

ASHRAE 90.1-2004 Using Appendix G for Building Simulation Modeling

Presented by:

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ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method

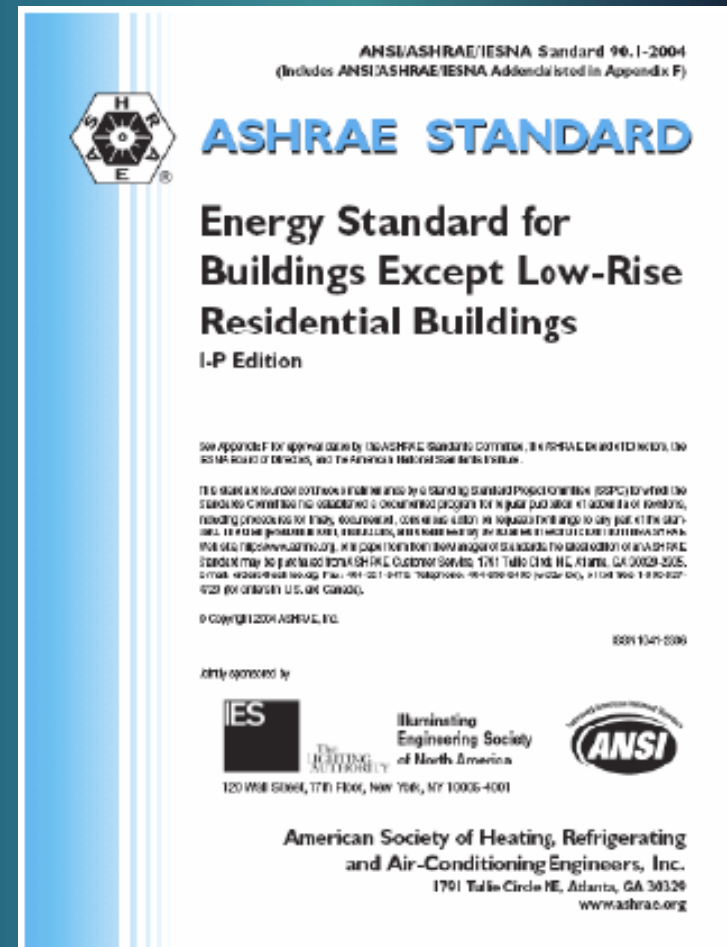
- Brief History of ASHRAE 90.1
- Overview of ASHRAE 90.1 Appendix G
- Brief Discussion on ECB Method of 90.1 (Chapter 11)
- Discussion on differences in ECB and Appendix G in ASHRAE 90.1
- Summary of Appendix G Criteria for Building Modeling

Brief Introduction to ASHRAE 90.1

Purpose:

“To provide **minimum** requirements for the energy-efficient design of buildings except low-rise residential buildings”

Available at www.ashrae.org



History of ASHRAE 90.1

- Originally published in 1975 during the 1st energy crisis
- Updated and re-issued in 1980, 1989, 1999, 2004 and 2007
- Starting in 2001, the Standard is to be updated at the beginning of every 3rd year (Continual Maintenance)
- 2004 Edition modifications:
 - reduces climate zones from 26 to 8
 - reduces lighting LPD's
 - adds Appendix G.
 - Incorporates 31 addenda since 2001 edition
- 2007 Edition:
 - Incorporates the modeling of laboratory environments that are not addressed in the 2004 edition.
 - Incorporates Appendices of 2004 Version

Provisions of ASHRAE 90.1

- Provides minimum energy-efficient requirements for the design and construction of:
 - New buildings and their systems
 - New portions of buildings and their systems
 - New systems and equipment in existing buildings
- Provisions of standard apply to the envelope of buildings, provided that the enclosed spaces are:
 - Heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h•ft²
 - Cooled by a cooling system whose sensible output capacity is greater than or equal to 5 Btu/h•ft².
- The provisions also apply to the following systems and equipment:
 - Heating, ventilating, and air conditioning
 - Service water heating
 - Electric power distribution and metering provisions
 - Electric motors and belt drives
 - Lighting.

