



Energy Modeling for LEED Using eQUEST

Christian E. Stalberg, Principal
Natural Intelligence, LLC
<http://naturalintelligence.us>



Schedule

day one: Whole Building Energy Performance Simulations, aka 'Energy Modeling' & eQUEST (Quick Energy Simulation Tool)

day two: Complying with ASHRAE 90.1 Appendix G 'Performance Rating Method' for LEED



Learning Objectives

Understand Value Proposition for Whole Building Energy Performance Simulations

Learn how to use eQUEST to model buildings & generate reports, then evaluate output

Understand how to use ASHRAE 90.1 Appendix G 'Performance Rating Method' within eQUEST to satisfy LEED requirements



day one

**Whole Building Energy
Performance Simulations, aka 'Energy
Modeling'
&
eQUEST (Quick Energy Simulation
Tool)**

Building Energy Modeling

What is Building Energy Modeling?

$$t_{a_j} = \frac{a + \sum_{i=1}^N A_i h_{ci} t_{si,j} + \rho c V_{infil_j} t_{o_j} + \rho c V_{vent_j} t_{v_j} + q_{c,int_j}}{-b + \sum_{i=1}^N A_i h_{ci} + \rho c V_{infil_j} + \rho c V_{vent_j}}$$

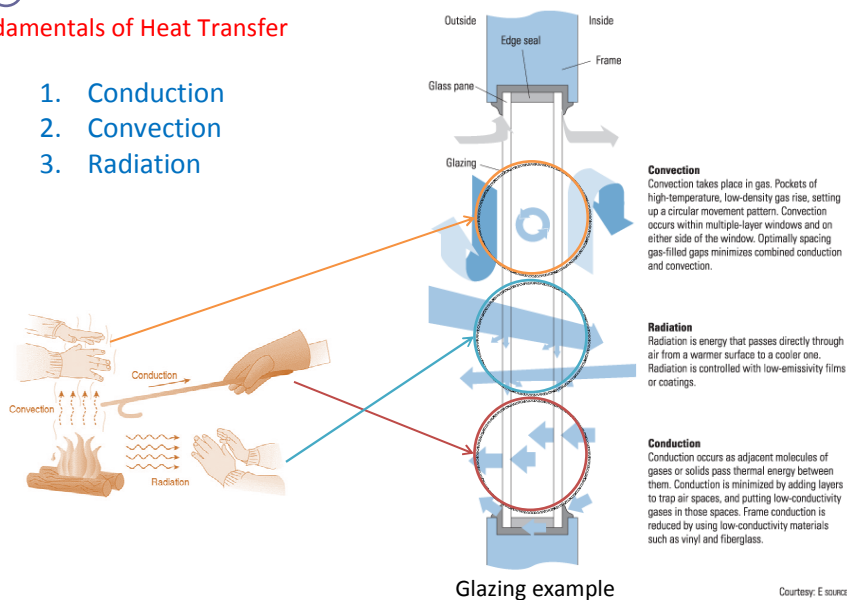
where

- N = number of zone surfaces
- A_i = area of i th surface, ft²
- h_{ci} = convection coefficient for i th surface, Btu/h·ft²·°F
- $t_{si,j}$ = surface temperature for i th surface at time step j , °F
- ρ = density, lb_m/ft³
- c = specific heat of air, Btu/lb_m·°F
- V = volumetric flow rate of air, ft³/h
- t_{o_j} = outdoor air temperature at time step j , °F
- t_{v_j} = ventilation air temperature at time step j , °F
- q_{c,int_j} = sum of convective portions of all internal heat gains at time step j , Btu/h

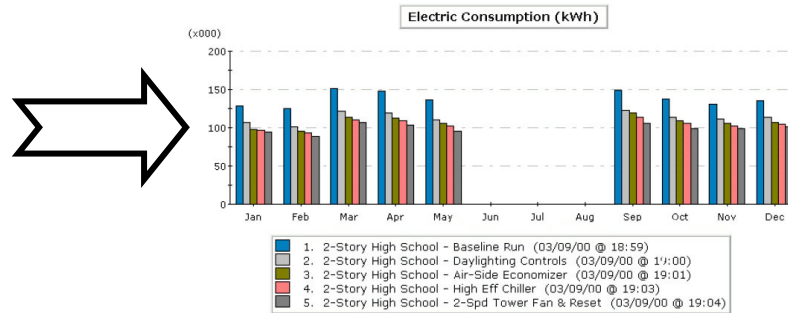
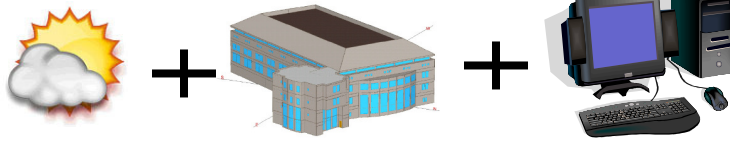
Building Energy Modeling

Fundamentals of Heat Transfer

1. Conduction
2. Convection
3. Radiation



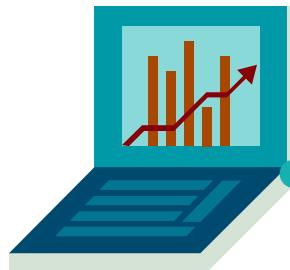
Building Energy Modeling



Building Energy Modeling

What is it?

- First - Heating and Cooling Peak Load Calculation (HCC) program (1967)
 - Calculated hourly peak
 - Gave annual heating-cooling loads (HVAC)
- U.S. DOE web site lists 391 software tools
- DOE-2 introduced in 1979
 - continually improved
 - the 'gold standard'



Building Energy Modeling

How is it done?

- 'Baseline' reflecting a code compliant building
- Additional models then generated
 - HVAC options
 - Glazing
 - Exterior shading
 - Daylighting
- Document both costs and benefits of modified energy design

Building Energy Modeling

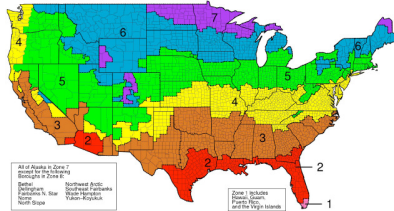
Typical Inputs:

- Building site data (weather data; orientation; adjacent structure shadows, etc.)
- Building envelope data (heat transfer surfaces e.g. walls, floors, roofs, windows, window shades & overhangs)
- Building operations and scheduling (occupancy, thermostat setpoints, daylighting photosensors, HVAC schedules)
- Internal loads (e.g. body heat, lights, equipment)
- HVAC equipment & performance
- Utility rates (electric/gas, peak/off-peak)
- Economic parameters (life-cycle costing, interest rates)

Building Energy Modeling

Fundamentals of Building Energy Simulation

1 Weather Data



BUILDING DESCRIPTION

Location
Design data
Construction data
Thermal zones
Internal loads
Usage profiles
Infiltration

SYSTEM DESCRIPTION

System types and sizes
Supply and return fans
Control and schedules
Outside air requirements

PLANT DESCRIPTION

Equipment types and sizes
Performance characteristics
Auxiliary equipment
Load assignment
Fuel types

ECONOMIC DATA

Economic factors
Project life
First cost
Maintenance cost

WEATHER LIBRARY

Dry-bulb temperature
Wet-bulb temperature
Cloud factor
Wind speed
Pressure

LOADS ANALYSIS

Hourly zone heating and cooling loads

Peak heating and cooling loads

SYSTEMS ANALYSIS

Hourly equipment loads by system

PLANT ANALYSIS

Fuel demand and consumption

ECONOMIC ANALYSIS

Life-cycle cost

Building Energy Modeling

Fundamentals of Building Energy Simulation

2 Building Data

BUILDING DESCRIPTION

Location
Design data
Construction data
Thermal zones
Internal loads
Usage profiles
Infiltration

SYSTEM DESCRIPTION

System types and sizes
Supply and return fans
Control and schedules
Outside air requirements

PLANT DESCRIPTION

Equipment types and sizes
Performance characteristics
Auxiliary equipment
Load assignment
Fuel types

ECONOMIC DATA

Economic factors
Project life
First cost
Maintenance cost

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Dry-bulb temperature
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Fuel demand and consumption

