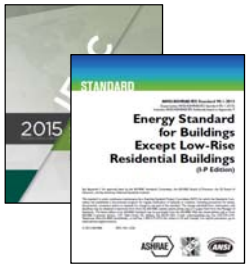
COMMERCIAL ENERGY CODE

2015 IECC & ASHRAE 90.1 -2013

SCOPE, ENVELOPE, LIGHTING & HVAC



Presented by Southface

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ABOUT SOUTHFACE

Building a Regenerative Economy, Responsible Resource Use & Social Equity Through a Healthy Built Environment for All

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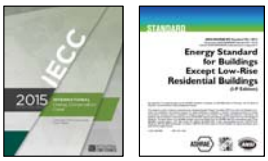
LEARNING OBJECTIVES



- Understand the scope, application and methods of demonstrating compliance with **IECC 2015** and **ASHRAE 90.1-2013** in commercial buildings
- Appreciate building science principles including heat, air, & moisture transfer and how they relate to the energy code
- Apply design and construction strategies in building projects to comply with ASHRAE 90.1-2013 / IECC 2015
- Experience COMcheck software and its application in showing code compliance

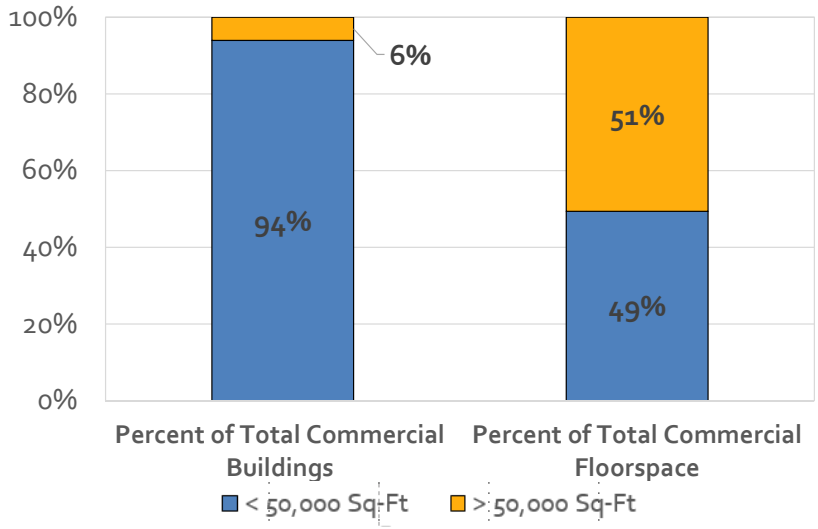
WHO ARE YOU?

Name
Home base
How long have you worked in the design/construction/utility world?

What are we sharing
Link to download presentation slides (pdf)
Climate Zone 2, 3 and 4 prescriptive tables

Please turn your cell phones to silent mode

U.S. COMMERCIAL BUILDING STOCK



Source: U.S. EIA, 2003 CBECS

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Advanced Commercial Building Initiative (ACBI)

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DEEP ENERGY PRESCRIPTIVE PACKAGE

- An overlay for ECLC
- Can be an independent prescriptive path
- 25% energy efficiency over code
- Webinar overview

earthcraft
Light Commercial

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Which uses the most / least energy per s.f.?

A. Education
B. Food service
C. Lodging
D. Warehouse / storage
E. Religious / worship

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Which uses the most / least energy per s.f.?

A. Education – 78.3, 78.6 kBtu/s.f.
B. Food – 322.9, 163.2 kBtu/s.f.
C. Lodging – 111, 91.2 kBtu/s.f.
D. Warehouse – 26.4, 34.1 kBtu/s.f.
E. Religious – 46.5, 41.8 kBtu/s.f.