Organization of ASHRAE 90.1-2004

Ch. 1 Purpose

Ch. 2 Scope

Ch. 3 Definitions

Ch. 4 Administration and Enforcement

Ch. 5 Building Envelope

Ch. 6 Heating, Ventilating and Air-Conditioning

Ch. 7 Service Water Heating

Ch. 8 Power

Ch. 9 Lighting

Ch. 10 Other Equipment

Ch. 11 Energy Cost Budget Method

Ch. 12 References (including Appendix G)

Organization of Sections 5-10 ASHRAE 90.1

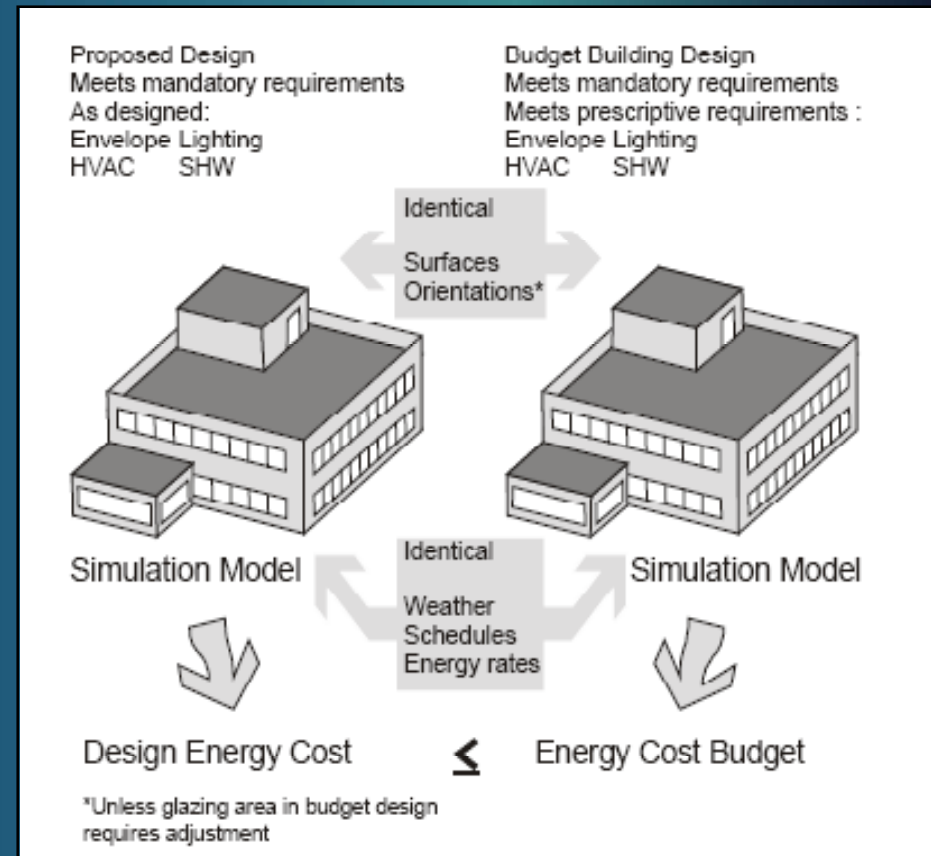
- x.1 General – Scope, other special conditions
- x.2 Compliance Paths
- x.3 Simplified Building (only used in HVAC Section)
- x.4 Mandatory Provisions (Must be followed for all buildings)
- x.5 Prescriptive Compliance Path (Must be followed or traded off with ECB)**
- x.6 Alternative Compliance Path (only in Envelope and Lighting sections)
- x.7 Submittals – Drawings, manuals, labeling, etc.
- x.8 Product Information – Equipment efficiencies, installation requirements, etc.

Chapter 11 – Energy Cost Budget (ECB) Summary

- Definition of ECB: “ The annual energy cost for the budget building design intended for use in determining minimum compliance with the standard.”
- Alternate to Prescriptive Path of other Chapters.
- Limits allowable energy costs of the design to those of a **building meeting the standard.**
- Can only be used if 5.4, 6.4, 7.4, 8.4, 9.4 and 10.4 mandatory requirements are met.