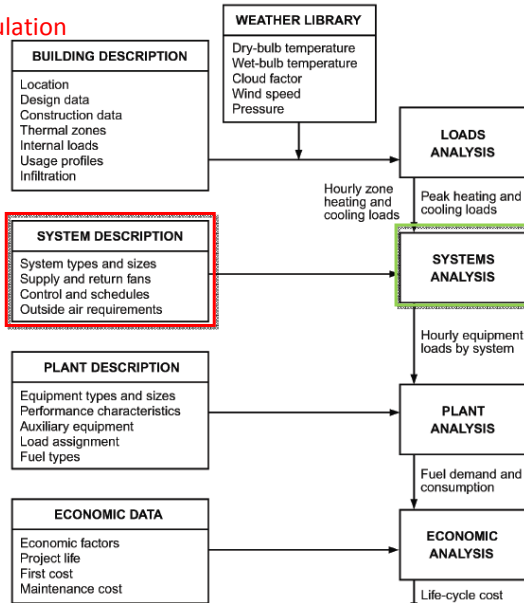
ECONOMIC ANALYSIS

Life-cycle cost

Building Energy Modeling

Fundamentals of Building Energy Simulation

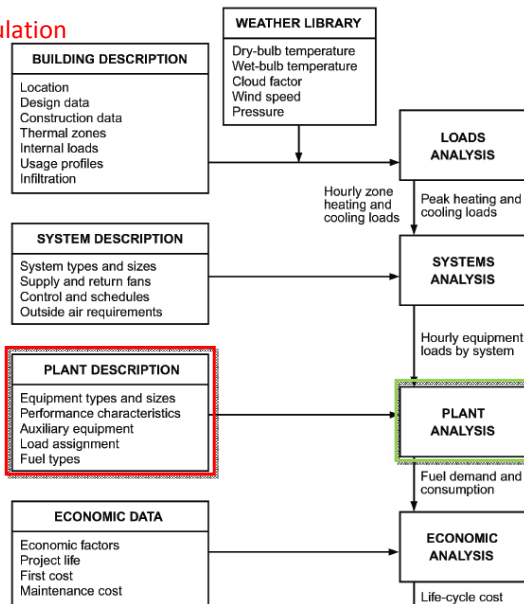
3 Systems Data



Building Energy Modeling

Fundamentals of Building Energy Simulation

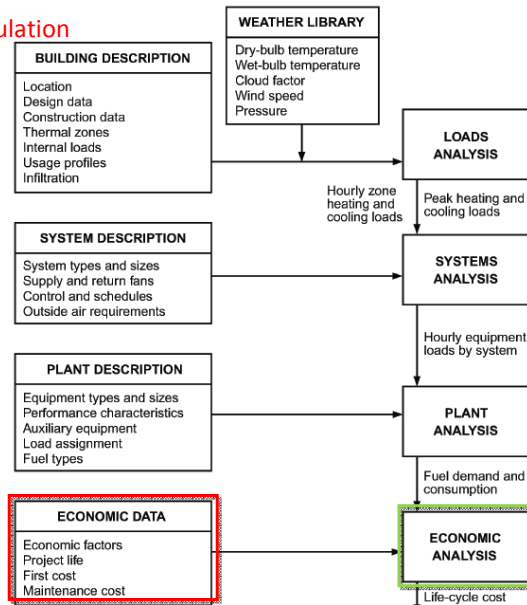
4 Plant Data



Building Energy Modeling

Fundamentals of Building Energy Simulation

5 Economic Data

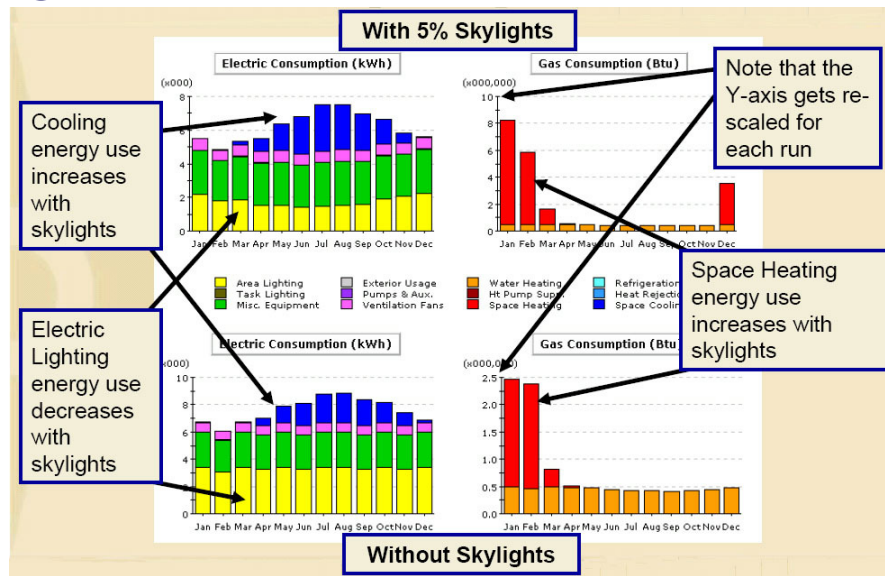


Building Energy Modeling

Typical Outputs:

- Summary of annual projected utility costs and savings
- Performance graphs (e.g., monthly energy use for gas and electric, monthly facility peak kW, etc.) in comparison to the baseline
- Input parameter information (e.g., internal load specifications, building envelope characteristics, HVAC system definitions, etc.)
- Assumptions of building characteristics (e.g., schedules, HVAC set points, etc.)
- Notations of changes from previous models (e.g., changes made between baseline and modeling iterations)
- Interpretation of results
- Software input and output files (electronic)

Building Energy Modeling



Building Energy Modeling

Detailed eQUEST/DOE-2 (SIM) Reports

GB6 DW DOE-2.2-44d3 11/20/2008 13:52:59 EDL RUN 1

REPORT- BEPS Building Energy Performance WEATHER FILE- Raleigh NC TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	581.2	22.5	320.1	8.2	963.7	0.0	16.2	220.7	0.0	0.0	160.0	121.5	2414.1
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	4567.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4567.7
MBTU	581.2	22.5	320.1	4576.0	963.7	0.0	16.2	220.7	0.0	0.0	160.0	121.5	6981.8
TOTAL SITE ENERGY				6981.83 MBTU			123.5 MBTU/SQFT-YR GROSS-AREA			123.5 MBTU/SQFT-YR NET-AREA			
TOTAL SOURCE ENERGY				11809.99 MBTU			209.0 MBTU/SQFT-YR GROSS-AREA			209.0 MBTU/SQFT-YR NET-AREA			
PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE =				52.3									
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED =				0.0									

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

Building Energy Modeling

Detailed eQUEST/DOE-2 (SIM) Reports (contd.)

GB6 DW				DOE-2.2-44d3 11/20/2008 13:52:59 BDL RUN 1									
REPORT- BEPU Building Utility Performance								WEATHER FILE- Raleigh				NC TMY2	
	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL

EM1 ELECTRICITY													
KWH	170285.	6598.	93799.	2411.	282374.	0.	4742.	64658.	0.	0.	46870.	35588.	707324.
FM1 NATURAL-GAS													
THERM	0.	0.	0.	45677.	0.	0.	0.	0.	0.	0.	0.	0.	45677.
TOTAL ELECTRICITY		707324. KWH		12.516 KWH		/SQFT-YR GROSS-AREA			12.516 KWH		/SQFT-YR NET-AREA		
TOTAL NATURAL-GAS		45677. THERM		0.808 THERM		/SQFT-YR GROSS-AREA			0.808 THERM		/SQFT-YR NET-AREA		
PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 52.3													
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.0													
NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.													

Building Energy Modeling

eQUEST Modeling Software Structure

- eQuest contains multiple user interfaces (3) that correspond to the design process
 - Schematic Design wizard
 - Design Development wizard
 - Detailed Interface
- All of these interfaces produce an input text file containing Building Description Language (BDL)
 - DOE2.2 uses this file for the building energy calculations
 - You can work directly in the BDL file ("fourth" user interface)
 - BDL is located in eQuest/project/projectname/projectname.inp ("the inp file")

Building Energy Modeling

eQUEST User Interfaces & Workflow

- Schematic design wizard good for preliminary analyses. Has default values and built-in workflow. Limitation: can only create one building shell
- Design Development wizard can create multiple shells for a single building. Also has default values and built-in workflow.
- Detailed Interface allows for greatest flexibility and while it has default values, there is no workflow.

NOTE:

A 'shell' is any area of a building that shares the same or a similar footprint, HVAC zoning, ceiling height, envelope construction type or HVAC services.

Building Energy Modeling

Important eQuest Rule

- Once you've used a user interface to make a change in the model, you cannot return to a more simple user interface without over-writing those changes, e.g. going from Schematic wizard to Design Development wizard and back.
- In other words, you can go from a simple to more complex interface, but not backwards without losing changes.

Building Energy Modeling

eQUEST Model Input Data Collection

Item	Source	Schematic	Design Development	Construction Documents
Architectural				
building and zone areas	plan sheets	x	x	x
envelope construction materials	wall sections		x	x
surface areas (by orientation)	building elevations	x	x	x
fenestration areas (by orientation)	building elevations	x	x	x
fenestration u-value & SC	window schedule or specifications			x x
Mechanical				
HVAC zoning	HVAC plans		x	x
design flow rates	HVAC plans		x	x
equipment descriptions	equipment schedules or specifications			x x
control sequences	control diagrams or specifications			x x
Electrical				
lighting equipment	lighting layout or lighting schedule		x	x x
Internal Loads				
peak occupancy (by zone)	owner, operator	x	x	x
peak lighting (by zone)	lighting plans		x	x
peak equipment (by zone)	mech or owner		x	x

Building Energy Modeling

eQUEST Model Input Data Collection (contd.)

