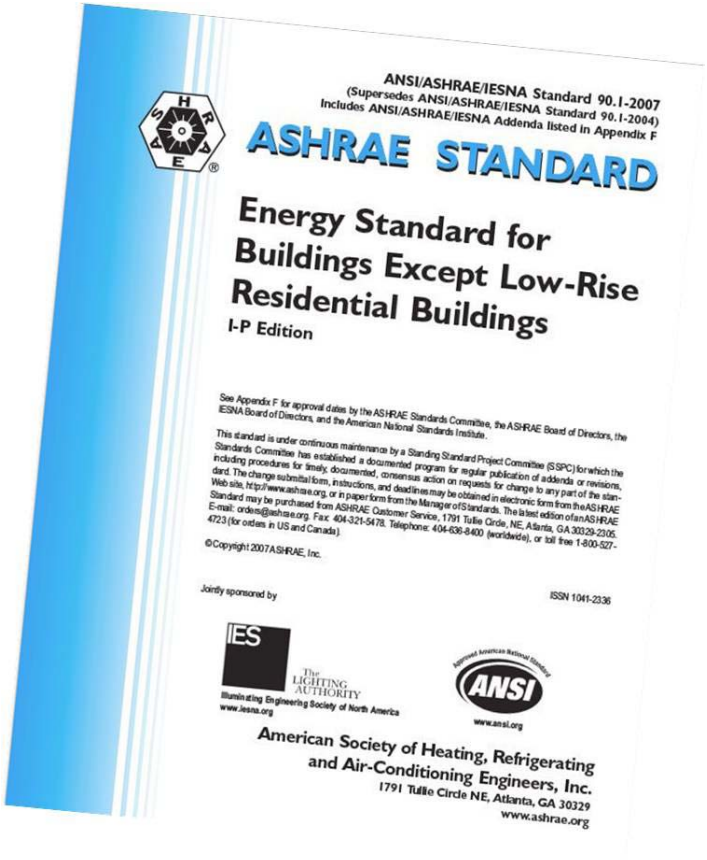
Energy Modeling for LEED Using ASHRAE/ANSI 90.1-2004 Appendix G

CENTRAL PENNSYLVANIA CHAPTER OF ASHRAE

March 31, 2011



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Program Overview:

- LEED Rating Systems and minimum energy performance requirements
- Energy Cost Budget versus Performance Rating Method modeling protocol
- 90.1-2004 Appendix G modeling requirements and common mistakes
- USGBC requirements for District Thermal and Combined Heat and Power Systems
- Changes in 90.1-2007 Appendix G modeling protocol
- Energy performance documentation for LEED 2009 (EAp2 and EAc1)
- Resources and references
- Questions and answers

Learning Objectives

- Understand how to ASHRAE 90.1-2004 Appendix G modeling protocol to estimate energy savings for LEED projects
- Save time wasted by understanding the modeling protocol and helpful resources
- Save time completing LEED documentation by understanding what reviewers need to see
- Learn what NOT to do from a veteran reviewer who has seen almost everything you can do wrong
- Discover how to approach modeling and presenting unusual systems configurations and energy saving measures
- An opportunity to finally ask that burning question from you last LEED reviewer comments: “What were they thinking?”

Program Overview

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- Resources and references
- Questions and answers

Background

- LEED Rating Systems using ASHRAE 90.1-2004 Appendix G modeling protocol:
  - LEED for New Construction v2.2
  - LEED for Schools 2007
  - LEED for Commercial Interiors v2.0 (EAc1.3)
  - LEED for Core & Shell v2.0
  - LEED for Retail – New Construction (Pilot)
  - LEED for Retail – Commercial Interiors (Pilot)

Background

- Energy Modeling not required for:
  - LEED for Existing Buildings O&M (2008)
  - LEED for Existing Buildings v2.0
  - LEED for Homes 2007
  - LEED for Neighborhood Development (Pilot)
  - LEED for Commercial Interiors (EAc1.1 and EAc1.2)
- All projects after June 26, 2009 are registered under LEED 2009 Rating System