Chapter 11 Compliant if...

- The design energy cost (annual energy cost of proposed design) does not exceed the energy cost budget and...
- The energy efficiency level of components specified in contract documents meet or exceed the efficiency levels used to calculate the design energy cost.



Chapter 11 (ECB) to be used...

- When trading off portions of the requirements only relating to the applicable building permit.
- The only real way to deal with unique designs, renewable energy, high-efficient equipment, etc.

ASHRAE 90.1-2004 *Informative Appendix G*

- Appendix G is a building performance rating method that is a modification of the ECB method (Section 11) intended for use in rating the energy efficiency of building designs that **exceed** the requirements of Standard 90.1.
- It is **not** an alternative path for compliance; rather, it is for those wishing to **quantify performance** that substantially exceeds the requirements of Standard 90.1
- Like ECB method, it requires the use of simulation software.

Differences in Appendix G and ECB Method

- Performance Rating Method (Appendix G) includes total energy consumption for all end uses.
- Credit is offered for better building orientation
- Interior or exterior automatic shading devices may be modeled and credited.
- Credit is given for occupancy sensors and timers for lighting
- Greater credit is given for HVAC system selection

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
General (G1)

- Scope : Modification to ECB Method
- Performance Rating:
$$\% \text{ Improvement} = \frac{100 \times (\text{Baseline Building performance} - \text{Proposed Building performance})}{\text{Baseline Building Performance}}$$
- Trade Off Limits: Only parameters relating to the systems being modified can vary.
- Documentation Requirements:
 - (a) Values for Baseline and proposed building and % Improvement
 - (b) A list of energy-related features
 - (c) Input and output reports from the simulation program

ASHRAE 90.1-2004

Appendix G Supplement

Building Performance Rating Method

Simulation General Requirements (G2)

- Performance Calculations:
 - a. The same simulation program
 - b. The same weather data
 - c. The same energy rates
- Simulation Program:
 - a. Must be approved by the rating authority
 - b. Must model 8,760 hours per year (**vs. 1,400 hours per year for ECB**)
 - c. Hourly variations in occupancy, lighting power, etc.
 - d. Ten or more thermal zones
 - e. Part load performance curves for HVAC equipment.
 - f. Air-side economizers
- Climate Data:
 - a. Simulation must use hourly values of climate data for the site.

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Simulation General Requirements (G2) (Continued)

- Energy Rates:
 - a. Actual Energy Rates must be used **or ...**
 - b. Average rates published by DOE's Energy Information Administration (EIA)
 - c. Rate sources can't be mixed.
 - d. Exception: 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. Baseline building shall use purchased energy.

- Exceptional Calculation Methods:
 - a. If no simulation program is available that adequately models a building (i.e., Lab) the **rating authority** may approve an exceptional calculation method.
 - b. Must be documented, including calculations performed and additional information supporting accuracy of the method.

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculations of the Proposed and Baseline Building Performance (G3)

- Building Performance Calculations:
 - a. Simulation model for calculating building performance for Proposed and Baseline buildings in Table G3.1:

ASHRAE 90.1-2004

Appendix G Supplement

Building Performance Rating Method

Calculations of the Proposed and Baseline Building Performance (G3)

Proposed Building Performance Vs. Baseline Building Performance – Table G3.1

1. Design Model	Same Criteria for both baseline and proposed building models
2. Additions and Alterations	Same Criteria for both baseline and proposed building models
3. Space Use Classification	Same Criteria for both baseline and proposed building models
4. Schedules	Changes to schedules allowed for energy efficient measures in proposed building: <ul style="list-style-type: none"> • Lighting Controls • Demand Control Ventilation • Natural Ventilation • Service water heating loads
5. Building Envelope	<ul style="list-style-type: none"> • orientation and fenestration locations normalized in model of Baseline Building • Baseline Envelope must meet code requirements for common construction type from Table 5.5 1-8. • Only automatic controlled shading devices may be modeled on Proposed Building.
6. Lighting	<ul style="list-style-type: none"> • Credit for automatic controls for daylighting is allowed only in Proposed Building via software of schedules • Credit for Lighting control systems can be taken in the Proposed building by the applicable percentages in Table G3.2 • No automatic lighting controls shall be modeled in the baseline building.
7. Thermal Blocks – HVAC Zones Designed	Same Criteria for both baseline and proposed building models (See tables G3.1.1A and G3.1.1B)