Item	Source	Schematic	Design Development	Construction Documents
Operations				
per zone:				
occ, lights, equip schedules	owner or operator	x	x	x
thermostat schedules	owner or operator	x	x	x
per terminal system:				
outside air operations	HVAC equip schedule			x
hot & cold deck temperatures	HVAC equip schedule			x
fan schedules	owner or operator	x	x	x
fan kW	HVAC equip schedule		x	x
per primary system:				
lock-out schedules	control sequences			x
Economic				
utility schedules (all fuels)	utility representative	x	x	x
equipment costs	designer or manufacturer		x	x
life-cycle cost parameters	owner	x	x	x

Building Energy Modeling

Using DWG files with eQUEST

- DWG files can be imported into eQUEST for purposes of tracing floor plans and zones
- Individual floors can be imported and/or floor mirror multipliers can be used
- Scaling must be carefully maintained
- Possible to resize after importation, but risky!

Building Energy Modeling

Energy Modeling Prologue

- Energy modeling is complex and difficult
- Energy modeling generates an estimate
- Energy modeling is more of an art than science
- Energy modeling success depends upon the modeler's judgment, i.e. garbage in, garbage out/
Hint: EPAs Target Finder can be your friend
- If you're not an HVAC design engineer, you'll be okay but you can get into deep water real fast (seek out expertise!)

Building Energy Modeling

eQUEST Schematic Design Wizard Exercise

- Find the eQUEST Introductory Tutorial included in your eQUEST version 3.64 install at ~\My Documents\eQUEST 3-64 Data\Tutorials\All\Introductory Tutorial
- Go to page 29 to start exercise
- Skip **Importing DWG Files for Custom Footprints**. We will do this in the next exercise.

Building Energy Modeling

eQUEST Design Development Wizard Exercise

- Download the eQUEST Training Workbook and Examples at <http://doe2.com/download/equest/eQuestTrainingWorkbook.pdf> and http://doe2.com/download/equest/eQuestTrainingWorkbook_Examples.zip
- Go to page 191



day two

Complying with ASHRAE 90.1 Appendix G for LEED

ASHRAE 90.1-2007

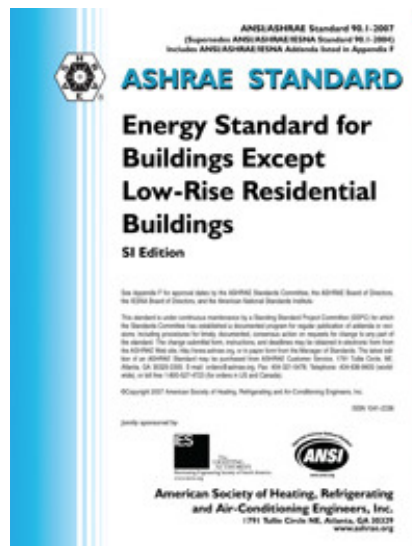
Appendix G – Performance Rating Method

How to comply with LEED Energy & Atmosphere when using eQUEST to satisfy:

- Prerequisite 2 Option 1 - Minimum Energy Performance (required, no points)
- Credit 1 – Optimize Energy Performance (1-19 points)



Complying With ASHRAE Appendix G for LEED



Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

ASHRAE / IESNA 90.1-2007

Energy standard for buildings **EXCEPT** low-rise residential

Purpose

- Establishes minimum requirements for energy-efficient design of buildings, **EXCEPT** low-rise residential buildings.
- Does **NOT** apply to single-family houses, multi-family structures of 3 or fewer levels above grade, manufactured houses (mobile & modular homes) or buildings that do not use either electricity or fossil fuel.

Performance Rating Method (Appendix G)

Provides a method for demonstrating performance beyond ASHRAE / IESNA 90.1-2007 standards.

In all cases, the mandatory provisions must still be met!

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

What are we calculating?

Annual energy cost of BASELINE & PROPOSED building for comparison

Proposed building should meet all Mandatory Provisions!!

In order to compare (baseline vs proposed),

- *Use same computer simulation programs*
- *Use same climate data*
- *Use same purchased energy rates*
- *Use same schedules of operation (except for energy efficiency features)*

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

What to model?

Major Components of ASHRAE 90.1-2007

- Building Envelope
- Heating, Ventilating and Air Conditioning
- Service Water Heating
- Power
- Lighting
- Other Equipment

Complying With Requirements

ASHRAE 90.1-2007 Appendix G

What to model?

Baseline & Proposed Models: Components

- Building Envelope
- Building Orientation
- Space Use Classification
- Schedule of Operation
- Occupancy
- Zoning & Thermal Blocks
- Lighting Systems
- HVAC Systems
- Process Energy
- Service Hot Water Systems
- Energy Rates



Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Exceptions

Building Envelope

Baseline

Model building envelope for baseline design using Table G3.1.5.

Model above-grade walls, roof, and floor assemblies using lightweight assembly types (i.e., steel-framed walls, roofs with insulation entirely above deck, and steel-joint floors). Match values with appropriate assembly maximum U-factors in Tables 5.5-1 through 5.5-8.

Proposed

Building components must be modeled as shown in architectural drawings. Model any exceptions using Table G3.1.5.

Un-insulated assemblies (Less than 5% need not be modeled)
Surface angles (orientation & tilt)



Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Building Envelope

Proposed

Exterior roof surfaces **may be modeled with reflectance 0.45** if the reflectance of the proposed design roof is greater than 0.70 and its emittance is greater than 0.75. All other roof surfaces will be modeled with a reflectance of 0.30.

Manually operated shading devices such as blinds and shades will not be modeled.

Automatically controlled fenestration shades or blinds may be modeled, however permanent shading devices such as fins, overhangs, and light shelves may be modeled.

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Building Envelope

TABLE 5.5-5 Building Envelope Requirements For Climate Zone 5 (A, B, C)*

Opaque Elements	Non Residential		Residential		Semi Heated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.119	R-7.6 c.i.
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.090	R-11.4 c.i.	U-0.080	R-13.3 c.i.	U-0.151 ^a	R-5.7 c.i. ^a
Metal Building	U-0.113	R-13.0	U-0.057	R-13.0 + R-13.0	U-0.123	R-11.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.064	R-13.0 + R-3.8 c.i.	U-0.051	R-13.0 + R-7.5 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-0.119	R-7.5 c.i.	C-0.119	R-7.5 c.i.	C-1.140	NR
Floors						
Mass	U-0.074	R-10.4 c.i.	U-0.064	R-12.5 c.i.	U-0.137	R-4.2 c.i.
Steel-Joist	U-0.038	R-30.0	U-0.038	R-30.0	U-0.052	R-19.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.051	R-19.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.540	R-10 for 24 in.	F-0.730	NR
Heated	F-0.860	R-15 for 24 in.	F-0.860	R-15 for 24 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.500		U-0.700	
Nonswinging	U-0.500		U-0.500		U-1.450	

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Building Envelope

TABLE 5.5-5 Building Envelope Requirements For Climate Zone 5 (A, B, C)*

Fenestration	Non Residential		Residential		Semi Heated	
	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC
Vertical Glazing, % of Wall						
Nonmetal framing (all) ^b	U-0.35		U-0.35		U-1.20	
Metal framing (curtainwall/storefront) ^c	U-0.45	SHGC-0.40 all	U-0.45	SHGC-0.40 all	U-1.20	SHGC-NR all
Metal framing (entrance door) ^c	U-0.80		U-0.80		U-1.20	
Metal framing (all other) ^c	U-0.55		U-0.55		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%-2.0%	U _{all} -1.17	SHGC _{all} -0.49	U _{all} -1.17	SHGC _{all} -0.49	U _{all} -1.98	SHGC _{all} -NR
2.1%-5.0%	U _{all} -1.17	SHGC _{all} -0.39	U _{all} -1.17	SHGC _{all} -0.39	U _{all} -1.98	SHGC _{all} -NR
Skylight with Curb, Plastic, % of Roof						
0%-2.0%	U _{all} -1.10	SHGC _{all} -0.77	U _{all} -1.10	SHGC _{all} -0.77	U _{all} -1.90	SHGC _{all} -NR
2.1%-5.0%	U _{all} -1.10	SHGC _{all} -0.62	U _{all} -1.10	SHGC _{all} -0.62	U _{all} -1.90	SHGC _{all} -NR
Skylight without Curb, All, % of Roof						
0%-2.0%	U _{all} -0.69	SHGC _{all} -0.49	U _{all} -0.69	SHGC _{all} -0.49	U _{all} -1.36	SHGC _{all} -NR
2.1%-5.0%	U _{all} -0.69	SHGC _{all} -0.39	U _{all} -0.69	SHGC _{all} -0.39	U _{all} -1.36	SHGC _{all} -NR