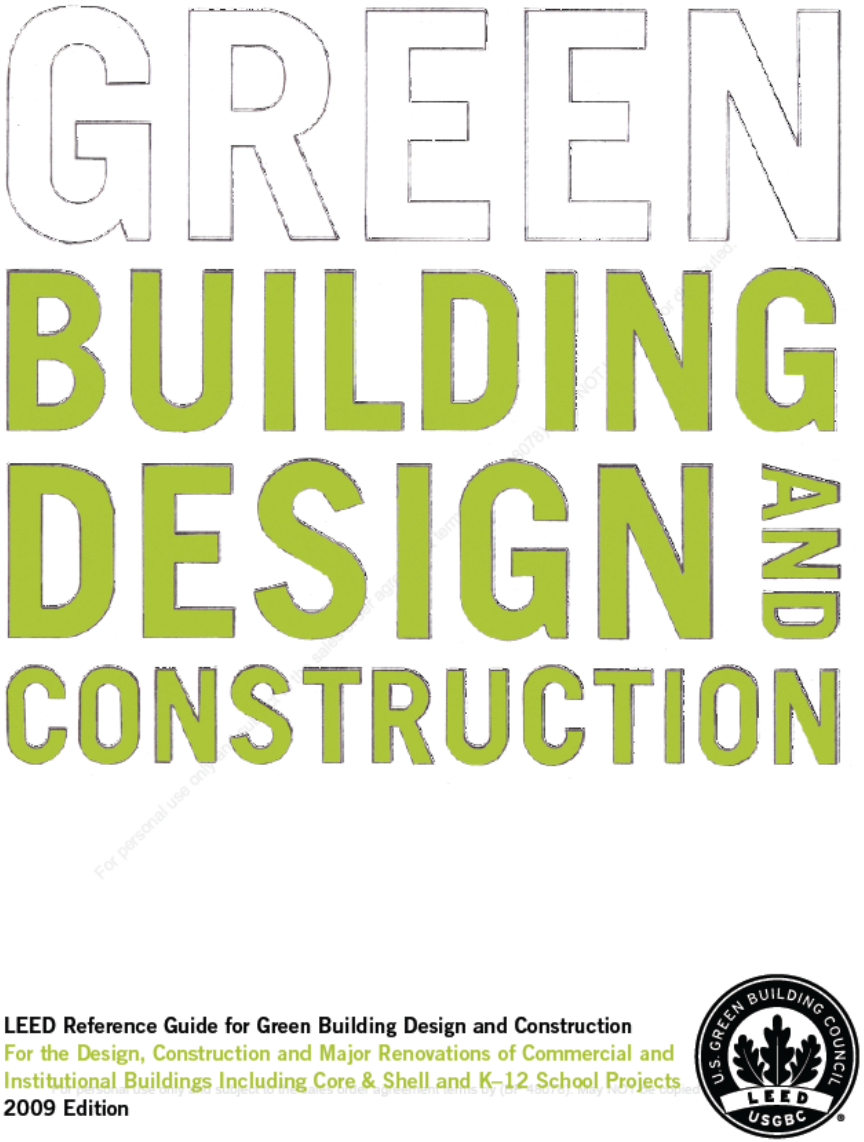
LEED

Leadership in **Energy** and Environmental Design

- Projects registered before June 26, 2007
  - Energy and Atmosphere Prerequisite 1 (EAp1) – meet ASHRAE 90.1-2004 mandatory and prescriptive requirements
  - Projects could achieve LEED certification without implementing ANY energy savings measures
  - Showing energy savings in Energy and Atmosphere Credit 1 (EAc1) was optional

LEED
Leadership in **Energy** and Environmental Design

- Projects registered after June 26, 2007
  - Must achieve two points in EAc1 using energy simulations or one of the prescriptive paths
  - For Option 1 - Whole Building Energy Simulation
    - New buildings - minimum 14% energy savings
    - Existing buildings - minimum 3.5% energy savings
  - Projects cannot be certified without energy saving design strategies



LEED 2009 Rating Systems

- Includes:
  - o New Construction
  - o Schools
  - o Core and Shell
- O & M considerations
- All rating systems have 100 base points with up to 10 additional points for Innovation in Design and Regional Priority credits

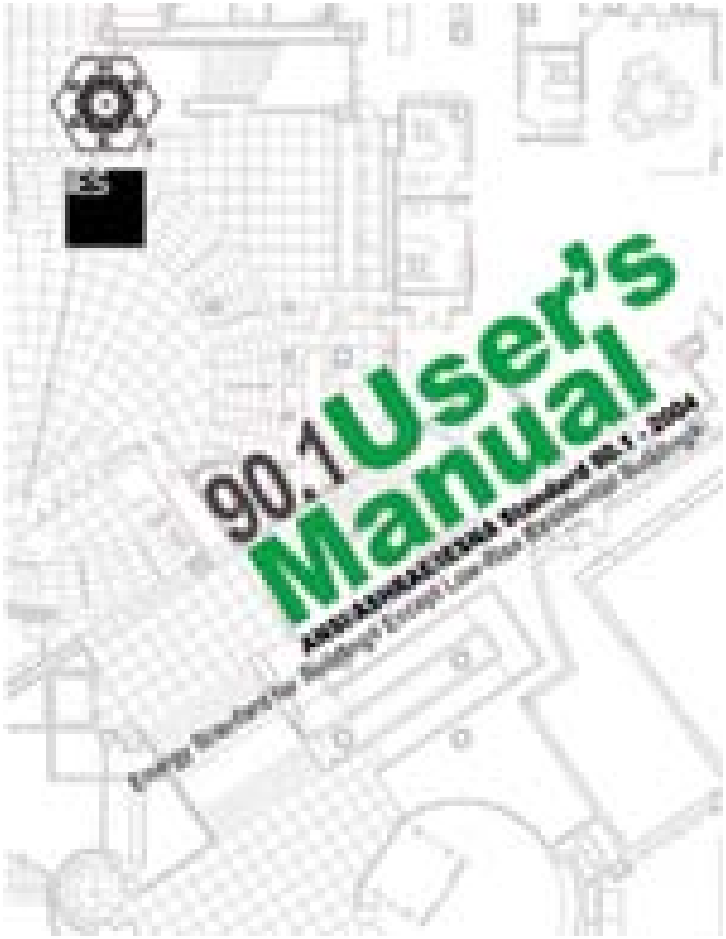
ASHRAE 90.1 Modeling Protocols

- Section 11 – Energy Cost Budget (ECB)
  - Used for trade-offs among prescriptive requirements for envelope, mechanical system, service hot water systems, lighting, and motor requirements to demonstrate the overall building performance meets ASHRAE 90.1 minimum standards
  - Modeling protocol pairs components in the proposed design against the prescriptive requirements for similar building components
  - Proposed HVAC systems mapped individually to baseline systems bases on condenser cooling source, heating energy source, and building classification (residential or non-residential) and number of zones served.