ASHRAE 90.1-2004

Appendix G Supplement

Building Performance Rating Method

Calculations of the Proposed and Baseline Building Performance (G3)

Proposed Building Performance Vs. Baseline Building Performance (Continued)

8. Thermal Blocks – HVAC Zones Not Designed	Same Criteria for both baseline and proposed building models
9. Thermal Blocks – Multifamily Residential Buildings	Same Criteria for both baseline and proposed building models
10. HVAC Systems	<ul style="list-style-type: none"> ● Use actual equipment efficiencies, if known, for proposed building model ● If no heating system exists in proposed building, it shall be the same as baseline building (Same for cooling) ● Baseline building HVAC systems shall be as defined in Table G3.1.1 and G3.1.2
11. Service Hot Water Systems	<ul style="list-style-type: none"> ● Use actual equipment efficiencies for hot water system for proposed building model. ● Baseline building energy source shall be the same as proposed building.
12. Receptacle and other Loads	<ul style="list-style-type: none"> ● Both models shall use the same receptacle and process load (NOTE: NC-Senate Bill 668 exception: Process loads can be excluded from model for both scenarios) ● Motor efficiency for baseline building shall be minimum from Section 10
13. Modeling Limitations to the Simulation Program	<ul style="list-style-type: none"> ● Same Criteria for both baseline and proposed building models

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
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- Allowable Reduction of Lighting Power for Automatically Controlled Lighting Systems:
(or schedules can be adjusted)

TABLE G3.2 POWER ADJUSTMENT PERCENTAGES FOR AUTOMATIC LIGHTING CONTROLS		
Automatic Control Devices	Non 24-hour and \leq 5000 sq. ft.	All Other
(1) Programmable Timing Control	10%	0%
(2) Occupancy Sensor	15%	10%
(3) Occupancy Sensor and Programmable Timing Device	15%	10%

ASHRAE 90.1-2004

Appendix G Supplement

Building Performance Rating Method

Calculations of the Proposed and Baseline Building Performance (G3)

- **Baseline HVAC System Type and Description:**
 - a. Simulation model for calculating building performance for Proposed and Baseline buildings in Table G3.1.1.A for building requirements and Table G3.1.1.B for system descriptions:

TABLE G3.1.1.A BASELINE HVAC SYSTEM TYPES		
Building Type	Fossil Fuel, Fossil/Electric Hybrid & Purchased Heat	Electric & Other
Residential	System 1 – PTAC	System 2 – PTHP
Non-residential & 3 floor or less & 75,000 sq. ft.	System 3 – PSZ-AC	System 4 – PSZ-HP
Non-residential & 4 or 5 floors & < 75,000 sq. ft. or 5 floors or less & 75,000 sq. ft. – 150,000 sq. ft.	System 5 – Packaged VAV w/ Re-heat	System 6 – Packaged VAV with PFP Boxes
Non-residential & more than 5 floors or greater than 150,000 sq. ft.	System 7 – VAV w/ Re-heat	System 8 – VAV with PFP Boxes

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculations of the Proposed and Baseline Building Performance (G3)

TABLE G3.1.1B Baseline System Descriptions

System No.	System Type	Fan Control	Cooling Type	Heating Type
1. PTAC	Packaged Terminal Air Conditioner	Constant Volume	Direct Expansion	Hot Water Fossil Fuel Boiler
2. PTHP	Packaged Terminal Heat Pump	Constant Volume	Direct Expansion	Electric Heat Pump
3. PSZ-AC	Pkgd. Rooftop Air Conditioner	Constant Volume	Direct Expansion	Fossil Fuel Furnace
4. PSZ-HP	Pkgd. Rooftop heat pump	Constant Volume	Direct Expansion	Electric Heat Pump
5. P-VAV w/ Re-heat	Pkgd. Rooftop VAV with re-heat	VAV	Direct Expansion	Hot Water Fossil Fuel Boiler
6. P-VAV w/ PFP Boxes	Pkgd. Rooftop VAV with reheat	VAV	Direct Expansion	Electric Resistance
7. VAV with Re-heat	Pkgd. Rooftop VAV with Re-heat	VAV	Chilled Water	Hot Water Fossil Fuel Boiler
8. VAV with PFP Boxes	VAV with Re-heat	VAV	Chilled Water	Electric Resistance