	Sum of Major Fuel Consumption (trillion Btu)			Energy Intensity for Sum of Major Fuels (thousand Btu/ square foot)		
	1,001 to 10,000 Square Feet	10,001 to 100,000 Square Feet	Over 100,000 Square Feet	1,001 to 10,000 Square Feet	10,001 to 100,000 Square Feet	Over 100,000 Square Feet
All Buildings*	1,188	2,208	2,425	88.8	75.5	109.5
Principal Building Activity						
Education	63	423	334	78.3	78.6	90.7
Food Sales	144	Q	Q	188.5	Q	Q
Food Service	318	108	Q	322.9	163.2	Q
Health Care	32	104	457	71.8	125.1	242.9
Inpatient	N	Q	436	N	Q	252.9
Outpatient	32	66	Q	71.8	100.5	Q
Lodging	29	207	273	111.0	91.2	106.7
Retail (Other Than Mall)	110	137	72	80.9	64.1	87.8
Office	171	412	551	73.5	89.5	104.2
Public Assembly	59	150	Q	69.5	80.8	Q
Public Order and Safety	22	Q	Q	94.3	Q	Q
Religious Worship	54	100	Q	46.5	41.8	Q
Service	120	144	Q	68.4	77.2	Q
Warehouse and Storage	47	157	253	26.4	34.1	68.0
Other	Q	100	Q	Q	166.8	Q
Vacant	Q	Q	Q	Q	Q	Q

Under 10k s.f., Between 10-100k s.f.

Ref: 2003 CBECS

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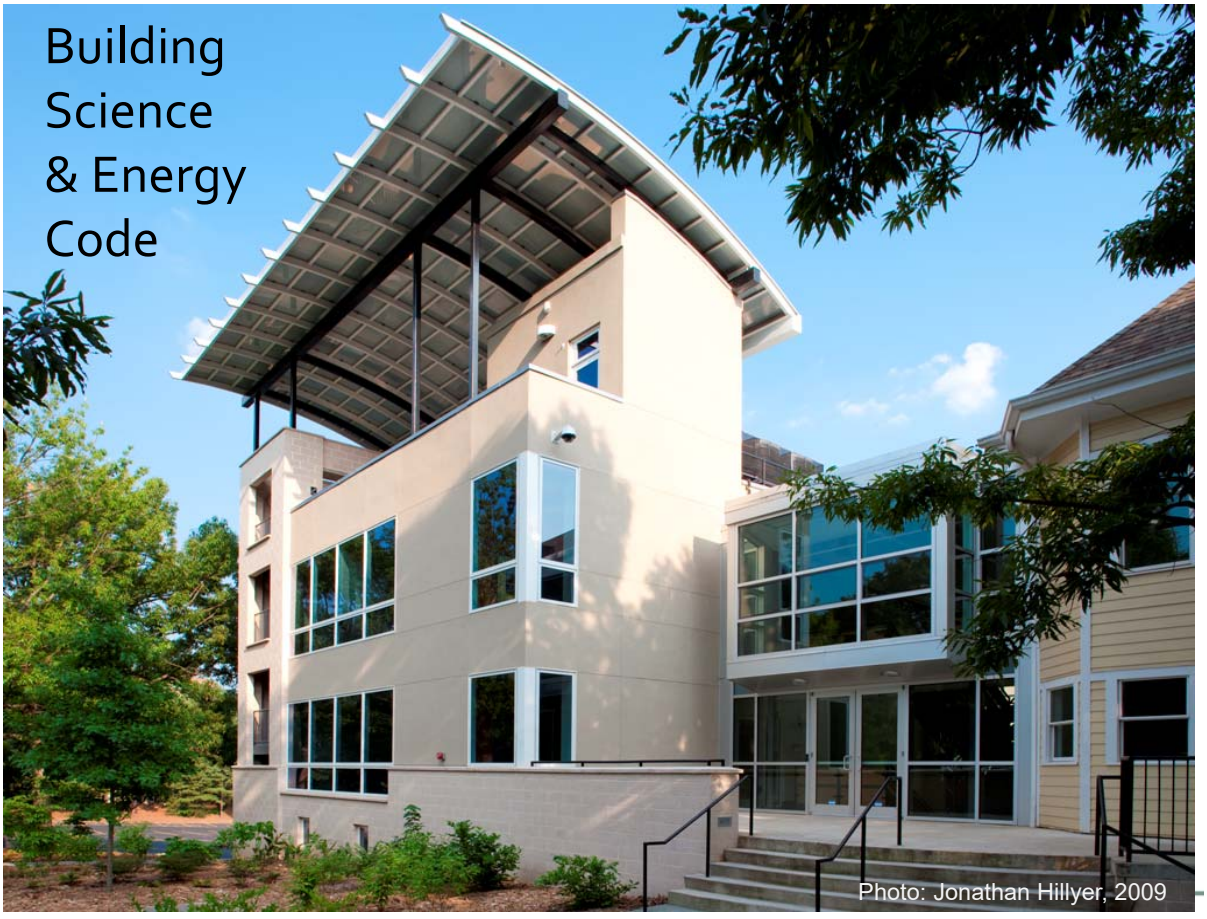