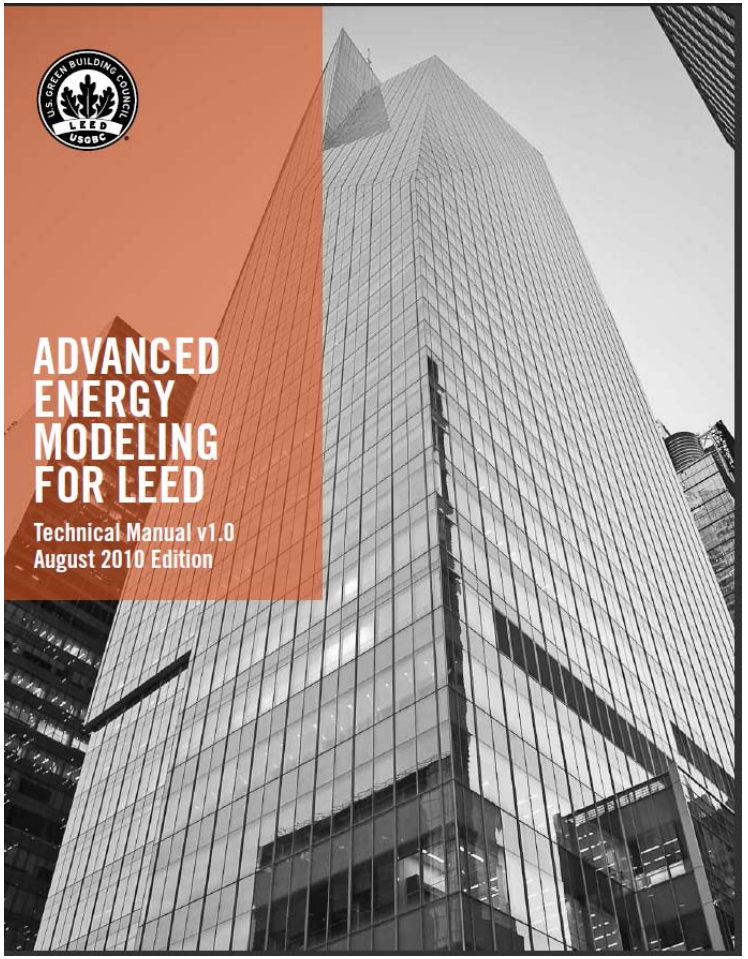
ASHRAE 90.1 Modeling Protocols

- Appendix G – Performance Rating System (PRM)
  - New in 2004, this Informative Appendix is not intended to be used to demonstrate compliance with the Standard, but to provide a universal baseline against which projected energy savings can be measured.
  - Modeling protocol pairs proposed building and systems against lightweight building constructions, and prescriptive requirements of Sections 5.5, 6.5, 7.5, and 9.5.
  - Baseline building is modeled without self-shading and rotated 90^{o}, 180^{o}, and 270^{o} to allow projects to show savings from building features and orientation.

Useful References:



Available at www.ashrae.org



Available at www.usgbc.org

Other Resources:

- LEED Reference Guides
  - Provides additional guidance in meeting the requirements and submittal documentation required.
- www.usgbc.org
  - Official memoranda including guidance for modeling District Thermal and Combined Heat and Power systems
  - Credit Interpretation Rulings (CIRs) and LEED Interpretation (LI)

ASHRAE 90.1-2004 Appendix G

- Defines the modeling protocol for the Proposed and Baseline case including:
  - Building Envelope
  - HVAC Systems
  - Service Hot Water Systems
  - Exterior Lighting
  - Interior Lighting
  - Electric Motors

General Rules

- Simulations must be performed hourly for a full year (8760 hours)
- Energy rates (Section G2.1)
  - can be either actual local utility rates or state average prices published by DOE's Energy Information Administration (EIA) for commercial buildings
  - Rates from different sources cannot be mixed in the same project
  - Exception for on-site renewable energy sources

General Rules

- Exceptional Calculations (Section G2.5)
  - Must be used to show savings associated with:
    - building components or systems that cannot be modeled directly in the software
    - Savings estimated using a schedule change
  - Required documentation
    - Detailed description of strategy in Proposed design and any work-around used to simulate unusual system
    - Justification for Baseline used to estimate savings
    - Confirmation the proposed strategy is above and beyond industry standards

General Rules

- Baseline HVAC System Type (Section G3.1.1)
  - Based on Table G3.1.1A:
    - Usage – Residential or Non-Residential – Section 3.2 defines Residential as “Spaces in buildings used primarily for living and sleeping. Residential spaces include…dwelling units, hotel/motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/sorority houses, hostels, prisons, and fire stations.
    - Number of Floors
    - Conditioned Floor Area
    - Heating Source

TABLE G3.1.1A *Baseline* HVAC System Types

Building Type	Fossil Fuel, Fossil/Electric Hybrid, & Purchased Heat	Electric and Other
Residential	System 1 – PTAC	System 2 - PTHP
Nonresidential & 3 Floors or Less & <75,000 ft^2	System 3 – PSZ-AC	System 4 – PSZ-HP
Nonresidential & 4 or 5 Floors & <75,000 ft^2 or 5 Floors or Less & 75,000 ft^2 to 150,000 ft^2	System 5 - Packaged VAV w/ Reheat	System 6 - Packaged VAV w/PFP Boxes
Nonresidential & More than 5 Floors or >150,000 ft^2	System 7 - VAV w/Reheat	System 8 - VAV w/PFP Boxes

Notes:
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.
Where no heating system is to be provided or no heating energy source is specified, use the "Electric and Other" heating source classification.
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 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	Packaged rooftop air conditioner	Constant Volume	Direct Expansion	Fossil Fuel Furnace
4. PSZ-HP	Packaged rooftop heat pump	Constant Volume	Direct Expansion	Electric Heat Pump
5. Packaged VAV w/ Reheat	Packaged rooftop variable air volume with reheat	VAV	Direct Expansion	Hot Water Fossil Fuel Boiler
6. Packaged VAV w/PFP Boxes	Packaged rooftop variable air volume with reheat	VAV	Direct Expansion	Electric Resistance
7. VAV w/Reheat	Packaged rooftop variable air volume with reheat	VAV	Chilled Water	Hot Water Fossil Fuel Boiler
8. VAV w/PFP Boxes	Variable air volume with reheat	VAV	Chilled Water	Electric Resistance