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Building Envelope

TABLE 5.5-5 Building Envelope Requirements For Climate Zone 5 (A, B, C)*

	Non Residential		Residential		Semi Heated	
<i>Skylight with Curb, Glass, % of Roof</i>						
0%-2.0%	$U_{all}=1.17$	$SHGC_{all}=0.49$	$U_{all}=1.17$	$SHGC_{all}=0.49$	$U_{all}=1.98$	$SHGC_{all}=NR$
2.1%-5.0%	$U_{all}=1.17$	$SHGC_{all}=0.39$	$U_{all}=1.17$	$SHGC_{all}=0.39$	$U_{all}=1.98$	$SHGC_{all}=NR$
<i>Skylight with Curb, Plastic, % of Roof</i>						
0%-2.0%	$U_{all}=1.10$	$SHGC_{all}=0.77$	$U_{all}=1.10$	$SHGC_{all}=0.77$	$U_{all}=1.90$	$SHGC_{all}=NR$
2.1%-5.0%	$U_{all}=1.10$	$SHGC_{all}=0.62$	$U_{all}=1.10$	$SHGC_{all}=0.62$	$U_{all}=1.90$	$SHGC_{all}=NR$
<i>Skylight without Curb, All, % of Roof</i>						
0%-2.0%	$U_{all}=0.69$	$SHGC_{all}=0.49$	$U_{all}=0.69$	$SHGC_{all}=0.49$	$U_{all}=1.36$	$SHGC_{all}=NR$
2.1%-5.0%	$U_{all}=0.69$	$SHGC_{all}=0.39$	$U_{all}=0.69$	$SHGC_{all}=0.39$	$U_{all}=1.36$	$SHGC_{all}=NR$

Skylight area equal to proposed or 5% of gross roof area (whichever is smaller).

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Fenestration

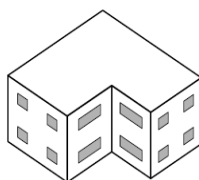
Building Envelope

Baseline

Match percentage of vertical fenestration in baseline and proposed designs, or use 40% of gross wall area, whichever is less. Distribute windows on each face of building in same proportion as in proposed design. Fenestration U-factor must match appropriate requirements in Tables 5.5-1 through 5.5-8.

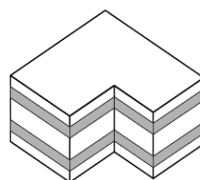
Proposed

Model fenestration location and its properties (U-value, solar heat gain coefficient, and transmittance) as shown on architectural drawings.



Window Area
From Plans

Proposed Building



Equal Glass Area
Distributed As
Horizontal Blinds

Baseline Building
Maximum 40%

(distributed on each face)

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Shading Projections

Building Envelope

Baseline

Proposed

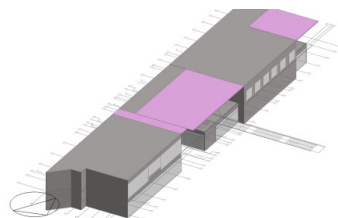
Use fixed vertical glazing in baseline design, flush to exterior wall with no shading projections.

Do not model manually controlled interior shading devices, such as blinds or curtains, in baseline design.

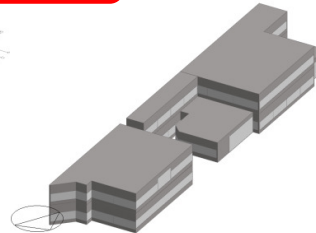
Shading projections in proposed design, which reduce solar gains on glazing, can also be modeled to demonstrate energy savings compared with baseline.

Manually controlled interior shading devices such as blinds and curtains should not be modeled.

Automatically controlled interior shading devices can be modeled, as per Appendix G.



As-Is (designed)



Baseline

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Rotations

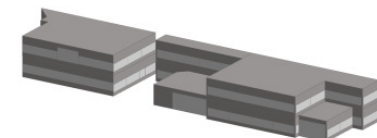
Orientation

Baseline

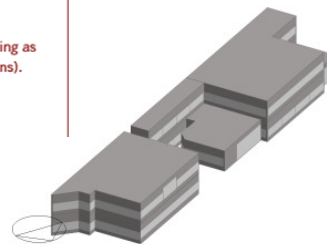
Proposed

4 baseline design simulations are required for generating baseline building performance. Models are identical except that building orientation for each model is modified as described in Table G3.5.1(a), and window solar heat gain coefficients are revised to reflect minimum ASHRAE building envelope requirements for revised building orientation.

Proposed design models building as designed (with minor exceptions).



0d Rotation
(Actual Orientation)



90d Rotation.....

180d Rotation.....

270d Rotation.....

AVERAGE RESULTS

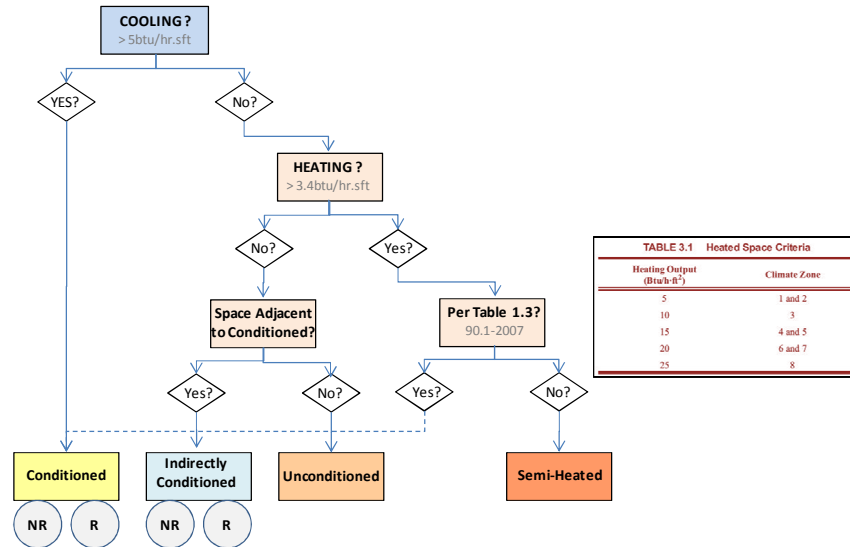
No Self Shading for base building!

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Space Use Classification

ASHRAE 90.1 Space Classification



Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Schedule of Operation

Operating Hours

Baseline	Proposed
Same as proposed design. Exception: Schedules may differ from proposed design if proposed design is implementing some nonstandard efficiency measures.	Use actual operating hours for schedule of operation in proposed design. Exception: Schedules can be modified if schedule changes are necessary to model nonstandard efficiency measures such as lighting controls, natural ventilation, demand control ventilation, or service water heating load reductions (Table G3.1.4). Describe any schedule of operation differences between baseline building model and proposed building.

Schedules should be capable of modeling,

Occupancy

Lighting Power

Misc Equipment Power

Thermostat Setpoints

HVAC System Operation

Use accurate schedule (from client)

Alternatively, use California Nonresidential ACM Approval Manual

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Operating Hours

Schedule of Operation

Baseline

Proposed

Same as proposed design.

Exception: Schedules may differ from proposed design if proposed design is implementing some nonstandard efficiency measures.

Use actual operating hours for schedule of operation in proposed design.

Exception: Schedules can be modified if schedule changes are necessary to model nonstandard efficiency measures such as lighting controls, natural ventilation, demand control ventilation, or service water heating load reductions (Table G3.1.4).

Describe any schedule of operation differences between baseline building model and proposed building.

For proposed, NON-STANDARD Schedules possible,

Lighting Controls

Natural Ventilation

Demand Control Ventilation

Etc...

But, need to provide extensive documentation!!!

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Occupancy

Schedule of Operation

California Nonresidential Alternative Calculation Method (ACM) Manual

Table N2-4 Schedule Types of Occupancies and Sub-Occupancies

Occupancy or Sub-Occupancy Type	Schedule
Atrium	Table 2-5 Nonresidential
Auditorium	Table 2-5 Nonresidential
Auto Repair	Table 2-5 Nonresidential
Bar, Cocktail Lounge and Casino	Table 2-5 Nonresidential
Barber and Beauty Shop	Table 2-5 Nonresidential
Classrooms, Lecture, Training, Vocational Room	Table 2-5 Nonresidential
Civic Meeting Space	Table 2-5 Nonresidential
Commercial and Industrial Storage	Table 2-5 Nonresidential
Convention, Conference, Multipurpose, and Meeting Centers	Table 2-5 Nonresidential
Corridors, Restrooms, Stairs, and Support Areas	Table 2-5 Nonresidential
Dining	Table 2-5 Nonresidential
Electrical, Mechanical Room	Table 2-5 Nonresidential
Exercise Center, Gymnasium	Table 2-5 Nonresidential
Exhibit, Museum	Table 2-5 Nonresidential
Financial Transaction	Table 2-5 Nonresidential

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Occupancy

Schedule of Operation

California Nonresidential Alternative Calculation Method (ACM) Manual

Table N2-5 Nonresidential Occupancy Schedules (Other than Retail)

