exceptional calculation method to demonstrate above-standard performance using this method. Applications for approval of an exceptional method shall include documentation of the calculations performed and theoretical and/or empirical information supporting the accuracy of the method.

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.