General Rules

- Baseline System Exceptions to G3.1.1
  - (a) Additional system types must be used for non-predominant conditions (residential/non-residential or heating source) if conditions apply to 20,000 ft² of conditioned area or more
  - (b and c) Packaged single-zone systems (type 3 or 4) may be used in lieu of VAV systems (type 5, 6, 7, or 8) if zone loads or schedules differ from other zones served by VAV system
    - Peak thermal loads differ by more than 10 BTU/h-ft²
    - Schedules differ by more than 40 equivalent full-load hours per week
    - Zones with special pressurization, cross-contamination, or minimum circulation rate requirements

General Rules

- Section G3.1.1.1 Purchased Heat
  - Applies to projects registered before May 28, 2008
  - May 28, 2008 USGBC released Required Treatment of District Thermal Energy v1.0
    - Modeling protocol required two step modeling process to achieve more than 2 points
    - Provides more specific modeling protocol for projects with and without the central plant performance
    - Includes clarifications for related credits including: EAc2 (Renewables), EAp3/c4 (Refrigerant), EAc5 (M&V) and EAc6(Green Power)
    - Also clarifications for LEED-CS and LEED-CI

General Rules

- Baseline HVAC Equipment modeled with minimum efficiencies from Section 6
  - System Type 1 (PTAC w/ HW)
    - DX Cooling – Table 6.8.1D
    - Hot Water Boiler – Table 6.8.1F
  - System Type 2 (PTHP)
    - Heating & Cooling – Table 6.8.1D
  - System Type 3 (DX CV with Gas Furnace)
    - DX Cooling – Table 6.8.A (All Other heat)
    - Natural gas Furnace – Table 6.8.1E

General Rules

- Baseline HVAC system efficiencies (cont.)
  - System Type 4 (PSZ HP)
    - Heating & Cooling – Table 6.8.1B
  - System Type 5 (DX VAV w/ HW Reheat)
    - DX Cooling – Table 6.8.A (All Other heat)
    - Natural gas boiler – Table 6.8.1F
  - System Type 6 (DX VAV w/ Elect. Reheat FPB)
    - DX Cooling – Table 6.8.1A (All Other Heat)
    - Fan-Power Boxes w/ electric resistance reheat

General Rules

- Baseline HVAC system efficiencies (cont.)
  - System Type 7 (VAV w/ Chiller & HW Reheat)
    - Water-Cooled Chiller – Table 6.8.C
    - Natural gas boiler – Table 6.8.1F
  - System Type 8 (VAV w/ Chiller & Elect Reheat FPB)
    - Water-Cooled Chiller – Table 6.8.C
    - Heat - Fan-Power Boxes w/ electric resistance reheat

General Rules

- Table G3.1 is backbone of Appendix G
- Provides summary of modeling requirements for Baseline and Proposed case
- Building components not regulated by ASHRAE 90.1 are Process Loads
- Savings associated with components that cannot be modeled directly must use the exceptional calculation method

Table G3.1

- Table G3.1#1 Design Model
  - All loads within and associated with the building must be included in both models
  - Conditioned spaces modeled with heating and cooling even if not designed (same temperature and humidity control set points both cases)
- Table G3.1#2 Additions and Alterations
  - Partial modeling of building if conditions (a) through (d) are met
- Table G3.1#3 Space Usage Classifications must align with lighting classifications in Section 9.5.1 or 9.6.1

Schedules (Table G3.1#4)

- Proposed Case
  - All schedules must be identical in both buildings
  - Savings associated with components that cannot be modeled directly must use the exceptional calculation method
  - HVAC fan schedules
    - Occupied - run continuously
    - Unoccupied – cycle to meet loads
    - Exception – for systems only modeled to meet Appendix G requirements fans may cycle
- Baseline case – same as Proposed case

Building Envelope (Table G3.1#5)

- Proposed case – model as designed
  - Using construction assembly U-values
  - Reflectivity of 0.45 for white roofs
  - Window U-values and SHGC including frames
  - Fixed shades (fins and overhangs)
  - Include all spaces – conditioned & unconditioned

Building Envelope (Table G3.1#5)

- Baseline Case – same area as Proposed case
  - Use performance factors from Tables 5.5-1 through 5.5-8 based on usage and climate zone
    - Roof – Insulation Entirely above Deck
    - Exterior Walls – Steel-Framed
    - Floors (exposed) – Steel-Joist
    - Slab-on-Grade Floors – Unheated
    - Windows – based on proposed window to wall ratio
      - maximum 40% window to wall ratio
      - Addendum a – same window configuration as Proposed case
  - Same orientation then rotate 90, 180, and 270
  - Existing buildings – constructions prior to work