		Hour																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heating (°F)	WD	60	60	60	60	60	65	65	70	70	70	70	70	70	70	70	70	70	70	65	60	60	60	60	60
	Sat	60	60	60	60	60	65	65	65	65	65	65	65	65	65	65	65	60	60	60	60	60	60	60	60
	Sun	60	60	60	60	60	65	65	65	65	65	65	65	65	65	65	65	60	60	60	60	60	60	60	60
Cooling (°F)	WD	77	77	77	77	77	73	73	73	73	73	73	73	73	73	73	73	73	73	77	77	77	77	77	77
	Sat	77	77	77	77	77	73	73	73	73	73	73	73	73	73	73	73	73	73	77	77	77	77	77	77
	Sun	77	77	77	77	77	73	73	73	73	73	73	73	73	73	73	73	73	73	77	77	77	77	77	77
Lights (%)	WD	5	5	5	5	10	20	40	70	80	85	85	85	85	85	85	85	85	80	35	10	10	10	10	10
	Sat	5	5	5	5	5	10	15	25	25	25	25	25	25	25	20	20	20	15	10	10	10	10	10	10
	Sun	5	5	5	5	5	10	10	15	15	15	15	15	15	15	15	15	15	15	10	10	5	5	5	5
Equipment (%)	WD	15	15	15	15	15	20	35	60	70	70	70	70	70	70	70	70	65	45	30	20	20	15	15	15
	Sat	15	15	15	15	15	15	15	20	25	25	25	25	25	25	20	20	20	15	15	15	15	15	15	15
	Sun	15	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	15	15	15	15	15	15	15
Fans	WD	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off	off	off	off	off
	Sat	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	off	off	off	off	off	off	off	off	off
	Sun	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Occupancy

Schedule of Operation

California Nonresidential Alternative Calculation Method (ACM) Manual

Table N2-5 Nonresidential Occupancy Schedules (Other than Retail)

		Hour																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Infiltration (%)	WD	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100
	Sat	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100
	Sun	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
People	WD	0	0	0	0	5	10	25	65	65	65	65	60	60	65	65	65	65	40	25	10	5	5	5	0
	Sat	0	0	0	0	0	0	5	15	15	15	15	15	15	15	15	15	15	5	5	5	0	0	0	0
	Sun	0	0	0	0	0	0	0	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	0
Hot Water (%)	WD	0	0	0	0	10	10	50	50	50	50	70	90	90	80	50	70	50	50	50	10	10	10	10	0
	Sat	0	0	0	0	0	0	10	20	20	20	20	20	20	20	20	20	20	10	10	10	0	0	0	0
	Sun	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	0	0	0	0

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Occupancy

Baseline

Same as proposed design.

Use actual occupancy information (from client)

Use ASHRAE 90.1-2007 Table G-B

(Still not available? then try California Title 24 / California Nonresidential ACM Approval Manual; Table N2-2 & N2-3: Occupancy Assumptions)

Proposed

Use occupancy information from project information

Table G-B—Acceptable Occupant Densities, Receptacle Po

Building Type	Occupancy Density ^a Sq.Ft./Person (Btu/h · ft ²)
Assembly	50 (4.60)
Health/Institutional	200 (1.15)
Hotel/Motel	250 (0.92)
Light Manufacturing	750 (0.31)
Office	275 (0.84)
Parking Garage	NA
Restaurant	100 (2.30)
Retail	300 (0.77)
School	75 (3.07)
Warehouse	15,000 (0.02)

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Occupancy

Table N2-2

Occupancy Assumptions When Lighting Plans Are Submitted for the Entire Building or When Lighting Compliance Is not Performed

Occupancy Type	# People per 1000 ft ² (1)	Sensible Heat per Person (2)	Latent Heat per Person (2)	Receptacle Load W/ft ² (3)	Hot Water Btu/h per Person	Lighting W/ft ² (4)	Ventilation CFM/ft ² (5)
Auditoriums (8)	143	245	105	1.0	80	1.5	1.07
Convention Centers (8)	136	245	112	0.96	57	1.3	1.02
Financial Institutions	10	250	260	1.5	120	1.1	0.15
General Commercial and Industrial Work Buildings, High Bay	7	375	625	1.0	120	1.1	0.15
General Commercial and Industrial Work Buildings, Low Bay	7	375	625	1.0	120	1.0	0.15
Grocery Stores (8)	29	252	225	0.91	113	1.5	0.22
Hotel (8)	20	250	200	0.5	80	1.4	0.15
Industrial and Commercial Storage Buildings	5	288	403	0.43	108	0.7	0.15
Medical Buildings and Clinics	10	250	213	1.18	110	1.1	0.15
Office Buildings	10	250	208	1.34	108	1.1	0.15
Religious Facilities (8)	136	245	112	0.96	57	1.6	1.03
Restaurants (8)	45	274	334	0.79	386	1.2	0.38
Retail and Wholesale Stores (8)	29	252	224	0.94	116	1.5	0.22
Schools (8)	40	246	171	1.0	108	1.2	0.32
Theaters (8)	130	268	403	0.54	80	1.3	0.98
All Others	10	250	200	1.0	120	0.6	0.15

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Occupancy

Table N2-3 Area Occupancy Assumptions When Lighting Plans are Submitted for Portions or for the Entire Building or When Lighting Compliance is not Performed

Sub-Occupancy Type (1)	People per 1000 ft ² (2)	Sensible Heat per Person (3)	Latent Heat per Person (3)	Receptacle Load W/ft ² (4)	Hot Water Btu/h per Person	Lighting W/ft ² (5)	Ventilation CFM/ft ² (6)
Auditorium (10)	143	245	105	1.0	80	1.5	1.07
Auto Repair	10	275	475	1.0	120	1.1	1.50
Bar, Cocktail Lounge and Casino (10)	67	275	275	1.0	120	1.1	0.50
Barber and Beauty Shop	10	260	200	2.0	120	1.0	0.40
Classrooms, Lecture, Training, Vocational Room	50	245	155	1.0	120	1.2	0.38
Civic Meeting Space (10)	25	260	200	1.5	120	1.3	0.19
Commercial and Industrial Storage	3	275	475	0.2	120	0.6	0.15
Convention, Conference, Multi-purpose and Meeting Centers (10)	67	245	155	1.0	80	1.4	0.50
Corridors, Restrooms, Stairs, and Support Areas	10	260	250	0.2	0	0.6	0.15
Dining (10)	67	275	275	0.5	385	1.1	0.50
Electrical, Mechanical Room	3	260	250	0.2	0	0.7	0.15
Exercise, Center, Gymnasium	20	265	875	0.5	120	1.0	0.15
Exhibit, Museum (10)	67	260	250	1.5	80	2.0	0.50
Financial Transaction	10	260	250	1.5	120	1.2	0.15
Dry Cleaning (Coin Operated)	10	260	250	3.0	120	0.9	0.30
Dry Cleaning (Full Service Commercial)	10	260	250	3.0	120	0.9	0.45
General Commercial and Industrial Work, High Bay	10	275	475	1.0	120	1.1	0.15
General Commercial and Industrial Work, Low Bay	10	275	475	1.0	120	1.0	0.15

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Thermal Zoning

Thermal Block

HVAC Zone

Already designed (physically determined by HVAC system)

Thermal Block

Similar loads, systems → combined into a single block for modeling purposes

HVAC zones to Thermal Blocks (Conditions; all should be met)

1. Same space use classification (load & schedule)
2. For exterior, glazing should be in same orientation (within 45 deg)
3. All HVAC zones in a thermal block must be served by same HVAC system or same kind of HVAC system

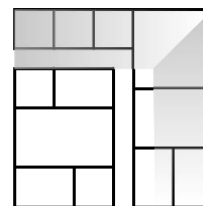
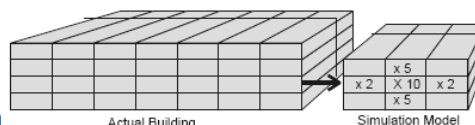


Figure G-E—Thermal Zoning in Building Simulation When the HVAC Zones Are Not Yet Designed



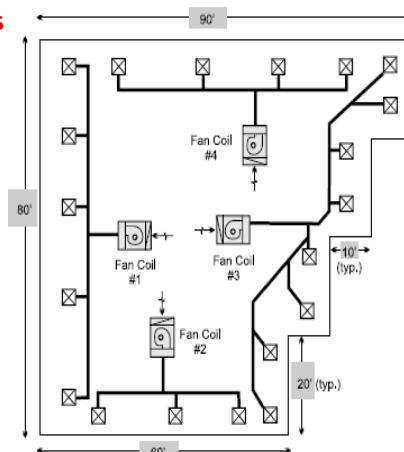
Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Thermal Block

Converting HVAC zones to Thermal Blocks (Conditions; all should be met)

1. Same space use classification (load & schedule)
2. For exterior, glazing should be in same orientation (within 45 deg)
3. All HVAC zones in a thermal block must be served by same HVAC system or same kind of HVAC system



Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Lighting Systems

Baseline

Model lighting using building area (9.5) or space-by-space (9.6) method depending on proposed design categorization.

The baseline design model should also include exterior lighting power allowance (9.4.5).