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- **Equipment Capacities:**
 - a. Baseline building equipment capacities shall be averaged based on sizing runs for each orientation (Actual, 90, 180, 270).
 - b. Capacities shall be oversized by 15% for cooling and 25% for heating
 - c. Unmet load capacities for BOTH models shall not exceed 300 hours
 - d. Unmet load hours for Proposed shall not exceed Baseline by 50 hours.
 - e. If exceeded, models need to be re-run and capacities adjusted
 - f. Unmet loads may be accepted by the rating authority with justification
 - g. Weather data must use 99.6% design days and 1% dry-bulb and 1% wet-bulb cooling temperatures.

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- Other HVAC Criteria:
 - a. If proposed design has a pre-heat coil, the baseline design must be modeled with a pre-heat coil with same control.
 - b. Supply and Return fans shall operate continuously during occupied mode and shall cycle during unoccupied mode.
 - c. If supply fan is modeled as cycling and fan energy is included in EER of equipment, fan energy shall not be modeled explicitly.
 - d. Minimum outdoor ventilation rates shall be the same for the proposed and baseline building designs. (except when modeling DCV in the proposed design)

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- **Economizer Requirements:**
 - e. Outdoor air economizers shall not be included in baseline HVAC systems 1 and 2., but shall be included in systems 3 and 4 based on building size. Table G3.1.2.6A indicates the minimum building conditioned floor areas where economizers should be included for Systems 3 & 4
(N.C. Zones have no requirements for economizer for any size building for Systems 3 &4)
 - f. Outdoor air economizers shall be included in HVAC systems 5 thru 8 for baseline model depending on climate zone. Table G3.1.2.6B indicates the minimum building conditioned floor areas where economizers should be included for Systems 5-8
(N.C. Zones have no requirements for economizers for Systems 5-8)
 - g. High-limit shut-off for economizers, if added, shall be a dry-bulb switch.

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- **Fan Power Requirements:**
 - h. System design supply airflow rates for the baseline building shall be based on a 20 degree supply air-to-room air temp. difference.
 - i. If return or relief fans are used in proposed building, they must also be modeled in baseline building. They must be sized for the baseline system air quantity minus the min. outside air or 90% of supply fan air, whichever is larger.
 - j. Supply fan power for all fans (except fan-powered VAV boxes) shall be calculated by formula given in section G3.1.2.9 (Except for system with filtration with pressure drops above 1" w.c.)

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- Exhaust Air Energy Recovery:
 - k. Fan systems above 5000 cfm with 70% or greater minimum outside air shall have an energy recovery system with at least 50% recovery “effectiveness”.
 - l. 50% recovery “effectiveness” means a change in enthalpy of the outdoor air supply equal to 50% of the difference between outdoor air and return air at design conditions.
 - m. Provisions to be made to bypass or control energy recovery system to permit economizer operation.

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- **Baseline HVAC System-Specific Requirements:**
 - a. Heat Pumps:
(Systems 2 & 4)
 - Modeled with Aux. electric heat.
 - Controlled with Multi-stage T'stat.
 - O.A. T'stat wired for aux. heat below 40 deg.