TABLE 5.5-4 Building Envelope Requirements For Climate Zone 4 (A,B,C)*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.063	R-15.0 ci	U-0.063	R-15.0 ci	U-0.218	R-3.8 ci
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.034	R-30.0	U-0.027	R-38.0	U-0.081	R-13.0
Walls, Above-Grade						
Mass	U-0.151[a]	R-5.7 ci[a]	U-0.104	R-9.5 ci	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-0.134	R-10.0
Steel-Framed	U-0.124	R-13.0	U-0.064	R-13.0 + R-7.5 ci	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
Wall, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.107	R-6.3 ci	U-0.087	R-8.3 ci	U-0.322	NR
Steel-Joist	U-0.052	R-19.0	U-0.038	R-30.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.051	R-19.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-0.950	R-7.5 for 24 in.	F-0.840	R-10 for 36 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Non-Swinging	U-1.450		U-0.500		U-1.450	
Fenestration	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**
Vertical Glazing,% of Wall						
0-10.0%	U_{fixed}-0.57	$SHGC_{all}$-0.39	U_{fixed}-0.57	$SHGC_{all}$-0.39	U_{fixed}-1.22	$SHGC_{all}$-NR
	U_{oper}-0.67	$SHGC_{north}$-0.49	U_{oper}-0.67	$SHGC_{north}$-0.49	U_{oper}-1.27	$SHGC_{north}$-NR
10.1-20.0%	U_{fixed}-0.57	$SHGC_{all}$-0.39	U_{fixed}-0.57	$SHGC_{all}$-0.39	U_{fixed}-1.22	$SHGC_{all}$-NR
	U_{oper}-0.67	$SHGC_{north}$-0.49	U_{oper}-0.67	$SHGC_{north}$-0.49	U_{oper}-1.27	$SHGC_{north}$-NR
20.1-30.0%	U_{fixed}-0.57	$SHGC_{all}$-0.39	U_{fixed}-0.57	$SHGC_{all}$-0.39	U_{fixed}-1.22	$SHGC_{all}$-NR
	U_{oper}-0.67	$SHGC_{north}$-0.49	U_{oper}-0.67	$SHGC_{north}$-0.49	U_{oper}-1.27	$SHGC_{north}$-NR
30.1-40.0%	U_{fixed}-0.57	$SHGC_{all}$-0.39	U_{fixed}-0.57	$SHGC_{all}$-0.39	U_{fixed}-1.22	$SHGC_{all}$-NR
	U_{oper}-0.67	$SHGC_{north}$-0.49	U_{oper}-0.67	$SHGC_{north}$-0.49	U_{oper}-1.27	$SHGC_{north}$-NR
40.1-50.0%	U_{fixed}-0.46	$SHGC_{all}$-0.25	U_{fixed}-0.46	$SHGC_{all}$-0.23	U_{fixed}-0.98	$SHGC_{all}$-NR
	U_{oper}-0.47	$SHGC_{north}$-0.36	U_{oper}-0.47	$SHGC_{north}$-0.36	U_{oper}-1.02	$SHGC_{north}$-NR
Skylight with Curb, Glass,% of Roof						
0-2.0%	U_{all}-1.17	$SHGC_{all}$-0.49	U_{all}-0.98	$SHGC_{all}$-0.36	U_{all}-1.98	$SHGC_{all}$-NR
2.1-5.0%	U_{all}-1.17	$SHGC_{all}$-0.39	U_{all}-0.98	$SHGC_{all}$-0.19	U_{all}-1.98	$SHGC_{all}$-NR
Skylight with Curb, Plastic,% of Roof						
0-2.0%	U_{all}-1.30	$SHGC_{all}$-0.65	U_{all}-1.30	$SHGC_{all}$-0.62	U_{all}-1.90	$SHGC_{all}$-NR
2.1-5.0%	U_{all}-1.30	$SHGC_{all}$-0.54	U_{all}-1.30	$SHGC_{all}$-0.27	U_{all}-1.90	$SHGC_{all}$-NR
Skylight without Curb, All,% of Roof						
0-2.0%	U_{all}-0.69	$SHGC_{all}$-0.69	U_{all}-0.58	$SHGC_{all}$-0.36	U_{all}-1.36	$SHGC_{all}$-NR
2.1-5.0%	U_{all}-0.69	$SHGC_{all}$-0.59	U_{all}-0.58	$SHGC_{all}$-0.19	U_{all}-1.36	$SHGC_{all}$-NR

*The following definitions apply: ci = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[a]Exception to A2.1.3.1 applies.

Common Mistakes – Building Envelope

- Proposed case
  - Wall/roof insulation between framing not corrected for effect of framing per Appendix A
  - White roof not modeled with reflectance of 0.45
  - Glazing – using center of glass U-value and SHGC
  - Manual window shading devices modeled
- Baseline case
  - Properties for wrong assemblies used
  - Existing constructions not modeled as exists before construction and rotated

Lighting (Table G3.1#6)

- Proposed Case
  - Lighting as designed
    - Building Area Method – average Lighting Power Density (LPD) in all spaces
    - Space by Space Method – as designed in each space
  - Schedules
    - Based on anticipated occupancy
    - Assumed to represent mandatory lighting controls in Section 9.4.1.1
  - Process lighting – exceptions to Section 9.2.2.3

Lighting (Table G3.1#6)

- Proposed Case – Lighting Controls
  - o Percent LPD reduction for spaces with occupancy sensors from Table G3.2
  - o No savings for spaces where occupancy sensors required by Section 9.4.1.2
    - Classrooms (except shops, labs, and K – 12)
    - Conference/meeting rooms
    - Employee lunch and break rooms

TABLE G3.2 Power Adjustment Percentages for Automatic Lighting Controls

Automatic Control Devices(s)	Non-24-hr and ≤5,000ft^2	All Other
(1) Programmable timing control	10%	0%
(2) Occupancy sensor	15%	10%
(3) Occupancy sensor and programmable timing control	15%	10%

Note: The 5,000 ft^2 condition pertains to the total conditioned floor area of the building.