Proposed

Model proposed design with installed lighting power density for each thermal block and account for all installed lighting on site including interior ambient and task lighting, parking garage lighting, and exterior lighting.

Interior Lighting Power Allowance Calculation

Building Area Method Space by Space Method

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type ^a	LPD (W/ft ²)
Automotive facility	0.9
Convention center	1.2
Courthouse	1.2
Dining: bar lounge/leisure	1.3
Dining: cafeteria/fast food	1.4
Dining: family	1.6
Dormitory	1.0
Exercise center	1.0
Gymnasium	1.1
Health-care clinic	1.0
Hospital	1.2

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Lighting Systems

Interior Lighting Power Allowance Calculation

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method

Common Space Types ^a	LPD, W/ft ²	Building-Specific Space Types	LPD, W/ft ²
Office—Enclosed	1.1	Gymnasium/Exercise Center	
Office—Open Plan	1.1	Playing Area	1.4
Conference/Meeting/Multipurpose	1.3	Exercise Area	0.9
Classroom/Lecture/Training	1.4	Courthouse/Police Station/Penitentiary	
For Penitentiary	1.3	Courtroom	1.9
Lobby	1.3	Confinement Cells	0.9
For Hotel	1.1	Judges' Chambers	1.3
For Performing Arts Theater	3.3	Fire Stations	
For Motion Picture Theater	1.1	Engine Room	0.8
Audience/Seating Area	0.9	Sleeping Quarters	0.3
For Gymnasium	0.4	Post Office—Sorting Area	1.2
For Exercise Center	0.3	Convention Center—Exhibit Space	1.3
For Convention Center	0.7	Library	
For Penitentiary	0.7	Card File and Cataloging	1.1
For Religious Buildings	1.7	Stacks	1.7
For Sports Arena	0.4	Reading Area	1.2
For Performing Arts Theater	2.6	Hospital	
For Motion Picture Theater	1.2	Emergency	2.7
For Transportation	0.5	Recovery	0.8

Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Lighting Systems

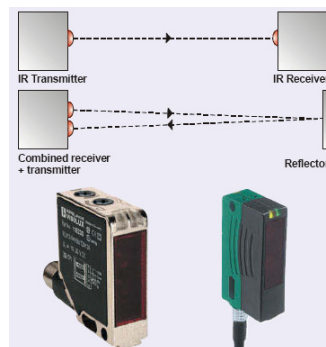
Interior Lighting Power Automatic Lighting Controls

Baseline

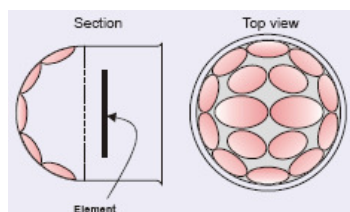
Proposed

Do not take credit for automatic lighting controls such as daylight controls, occupancy controls, or programmable controls.

Model any daylight responsive lighting control systems directly in proposed design energy simulation. Credit can also be taken for occupant sensor lighting controls (Table G3.1, No. 6) in spaces where they are not mandatory; however, note that such controls are mandatory per Section 9.4.1.2 in classrooms, conference rooms and employee lunch and break rooms.



Beam Detectors



Passive (IR) Detectors



Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

Lighting Systems

Interior Lighting Power
Automatic Lighting Controls

TABLE G3.2 Power Adjustment Percentages for Automatic Lighting Controls

Automatic Control Device(s)	Non-24-h and ≤5000 ft 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 5000 ft² condition pertains to the total conditioned floor area of the building.



Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

HVAC Systems

Cooling & Heating
System

Baseline

Determine HVAC system type using actual building area, usage, quantity of floors, occupancy (residential or nonresidential), and heating fuel source per Tables G3.1.1A and G3.1.1B.
As per G3.1.1, use same baseline HVAC system type for entire building except for, areas where occupancy, process loads or schedules differ significantly from rest of building or areas with varying pressurization, cross-contamination requirements

Proposed

Proposed design HVAC system type, quantities, should reflect actual design parameters except in cases where either heating system or cooling system has not been specified.

If no cooling system has been specified, proposed design must include cooling system modeled identically to baseline design cooling system.

If no heating system has been specified, proposed design should assume electric heating. For areas of project without heating or cooling systems (such as parking garages), there is no need to model heating or cooling systems in either proposed or baseline designs.

If no cooling system is specified in proposed, include similar to baseline

If no heating system is specified in proposed, include electric heating



Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

HVAC Systems

HVAC System Type

Baseline

Determine HVAC system type using actual building area, usage, quantity of floors, occupancy (residential or nonresidential), and heating fuel source per Tables G3.1.1A and G3.1.1B.

As per G3.1.1, use same baseline HVAC system type for entire building except for, areas where occupancy, process loads or schedules differ significantly from rest of building or areas with varying pressurization, cross-contamination requirements

Proposed

Proposed design HVAC system type, quantities, should reflect actual design parameters except in cases where either heating system or cooling system has not been specified.

If no cooling system has been specified, proposed design must include cooling system modeled identically to baseline design cooling system.

If no heating system has been specified, proposed design should assume electric heating. For areas of project without heating or cooling systems (such as parking garages), there is no need to model heating or cooling systems in either proposed or baseline designs.

Based on building type (usage), area & heating fuel source



Complying With ASHRAE Appendix G for LEED

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HVAC Systems

HVAC System Type

TABLE G3.1.1A Baseline HVAC System Types

Building Type	Fossil Fuel, Fossil/Electric Hybrid, and Purchased Heat	Electric and Other
Residential	System 1—PTAC	System 2—PTHP
Nonresidential and 3 Floors or Less and <25,000 ft ²	System 3—PSZ-AC	System 4—PSZ-HP
Nonresidential and 4 or 5 Floors and <25,000 ft ² or 5 Floors or Less and 25,000 ft ² to 150,000 ft ²	System 5—Packaged VAV with Reheat	System 6—Packaged VAV with PFP Boxes
Nonresidential and More than 5 Floors or >150,000 ft ²	System 7—VAV with Reheat	System 8—VAV with 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.

For laboratory spaces with a minimum of 5000 cfm of exhaust, use system type 5 or 7 and reduce the exhaust and makeup air volume to 50% of design values during unoccupied periods. For all-electric buildings, the heating shall be electric resistance.

PTAC - Packaged Terminal A/C

PTHP - Packaged Terminal Heat Pump

PSZ-AC - Packaged Single Zone A/C

PSZ-HP - Packaged Terminal Heat Pump

VAV - Variable Air Volume

PFP - Parallel Fan Powered



Complying With ASHRAE Appendix G for LEED

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HVAC System Type

HVAC Systems

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 with Reheat	Packaged rooftop VAV with reheat	VAV	Direct expansion	Hot-water fossil fuel boiler
6. Packaged VAV with PFP Boxes	Packaged rooftop VAV with reheat	VAV	Direct expansion	Electric resistance
7. VAV with Reheat	Packaged rooftop VAV with reheat	VAV	Chilled water	Hot-water fossil fuel boiler
8. VAV with PFP Boxes	VAV with reheat	VAV	Chilled water	Electric resistance



Complying With ASHRAE Appendix G for LEED

ASHRAE 90.1-2007 Appendix G

HVAC System Type
(Combined Chart)

HVAC Systems

		Nonresidential			
		Residential	Less than 3 floors or less than 75,000 ft²	4 or 5 floors or less than 75,000 ft² or 5 floors or less and 75,000–150,000 ft²	More than 5 floors or more than 150,000 ft²
Heating Source	Number/Code	1—PTAC	3—PSZ-AC	5—PVAV w/ Reheat	7—VAV w/ Reheat
Fossil Fuel, Fossil/Electric Hybrid & Purchased Heat	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
Electric and Other	Number/Code	2—PTHP	4—PSZ-HP	6—PVAV w/ PFP Boxes	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

Complying With ASHRAE Appendix G for LEED

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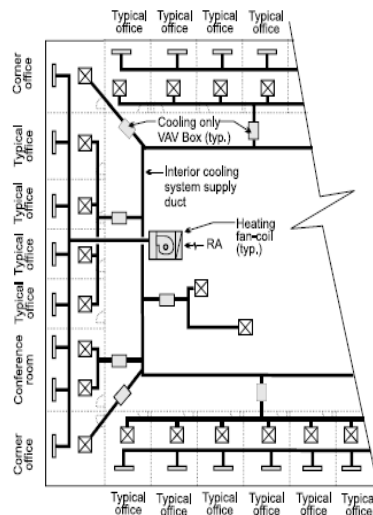
HVAC Systems

For systems 1,2,3 & 4
Each Thermal Block shall be modeled with its own HVAC system

For systems 5,6,7 & 8
Each floor shall be modeled with a separate HVAC system.

Floor with identical thermal blocks can be grouped together.