 - b. Boilers:
(System 1,5, & 7)
 - Boilers shall be natural draft for Baseline
 - Use same fuel as proposed building
 - Single boiler (<15,000 sq.ft.)
 - Dual boilers (> 15,000 sq. ft.) – Staged for load

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- **Baseline HVAC System-Specific Requirements:**

- | | |
|---|--|
| c. Hot Water Temp:
(Systems 1,5, 7) | Modeled with 180 deg. HWS
Modeled with 130 deg. HWR |
| d. Hot Water Reset:
(Systems 1,5, 7) | Reset on O.A. DB Temp.
180 deg. @ 20 deg. and below
150 deg. @ 50 deg. and above
Ramped linearly between limits |

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- **Baseline HVAC System-Specific Requirements:**

**g. Chillers:
(Systems 7 & 8)**

**All baseline chillers shall be electric,
regardless of source for proposed building.**

Table G3.1.3.7 Type and Number of Chillers

Building-Conditioned Floor Area	No. and Type of Chillers
< / = 120,000 sq. ft.	(1) Screw Chiller
>120,000 and <240,000 sq. ft.	(2) Screw Chillers sized Equally
>/= 240,000 sq. ft.	(2) Cent. Chillers with min. chiller added so no chiller is larger than 800 tons, all sized equal.

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- **Baseline HVAC System-Specific Requirements:**

- c. Chilled Water Temp: Modeled with 44 deg. CHWS
(Systems 7 & 8) Modeled with 56 deg. CHWR
- d. Chilled Water Reset: Reset on O.A. DB Temp.
(Systems 7 & 8) 44 deg. @ 80 deg. and above
54 deg. @ 60 deg. and below
Ramped linearly between limits

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- **Baseline HVAC System-Specific Requirements:**
 - e. Chilled Water Pumps: 22W/gpm baseline pump power
(Systems 7 & 8)
 - Under 120K sq. ft. shall be primary/secondary
(Pump shall ride pump curve)
 - Over 120K sq. ft. shall be primary/secondary
(With VFD)

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- Baseline HVAC System-Specific Requirements:

- f. Heat Rejection:
(Systems 7 & 8)
 - Axial fan cooling tower with 2-speed fans
 - 85 deg. CWS temp **OR** 10 deg. approach (WB)
 - (Whichever is lower)
 - 10 deg. water temperature rise.
 - Maintain 70 deg. CWS when possible w/ O.A.
 - 10W/gpm for condenser water pump power
 - Separate pumps for each chiller & condenser

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- **Baseline HVAC System-Specific Requirements:**

h. Supply Air Temp Reset:
(Systems 5-8)

Based on Zone Demand from
Design Temp. difference 10 deg.
under min. load conditions

Design airflow rates sized for reset

i. VAV Minimum flow Setpoints
(Systems 5 & 7)

VAV re-heat boxes .4 cfm/sq. ft. of
floor area served.

ASHRAE 90.1-2004
Appendix G Supplement
Building Performance Rating Method
Calculation of the Proposed and Baseline Building Performance (G3)
(continued)

- **Baseline HVAC System-Specific Requirements:**

j. VAV Box Fan Power:
(Systems 6 & 8)

Parallel - Sized for 50% of max. flow
Modeled with .35w/cfm fan power
Min. primary air is 30% of max. flow
OR Min. O.A. req., whichever is larger

i. VAV Part Load:
(Systems 5 & 8)

Supply Fans shall have VFD's
Model Part Load performance with
Method 1 (Load Ratio to Full load
power) **OR** Method 2 (Power
Equation)

Q&A

???

Contact Information:

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THANK YOU FOR YOUR ATTENDANCE!!

The following slides are to be included and discussed again if time allows

**SECTION 1.(c) of General Statute GS 143.135 – Article 8C
Standard for Major Facilities
Reports by Agencies and the Department**

The Sustainable Energy Efficient Buildings Program is established in the Department. Under this program:

All **MAJOR FACILITY PROJECTS** of public agencies shall be designed, constructed, and certified to at least a thirty percent (30%) greater energy efficiency than the standard under
ASHRAE 90.1-2004.

For **MAJOR RENOVATIONS** a twenty percent (20%) greater energy efficiency standard than
ASHRAE 90.1-2004
shall be used.

This section applies to major facility projects that have not entered the schematic design phase prior to the effective date of this section.

SECTION 1.(b) of General Statute GS 143.135 – Article 8C Standard for Major Facilities

DEFINITIONS

"DEPARTMENT" -- Department of Administration.