Lighting (Table G3.1#6)

- Baseline Case
  - Same categorization procedure as Proposed case with maximum allowance
    - Building Area Method – Table 9.5.1
    - Space by Space Method – Table 9.6.1
      - Additional lighting allowance for decorative (1.0 W/ft^2), task (0.35 W/ft^2), and display lighting (Section 9.6.3)
  - Lighting schedules – same as Proposed case
  - Lighting controls
    - None except where required by Section 9.4.1.2
    - Percent LPD reduction for spaces with occupancy sensors from table G3.2

Common Mistakes – Lighting

- Proposed case
  - Credit for occupancy sensors on all lights, not just ones controlled
  - Savings simulated using schedule change not submitted as exceptional calculation
- Baseline case
  - Different categorization procedures used than in Proposed case
  - Both Building Area and Space by Space Methods used in same building
  - Inappropriate building or space types used
  - Additional allowances in Section 6.3
    - Maximum allowance modeled – must use same additional power as Proposed case up to maximum
    - Occupancy sensors not modeled where required by Section 9.4.1.2

Thermal Blocks – HVAC Zones Designed (Table G3.1#7)

- Proposed Case
  - Thermal zones modeled as designed
  - Thermal zones may be combined into thermal blocks if:
    - Same space use classification
    - All zones with glazed exterior walls in block with same orientation (can deviate up to 45°)

    AND
    - Zones served by the same (or same kind of) HVAC system
- Baseline case - same as Proposed case

Common Mistakes – Thermal Blocks

- Proposed case
  - Not modeled with all systems as designed
  - Thermal zones combined into blocks, but do not meet all conditions
- Baseline case
  - Thermal zones and blocks not same as Proposed case
    - One packaged single-zone system for multiple thermal zones/blocks

Thermal Blocks – HVAC Zones Not Designed (Table G3.1#8)

- Proposed Case
  - Thermal blocks determined based on similar internal loads, occupancy, schedules, and
    - Separate interior (more than 15 ft from exterior wall) and perimeter blocks
    - Same exposure tor exterior blocks (may deviate by up to 45^{o})
    - Same roof and ceiling assemblies
- Baseline case - same as Proposed case

Thermal Blocks – Multifamily Residential Buildings (Table G3.1#9)

- Proposed Case
  - At least 1 thermal zone for each residential unit unless requirements for thermal blocks apply
  - Corner units and units with roof and floor exposures may only be combined with similar units
- Baseline case - same as Proposed case

HVAC Systems (Table G3.1#10)

- Proposed Case
  - Existing HVAC systems – model system type and efficiencies that reflect existing equipment
  - HVAC system designed - model system type and efficiencies as designed
  - HVAC system not designed - model same system type and efficiencies as determined for the Baseline case

HVAC Systems (Table G3.1#10)

- Baseline Case
  - Determined by building type, height, and conditioned floor area
  - As listed in Table G3.1.1A and described in Table G3.1.1B
  - Buildings eligible for multiple system types use the predominant condition to select system type
  - Apply exceptions to Section G3.1.1 that apply
    - Split residential and non-residential uses or different fuel sources if more than 20,000 ft²
    - Packaged single-zone systems for different schedules or internal loads
  - System requirements in Sections G3.1.2 and G3.1.3

TABLE G3.1.1A *Baseline* HVAC System Types

Building Type	Fossil Fuel, Fossil/Electric Hybrid, & Purchased Heat	Electric and Other
Residential	System 1 – PTAC	System 2 - PTHP
Nonresidential & 3 Floors or Less & <75,000 ft^2	System 3 – PSZ-AC	System 4 – PSZ-HP
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Notes:
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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	Packaged rooftop air conditioner	Constant Volume	Direct Expansion	Fossil Fuel Furnace
4. PSZ-HP	Packaged rooftop heat pump	Constant Volume	Direct Expansion	Electric Heat Pump
5. Packaged VAV w/ Reheat	Packaged rooftop variable air volume with reheat	VAV	Direct Expansion	Hot Water Fossil Fuel Boiler
6. Packaged VAV w/PFP Boxes	Packaged rooftop variable air volume with reheat	VAV	Direct Expansion	Electric Resistance
7. VAV w/Reheat	Packaged rooftop variable air volume with reheat	VAV	Chilled Water	Hot Water Fossil Fuel Boiler
8. VAV w/PFP Boxes	Variable air volume with reheat	VAV	Chilled Water	Electric Resistance

Common Mistakes – HVAC Systems

- Proposed case
  - Not modeled with all system capacity, efficiency, supply airflow, fan power, etc. as designed
  - Heating / cooling not modeled in all conditioned spaces as defined in Section 3.2
  - Conditioned Space
    - Cooled – sensible output capacity > 5 BTU/h-ft²
    - Heated – output capacity ≥ criteria in Table 3.1
    - Indirectly Conditioned – spaced indirectly heated/cooled by adjacent spaces
  - Semi-heated Space – not conditioned and output capacity ≥ 3.4 BTU/h-ft²
  - Unconditioned Space
    - not conditioned or semi-heated
    - Ventilated crawlspaces, attics, parking garages not enclosed

TABLE 3.1 Heated Space Criteria

Heating Output ($Btu/h \cdot ft^2$)	Climate Zone
5	1 and 2
10	3
15	4 and 5
20	6 and 7
25	8

Common Mistakes – HVAC Systems

- Baseline case
  - Heating / cooling not modeled in all conditioned spaces as defined in Section 3.2
  - Fossil fuel and electric heat modeled, but Exception G3.1.1(a) not applicable
  - Systems not modeled as prescribed in Sections G3.1.2 and G3.1.3
  - Semi-heated not modeled with the same heating type, capacity ratios, fan volume, and fan power as Proposed case

Service Hot Water (Table G3.1#11)