HVAC System Type Thermal Blocks



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HVAC Systems

Baseline	Proposed
HVAC equipment capacities for baseline system should be oversized 15% for cooling, and 25% for heating (G3.1.2.2 and G3.1.2.2.1).	Proposed design HVAC system should reflect actual design capacities and system efficiencies.
Unmet load hours (occupied periods where any zone is outside its temperature setpoints) may not be exceeded by more than 300 hours. Also, unmet load hours for proposed design may not exceed unmet load hours for baseline design by more than 50 (G3.1.2.2).	Same as baseline case.
Outdoor ventilation rates should be identical to proposed case.	Proposed design should reflect actual outdoor ventilation rates.

HVAC System Type Unmet Hours

Oversize Ratios

Heating 25%
Cooling 15%

Unmet Hours

Total 300 hrs
Difference 50 hrs

Outdoor Ventilation Rates

Same (Prop & Baseline)

**Minimum Ventilation
Per ASHRAE 62.1-2007**

(People, area, space type)



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HVAC Fans

HVAC Systems

Baseline

Operate fan continuously when spaces are occupied and cycle it during unoccupied hours. Except for spaces that have mandated minimum ventilation requirements, fan must remain on during occupied hours for health and safety reasons (G3.1.2.4).

Baseline system fan supply air volume should be based on a supply-air-to-room-air temperature difference of 20°F or required ventilation or makeup air, whichever is greater (G3.1.2.8).

Proposed

The proposed HVAC design should reflect actual fan operation, fan supply rate and fan motor horse power.

AHU TAG	MANUFACTURER & MODEL	TOTAL MBH	SENSIBLE MBH	TOTAL CFM
AHU-1	SONYO DHX4852	47.8	54.6	1272
AHU-2	SANYO UHX2452	25.0	27.0	632
CCU-1-3,12,15 &18	SANYO AHX1252	12.0	14.0	342
CCU-4-11,13,14,16 &17	SANYO AHX0752	7.5	8.5	282
WMU-1	SANYO KHX0952	9.6	11	353
WMU-2,3,4	SANYO KHX0752	7.5	8.5	353
WMU-5	SANYO KHX1252	12.0	14.0	353

GENERAL DATA	A/C UNIT TAG	RTU-1
	AREA SERVED	ALL AREAS
	MANUFACTURER/ MODEL	YORK/JJ048
	EER(SEER)/PLV	11.0/13.0
	REF./LBS.	R410A/12.0
	OPERATING WEIGHT LBS.	1000
	DIMENSIONS L x W x H (IN.)	83X45X33
	UNIT AIRFLOW DESIGN	DOWNFLOW
	SYSTEM CONTROL	THERMOSTAT & HUMIDISTAT
	AIR SYSTEM TYPE	CONSTANT VOLUME
COOLING SECTION	FILTER TYPE/EFF.	2" PLEATED / 30%
	NOMINAL TONNAGE/STAGES	4/1
	TOTAL COOLING CAP. MBH.	48.46
	TOTAL SENSIBLE CAP. MBH.	25.02
	E.A.T. D.B./W.B. °F (COIL)	81.47/69.88
	L.A.T. D.B./W.B. °F (COIL)	58.4/54.8
	L.A.T. D.B./W.B. °F (UNIT)	—
	SUPPLY AIR CFM	1000
	OUTSIDE AIR CFM	1000
	SUPPLY FAN E.S.P. (IN. W.G.)	0.6
	COIL ROWS/PPF	3/13



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HVAC Fans

HVAC Systems

Baseline

Operate fan continuously when spaces are occupied and cycle it during unoccupied hours. Except for spaces that have mandated minimum ventilation requirements, fan must remain on during occupied hours for health and safety reasons (G3.1.2.4).

Baseline system fan supply air volume should be based on a supply-air-to-room-air temperature difference of 20°F or required ventilation or makeup air, whichever is greater (G3.1.2.8).

Proposed

The proposed HVAC design should reflect actual fan operation, fan supply rate and fan motor horse power.

Fan System Operation

Supply & return fans → Operate continuously whenever spaces are **OCCUPIED**, and shall be cycled to meet heating & cooling loads during **UN-OCCUPIED** hours.

Supply, return and/or exhaust fans will remain ON (at all times) in spaces that have health & safety mandated min ventilation.



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HVAC Fans

HVAC Systems

Baseline

Operate fan continuously when spaces are occupied and cycle it during unoccupied hours. Except for spaces that have mandated minimum ventilation requirements, fan must remain on during occupied hours for health and safety reasons (G3.1.2.4).

Baseline system fan supply air volume should be based on a supply-air-to-room-air temperature difference of 20°F or required ventilation or makeup air, whichever is greater (G3.1.2.8).

Proposed

The proposed HVAC design should reflect actual fan operation, fan supply rate and fan motor horse power.

Design Airflow Rates for baseline:

Option 1: Supply-air-TO-Room-air temperature difference → 20deg F

Option 2: Required Ventilation Air

Option 3: Makeup Air

Whichever is greater!



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HVAC Fans

HVAC Systems

Baseline

Use this supply air volume to calculate total fan power for baseline system design (G3.1.2.9). This value reflects sum of power modeled for supply, exhaust, return, and relief fans.

Proposed

G3.1.2.9 System 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:

For Systems 1 and 2,

$$P_{fan} = CFM_S \cdot 0.3$$

For systems 3 through 8,

$$P_{fan} = bhp \times 746 / \text{Fan Motor Efficiency}$$

where

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

bhp = brake horsepower of *baseline* fan motor from Table G3.1.2.9

Fan Motor Efficiency = the efficiency from Table 10.8 for the next motor size greater than the bhp using the enclosed motor at 1800 rpm.

CFM_S = the baseline system maximum design supply fan airflow rate in cfm



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HVAC Systems

Fan Motor Efficiency

"next HP"

TABLE 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motors^a

Number of Poles ⇒	Minimum Nominal Full-Load Efficiency (%)					
	Open Motors			Enclosed Motor		
Synchronous Speed (RPM) ⇒	2	4	6	2	4	6
Motor Horsepower	3600	1800	1200	3600	1800	1200
1	—	82.5	80.0	75.5	82.5	80.0
1.5	82.5	84.0	84.0	82.5	84.0	85.5
2	84.0	84.0	85.5	84.0	84.0	86.5
3	84.0	86.5	86.5	85.5	87.5	87.5
5	85.5	87.5	87.5	87.5	87.5	87.5
7.5	87.5	88.5	88.5	88.5	89.5	89.5
10	88.5	89.5	90.2	89.5	89.5	89.5
15	89.5	91.0	90.2	90.2	91.0	90.2
20	90.2	91.0	91.0	90.2	91.0	90.2
25	91.0	91.7	91.7	91.0	92.4	91.7
30	91.0	92.4	92.4	91.0	92.4	91.7
40	91.7	93.0	93.0	91.7	93.0	93.0
50	92.4	93.0	93.0	92.4	93.0	93.0
60	93.0	93.6	93.6	93.0	93.6	93.6
75	93.0	94.1	93.6	93.0	94.1	93.6
100	93.0	94.1	94.1	93.6	94.5	94.1
125	93.6	94.5	94.1	94.5	94.5	94.1
150	93.6	95.0	94.5	94.5	95.0	95.0
200	94.5	95.0	94.5	95.0	95.0	95.0

^a Nominal efficiencies shall be established in accordance with NEMA Standard MG1. Design A and Design B are National Electric Manufacturers Association (NEMA) design class designations for fixed-frequency small and medium AC squirrel-cage induction motors.



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HVAC Systems

Fan Power Limitation ("A")

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	$hp \leq CFM_S \cdot 0.0011$	$hp \leq CFM_S \cdot 0.0015$
Option 2: Fan System bhp	Allowable Fan System bhp	$bhp \leq CFM_S \cdot 0.00094 + A$	$bhp \leq CFM_S \cdot 0.0013 + A$

^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 6.5.3.1.1.B in in. w.c.

CFM_D = the design airflow through each applicable device from Table 6.5.3.1.1.B in cubic feet per minute



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Fan Power Limitation ("A")

HVAC Systems

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.



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HVAC Systems

Baseline

Model economizers and exhaust air energy recovery systems in baseline HVAC systems when required for given climate zone and system parameters (G3.1.2.6 and G3.1.2.10).

Follow HVAC system-specific requirements (chillers, boilers, heat pumps) as indicated in G.3.1.3

Proposed

Include economizers if indicated in actual design parameters.

System-specific requirements should reflect actual conditions.

Economizers & Energy Recovery

TABLE G3.1.2.6A Climate Conditions under which Economizers are Included for Baseline Systems 3 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.

Exhaust Air Energy Recovery (Mandatory)

5000 CFM (Supply) AND
=>70% Outdoor Air (Supply)

→ ERV with 50% recovery effectiveness

TABLE G3.1.2.6B 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



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Chillers

HVAC Systems

Baseline

Model economizers and exhaust air energy recovery systems in baseline HVAC systems when required for given climate zone and system parameters (G3.1.2.6 and G3.1.2.10).

Proposed

Include economizers if indicated in actual design parameters.

Follow HVAC system-specific requirements (chillers, boilers, heat pumps) as indicated in G.3.1.3

System-specific requirements should reflect actual conditions.