"INSTITUTIONS OF HIGHER EDUCATION" -- The constituent institutions of The University of North Carolina, the regional institutions as defined in G.S. 115D-2, and the community colleges as defined in G.S. 115D-2.

"MAJOR FACILITY PROJECT" -- A construction project larger than 20,000 gross square feet of occupied or conditioned space, as defined in the North Carolina State Building Code. Does not include transmitter buildings or pumping stations.

"MAJOR RENOVATION" -- A building renovation project when the renovation cost is greater than fifty percent (50%) of the insurance value of the building and the project is larger than 20,000 gross square feet of occupied or conditioned space, as defined in the North Carolina State Building Code, and whose construction is funded in whole or in part by the State of North Carolina.

"PUBLIC AGENCY" -- Every State office, officer, board, department, and commission and institutions of higher

"ASHRAE" -- American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Energy Model Guideline

General Information

- Buildings with historic, architectural, or cultural significance as defined under Part 4 of Article 2 of Chapter 143B of the General Statutes are excluded from the Statute requirements.
- Computer simulations shall be utilized to model acceptable compliance with the energy reduction requirement of the Statute, in accordance with Appendix G of ASHRAE 90.1-2004.
- The resultant energy costs of the modeled buildings shall be utilized to perform the life cycle cost analysis (LCCA) required in section 303 of the State Construction Manual (http://www.nc-sco.com/Guidelines/LCCA/TOC_LCCA.htm).
- The LCCA shall be performed on the building as an entity, comparing the life cycle cost of the ASHRAE 90.1-2004 compliant baseline building with one or more alternate buildings with resultant energy savings greater than or equal to the levels mandated by the General Statute.

Energy Modeling Simulation

- ASHRAE 90.1-2004 Appendix G – Performance Rating Method shall be used as the calculation methodology to establish a percentage improvement of the proposed building over the baseline ASHRAE 90.1-2004 compliant building model.
- Pre-approved simulation software includes the latest versions of DOE-2, Blast, EnergyPlus, eQUEST, EnergyPro, Carrier Hourly Analysis Program (HAP), and Trane Trace.
- Designers wishing to utilize other simulation software should submit documentation to the SCO for approval in the advance planning stage of the project indicating how the software complies with ASHRAE Standard 140 requirements, latest edition.

Submittals & Strategies

- Energy Model reports shall be submitted beginning in the schematic design phase, and shall be completed no later than the Design Development. The energy model shall be updated, if necessary, and re-submitted at Construction Document Phase.
- Refer to Section 300 of the State Construction Manual for submittal requirements for each phase of the project.
- Energy Strategies shall be utilized for variable building elements, as applicable for each project. Each of the following categories shall be evaluated, and decisions on which items will be pursued shall be summarized in Energy Model summary:
 - Building Envelope
 - Lighting control and lighting design
 - HVAC system control and design
 - Service water heating systems

Computer Simulation Conditions & Constraints

The following constraints shall apply to the energy modeling at each program run:

- Only one building geometry shall be used for a given project analysis.
- Plug and process loads shall be excluded from the analysis for both the baseline building and the energy efficient alternate building(s), with the assumption that they will be identical in both the baseline building and the energy efficient option(s). However, the plug and process loads can be included in the analysis as an energy saving measure if they alter between the base building analysis and the energy efficient alternate buildings in a documented method that allows for energy reduction.
- The cost of energy (energy rate) must be the same for the base building and all modeled options.

Computer Simulation Conditions & Constraints

- The same energy simulation software program shall be used for each phase (SD,DD,CD) of the project submittal, as well as for each energy conservation strategy. ASHRAE 90.1-2004 Appendix G – Performance Rating Method shall be used as the calculation methodology to establish a percentage improvement of the proposed building over the baseline model.
- Exceptions are allowed for the above constraints provided those exceptions are requested in writing from SCO during the schematic design submittal phase, and written approval has been granted.
- An unlimited number of options can be modeled for each building, but designer must use judgment to determine options resulting in best energy savings and lower first costs, which will be compared in the resultant life cycle cost analysis to provide an overall lowest building cost for the long term.