- Proposed Case
  - SHW system exists – system type, fuel source, capacity, and efficiency of actual equipment
  - SHW system designed – model system type, fuel source, and efficiency as designed
  - SHW system not designed
    - Buildings with SHW loads - model same system type, fuel source, and efficiency as determined for the Baseline case
    - Buildings without SHW loads – no system modeled

Service Hot Water (Table G3.1#11)

- Baseline Case
  - SHW system exists – system type, fuel source, capacity, and efficiency of actual equipment
  - New SHW system designed – model system type and fuel source as Proposed case with minimum efficiency from Table 7.8
    - Combined SHW and heating systems in Proposed case modeled with separate systems
    - Heat pump water heaters in the Proposed case – electric resistance baseline
  - SHW system not designed
    - Buildings with SHW loads - model with electric resistance with efficiency from Table 7.8
    - Buildings without SHW loads – no system modeled
  - If condenser energy recovery required in Proposed case for SHW (Section 6.5.6.2) model energy recovery even if exceptions apply to Proposed case

Common Mistakes – SHW Systems

- Proposed case
  - Not modeled with all system capacity, fuel source, and efficiency as designed
  - Savings for reduced SHW consumption from water use reduction strategies (WEc3)
    - No calculations provided
    - Calculations use flush and flow fixture water consumption
    - Calculations assume 75% or more of flow fixture water is hot without justification
- Baseline case
  - Different fuel source from Proposed case
  - Combined systems not split

Receptacle and Other (Table G3.1#12)

- Proposed case
  - All anticipated receptacle and process loads modeled
- Baseline case
  - Same as Proposed case, including fractional HP motors
  - Motors with prescribed efficiencies in Section 10 may be modeled with efficiency from Table 10.8

Common Mistakes – Receptacle/Other

- Proposed case
  - All anticipated process loads not modeled
  - Savings for process loads not submitted using exceptional calculations
- Baseline case
  - Process loads
    - Non-process loads (regulated) marked as process
    - Load arbitrarily set to 25% Baseline energy cost
    - No narrative justifying process loads less than LEED default (25%)

Baseline HVAC System Requirements

- Equipment Capacities (Section G3.1.2.2)
  - Cooling oversized by 15%
  - Heating oversized by 25%
  - Unmet load hours
    - Cannot exceed 300 hours (Baseline and Proposed case)
    - Proposed cannot exceed Baseline by more than 50 hours
- Preheat Coils (Section G3.1.2.3)
  - Must be modeled if included in Proposed case
  - Same controls as Proposed case

Baseline HVAC System Requirements

- Fan System Operation (Section G3.1.2.4)
  - Occupied periods – fans run continuously
  - Unoccupied periods – fans cycle to maintain unoccupied setpoints
- Ventilation (Section G3.1.2.5)
  - Minimum rates same as proposed design
  - Exception – Demand control in Proposed case but not required by Section 6.4.3.8(9)
    - Baseline ventilation rates modeled at minimum as calculated for Minimum IAQ Performance (EQp1)
    - Proposed minimums must provide at least minimum area ventilation rate

Baseline HVAC System Requirements

- Economizers (Sections G3.1.2.6 & G3.1.2.7)
  - None required for Residential System Types (1 & 2)
  - Modeled as required by Tables G3.1.2.6
  - Exceptions - Proposed case
    - Systems with gas-phase air cleaning
    - Supermarkets with open case refrigeration

TABLE G3.1.2.6A Minimum Building Conditioned Floor Areas at Which Economizers Are Included for Baseline Systems 3 and 4

Climate Zone	Area Interior	Area Perimeter
1a,1b,2a,3a,4a	N.R.	N.R.
2b,5a,6a,7,8	15,000 ft^2	N.R.
3b,3c,4b,4c,5b,5c,6b	10,000 ft^2	25,000 ft^2

N.R. means that there is no conditioned building floor area for which economizers are included for the type of zone and climate.

TABLE G3.1.2.6B Climate Conditions under which Economizers are Included for Baseline Systems 5 through 8

Climate Zone	Conditions
1a,1b,2a,3a,4a	N.R.
Others	Economizer Included

N.R. means that there is no conditioned building floor area for which economizers are included for the type of zone and climate.

TABLE G3.1.2.6C Economizer High-Limit Shutoff

Climate Zone	High-Limit Shutoff
1b,2b,3b,3c,4b,4c,5b,5c,6b,7,8	75°F
5a,6a,7a	70°F
Others	65°F

Baseline HVAC System Requirements

- Design Airflow Rates (Section G3.1.2.8)
  - Supply airflow based on 20^{o} cooling supply to room air temperature difference
  - Return Fans
    - Only if included in Proposed case
    - Sized for larger: supply airflow less minimum outside air or 90% supply airflow
- Supply Fan Power (Section G3.1.2.9)
  - Calculations determine Baseline total SYSTEM fan power
    - Systems with multiple fans must apportion calculated power among all Baseline system fans (supply, return relief, exhaust)
    - Addendum ac revises fan power calculations
  - Exhaust Fans
    - System fan if operate continuously based on HVAC system schedule in adjacent spaces
    - Process if operate intermittently during occupied periods

TABLE 6.5.3.1.1A Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan System Motor Nameplate hp	Allowable Nameplate Motor hp	$hp \le CFM_S \cdot 0.0011$	$hp \le CFM_S \cdot 0.0015$
Option 2: Fan System bhp	Allowable Fan System bhp	$bhp \le CFM_S \cdot 0.00094 + A$	$bhp \le CFM_S \cdot 0.0013 + A$

[a] where

CFM_S = the maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute
hp = the maximum combined motor nameplate horsepower
bhp = the maximum combined fan brake horsepower
A = sum of $(PD \times CFM_D/4131)$
where
PD = each applicable pressure drop adjustment from Table 6.5.3.1.1B in in. w.c.
CFM_D = the design airflow through each applicable device from Table 6.5.3.1.1B in cubic feet per minute