**For Systems 7 & 8,
Electric chillers (baseline)
Table G3.1.3.7 (type & number)**

**Chilled water design
Supply @ 44 degF
Return @ 56 degF**

TABLE G3.1.3.7 Type and Number of Chillers

Building Peak Cooling Load	Number and Type of Chiller(s)
≤300 tons	1 water-cooled screw chiller
>300 tons, <600 tons	2 water-cooled screw chillers sized equally
≥600 tons	2 water-cooled centrifugal chillers minimum with chillers added so that no chiller is larger than 800 tons, all sized equally



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Demand Control Ventilation

HVAC Systems

Ventilation Controls for High Occupancy Areas:

Demand Control Ventilation (DCV) – modulate the amount of outdoor air supplied to a space as a **function of the number of people present**.

- Standard requires DCV for all ventilation systems with design outdoor air capacities >3000 CFM serving occupancy density > 100 people / 1000 sf
- DCV is activated based on CO2 levels
- CO2 sensors located within occupied zone (or return air)



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Process Energy

Process loads must be identical to proposed building. Occupancy and occupancy schedules may not be changed. However, variations of power requirements, schedules or control sequences are allowed based upon documentation that installed equipment in proposed design represents significant verifiable departure from documented conventional practice.

Model separate meters for tenant receptacle loads and process loads.
Use same values for receptacle loads as used in proposed building.

Process energy includes office and general miscellaneous equipment, computers, elevators and escalators, kitchen cooking and refrigeration, laundry washing and drying, lighting exempt from lighting power allowance (e.g., lighting integral to medical equipment), and other (e.g., waterfall pumps).

Table G-B provides acceptable receptacle power densities per occupancy type, which can be incorporated into building energy models. Other process energy inputs such as elevators, escalators, data center and telecom room computing equipment, refrigeration, process lighting, and non-HVAC motors should be modeled based on actual power requirements, and assuming reasonable schedules of operation.

Total process energy cost must be equal to at least 25% of baseline building performance.

For buildings where process energy cost is less than 25% of baseline building energy cost, include documentation substantiating that process energy inputs are appropriate.

Process loads must be identical.

Minimum 25% of baseline building energy cost.



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Process Energy

Process loads must be identical to proposed building. Occupancy and occupancy schedules may not be changed. However, variations of power requirements, schedules or control sequences are allowed based upon documentation that installed equipment in proposed design represents significant verifiable departure from documented conventional practice.

Model separate meters for tenant receptacle loads and process loads.
Use same values for receptacle loads as used in proposed building.

Process energy includes office and general miscellaneous equipment, computers, elevators and escalators, kitchen cooking and refrigeration, laundry washing and drying, lighting exempt from lighting power allowance (e.g., lighting integral to medical equipment), and other (e.g., waterfall pumps).

Table G-B provides acceptable receptacle power densities per occupancy type, which can be incorporated into building energy models. Other process energy inputs such as elevators, escalators, data center and telecom room computing equipment, refrigeration, process lighting, and non-HVAC motors should be modeled based on actual power requirements, and assuming reasonable schedules of operation.

Total process energy cost must be equal to at least 25% of baseline building performance.

For buildings where process energy cost is less than 25% of baseline building energy cost, include documentation substantiating that process energy inputs are appropriate.

**Table G-B
For EPD (Receptacle load)**

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Process Energy

Table G-B—Acceptable Occupant Densities, Receptacle Power Densities, and Service Hot Water Consumption¹

Building Type	Occupancy Density ² Sq.Ft./Person (Btu/h · ft ²)	Receptacle Power Density ³ Watts/Sq.Ft. (Btu/h · ft ²)	Service Hot Water Quantities ⁴ Btu/h · Person
Assembly	50 (4.60)	0.25 (0.85)	215
Health/Institutional	200 (1.15)	1.00 (3.41)	135
Hotel/Motel	250 (0.92)	0.25 (0.85)	1,110
Light Manufacturing	750 (0.31)	0.20 (0.68)	225
Office	275 (0.84)	0.75 (2.56)	175
Parking Garage	NA	NA	NA
Restaurant	100 (2.30)	0.10 (0.34)	390
Retail	300 (0.77)	0.25 (0.85)	135
School	75 (3.07)	0.50 (1.71)	215
Warehouse	15,000 (0.02)	0.10 (0.34)	225

1. The occupancy densities, receptacle power densities, and service hot water consumption values are from ASHRAE Standard 90.1-1989 and addenda.
2. Values are in square feet of conditioned floor area per person. Heat generation in Btu per person per hour is 230 sensible and 190 latent. Figures in parentheses are equivalent Btu per hour per square foot.
3. Values are in Watts per square foot of conditioned floor area. Figures in parentheses are equivalent Btu per hour per square foot. These values are the minimum acceptable. If other process loads are not input (such as for computers, cooking, refrigeration, etc.), it is recommended that receptacle power densities be increased until total process energy consumption is equivalent to 25% of the total.
4. Values are in Btu per person per hour.

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Service Hot Water System

Baseline

Service hot water must use same energy sources as proposed building. System-related specific parameters must be modeled as indicated in Table G.3.1.1.

Proposed

Service hot water system type and its related performance parameters must be modeled to reflect actual system installed or designed in design documents.

Same energy source.

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required ^a	Test Procedure ^b
Electric water heaters	≤12 kW	Resistance ≥20 gal	0.93–0.00132V EF	DOE 10 CFR Part 430
	>12 kW	Resistance ≥20 gal	$20 + 35 \sqrt{V}$ SL, Btu/h	ANSI Z21.10.3
	≤24 Amps and ≤250 Volts	Heat Pump	0.93–0.00132V EF	DOE 10 CFR Part 430
Gas storage water heaters	≤75,000 Btu/h	≥20 gal	0.62–0.0019V EF	DOE 10 CFR Part 430
	>75,000 Btu/h	<4000 (Btu/h)/gal	$80\% E_f (Q/800 + 110 \sqrt{V})$ SL, Btu/h	ANSI Z21.10.3
Gas instantaneous water heaters	>50,000 Btu/h and <200,000 Btu/h	≥4000 (Btu/h)/gal and <2 gal	0.62–0.0019V EF	DOE 10 CFR Part 430
	≥200,000 Btu/h ^c	≥4000 (Btu/h)/gal and <10 gal	80% E_f	ANSI Z21.10.3
	≥200,000 Btu/h	≥4000 (Btu/h)/gal and ≥10 gal	$80\% E_f (Q/800 + 110 \sqrt{V})$ SL, Btu/h	

Performance required (baseline) is available in 90.1-2007

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Energy Rates

Baseline

Proposed

Use same rates for both baseline and proposed building.

Rates from local utility schedules are default option to compute energy costs. However, intent is to encourage simulations that provide owners value and help them minimize their energy costs.

In absence of local utility rate schedule or energy rate schedules approved by local ASHRAE 90.1-2007 adopting authority, use energy rates listed in state average prices, published annually by Energy Information Administration at <http://www.eia.doe.gov>. Regardless of source of rate schedule used, same rate schedule must be used in both baseline and proposed simulations.

Same rates for both baseline & proposed building.

Local utility or Energy Information Administration rates

U.S. Energy Information Administration
Independent Statistics and Analysis

Home > Electricity > EIA > Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State

Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State

Electric Power Monthly with data for October 2009
Report Released: January 15, 2010
Next Release Date: Mid-February 2010

Table 5.6.A. **Electric Power Monthly**
(Cents per kilowatt-hour)

Constant Season and State	Residential		Commercial		Industrial		Transportation		All Sectors	
	Oct. 09	Oct. 08	Oct. 09	Oct. 08	Oct. 09	Oct. 08	Oct. 09	Oct. 08	Oct. 09	Oct. 08
New England	17.27	16.76	16.46	15.84	11.41	12.77	7.2	7.48	15.43	16.35
Connecticut	20.79	20.12	15.52	15.5	10.92	13.92	13.52	8.71	19.38	19.75
Midwest	15.3	15.22	11.82	12.51	9.65	11.58	-	-	12.38	13.56

Complying With ASHRAE Appendix G for LEED

LEED EAp2 & EAc1 Requirements Exercise

- Using Building from Design Development Wizard Exercise (Completed on Day 1)
 - Let model created yesterday be the design case or 'proposed' building
 - Now create a basecase building model to comply with ASHRAE Appendix G
 - Remember the building is located in Seattle, WA
 - Don't forget to do four simulations, i.e. 0, 90, 180 & 270 degrees

Complying With ASHRAE Appendix G for LEED

LEED Forms

- EA Prerequisite 2: Minimum Energy Performance
- EA Credit 1: Optimize Energy Performance

LEED Worksheets

- EAp2 Section 1.4 Tables: Comparison of Baseline Design Versus Proposed Design

Energy Modeling for LEED Using eQUEST

Instructor contact information:

- Christian Stalberg
- Tel. 919-801-0734
- Email: cstalberg@naturalintelligence.us
- Website: <http://naturalintelligence.us>