TABLE 6.5.3.1.1B Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Fully ducted return and/or exhaust air systems	0.5 in. w.c.
Return and/or exhaust airflow control devices	0.5 in. w.c.
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at fan system design condition
Particulate Filtration Credit: MERV 9 through 12	0.5 in. w.c.
Particulate Filtration Credit: MERV 13 through 15	0.9 in. w.c.
Particulate Filtration Credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2× clean filter pressure drop at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition
Heat recovery device	Pressure drop of device at fan system design condition
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design condition
Sound Attenuation Section	0.15 in. w.c.
Deductions	
Fume Hood Exhaust Exception (required if 6.5.3.1.1 Exception [c] is taken)	–1.0 in. w.c.

Baseline HVAC System Requirements

- Exhaust Air Energy Recovery (Section G3.1.2.10)
  - Required in Baseline for systems with supply air > 5,000 cfm AND minimum outside airflow > 70% supply airflow
  - Modeled with 50% recovery effectiveness
  - Must include bypass controls for systems with economizers
  - Exceptions
    - Spaces not cooled and not heated above 60°F
    - Contaminated exhaust systems (fume & kitchen hood)
    - Heating systems – climate zones 1, 2, &3
    - Cooling systems – climate zones 3C, 4C, 5B, 5C, 6B, 7, & 8
    - Largest exhaust source < 75% design outdoor airflow
    - Dehumidification systems when Proposed case does NOT have series-style energy recovery coils

Common Mistakes – General HVAC System Requirements

- Equipment Capacities
  - Baseline systems not oversized
  - Baseline systems oversized at both System and Plant level
  - Unmet load hours exceed limits
- Preheat coils
  - Included in Proposed case, but not Baseline case
  - Fuel switching when exception G3.1.1(a) does not apply

Common Mistakes – General HVAC System Requirements

- Insufficient information provided
  - To verify if demand control ventilation is required and modeled with minimum rates from EQp1
  - Economizer high-limit temperatures
  - To verify if energy recovery is required and modeled with minimum rates from EQp1
- Supply airflow and Fan Power
  - Supply airflow re-calculated with $20^{o}F$ temperature difference in heating mode
  - Same method used for Proposed case fan power
  - Power calculated separately for each fan in system
  - Pressure adjustments applied, but not reported
  - Addendum ac applied, but not reported
  - Power calculated by software, but not verified with manual checks

System Specific Baseline Requirements

- Heat Pumps (System Types 2 & 4)
  - Auxiliary electric heat modeled as second stage of heating
  - Only enabled if outside air temperature < $40^{o}F$

System Specific Baseline Requirements

- Boilers & HW Loop
  - For conditioned floor area over 15,000 ft^2 - 2 equally sized boilers
  - Loop Temperatures: 180 ^oF HWS, 130 ^oF HWR
  - HWS reset based on outside air temperature
  - Pumps
    - Power = 19 W/gpm
    - Primary only with continuous variable flow
    - Conditioned area < 120,000 ft^2 - riding pump curve
    - Conditioned area > 120,000 ft^2 - variable speed drive

System Specific Baseline Requirements

- Chillers & CHW Loop
  - Type & number based on Table G3.1.3.7
  - Loop Temperatures:
    - CHW - 44°F supply, 56°F return
  - CHWS reset based on outside air temperature
  - Pumps
    - Power = 22 W/gpm
    - Separate pump for each chiller
    - Primary/secondary with continuous variable flow
    - Conditioned area < 120,000 ft² - riding pump curve
    - Conditioned area > 120,000 ft² - variable speed drive

System Specific Baseline Requirements

- Cooling Tower & CW Loop
  - Cooling Tower - 2-speed axial fan
  - Loop Temperatures:
    - CWS - 85^{o}F supply or 10^{o}F approach whichever is lower
    - Maintain 70^{o} CWS weather permitting
  - Pumps
    - Power = 19 W/gpm
    - Separate pump for each chiller
  - Interlock controls to operate with chiller(s)

System Specific Baseline Requirements

- Systems 5 through 8
  - Supply air reset - 10°F based on zone demand
  - Changed to 5°F in 90.1-2007
- VAV Minimum Flows:
  - Systems 5 & 7 – 0.4 cfm/ft²
  - Systems 6 & 8
    - Parallel fan power boxes
    - Fans sized for 50% peak supply airflow
    - Fan power = 0.35 W/cfm
    - Minimum position 30% peak supply airflow

New in LEED 2009

- Requires compliance with ASHRAE 90.1-2007
- Minimum Performance Requirements (MPRs)
  - Define the categories of buildings LEED Rating Systems were designed to evaluate
  - Projects must comply with each associated MPR to be eligible for LEED certification
- Prerequisite Energy Performance (EAp2)
  - New Construction – 10%
  - Existing Buildings – 5%

New in LEED 2009

- Optimize Energy Performance (EAc1)
  - 1 – 19 possible points for New Construction and School projects
  - 3 – 21 possible points for Core & Shell projects
- Regional Priority Credits
  - Provide incentive to address geographically specific environmental issues
  - Worth 1 additional point, up to 4 points
  - Credits automatically identified when project is registered based upon zip code
  - Searchable database on USGBC website

Minimum Performance Requirements

- Required characteristics for projects eligible for LEED 2009 Certification
  - Must commit to sharing actual whole project energy and water usage with USGBC/GBCI for at lest 5 years
  - Comply with Environmental Laws
  - Must be complete, permanent building with at least 1 FTE
  - Site boundary and minimum floor and floor area to site area requirements