Photo: Jonathan Hillyer, 2009

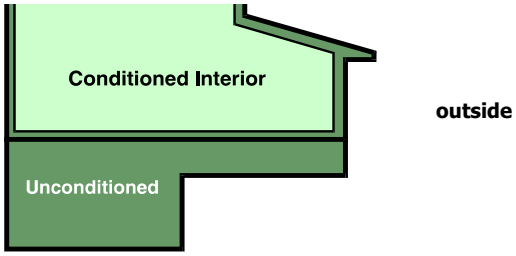
BUILDING SCIENCE FUNDAMENTALS

CONCEPTS

Understand
Building as a System

Control Flow of

- Heat
- Air
- Moisture



The building thermal envelope separates conditioned space from unconditioned (or outside) and consists of two elements: an air barrier and insulation that must be continuous and touching

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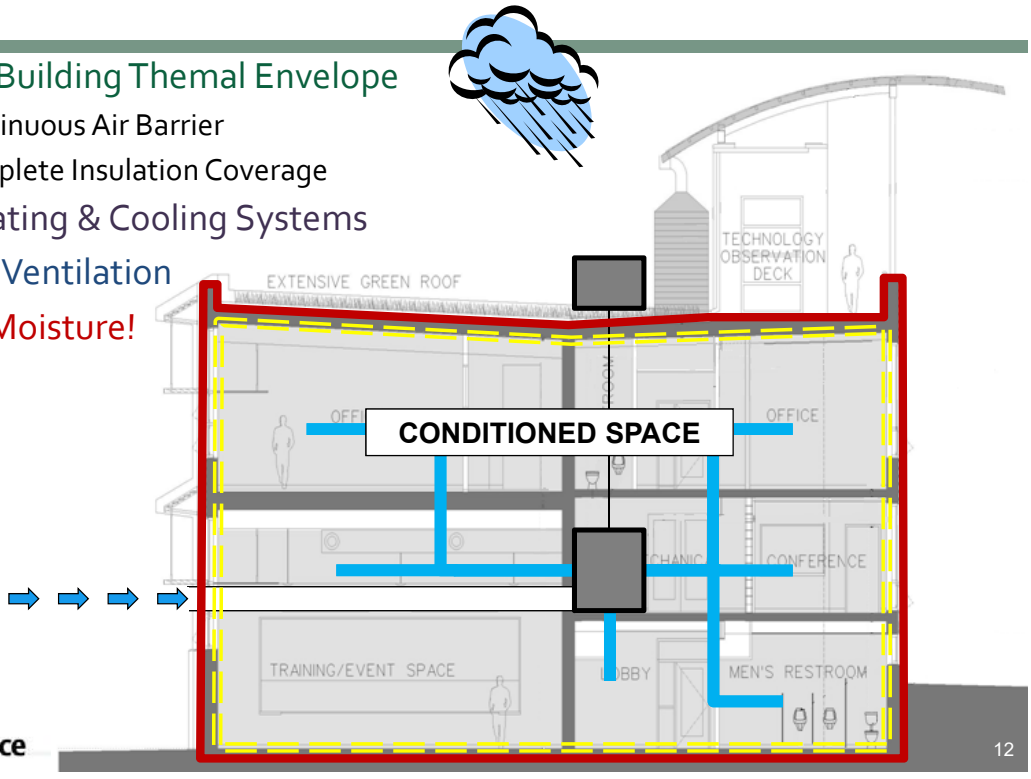
BUILDINGS ARE SYSTEMS

Complete Building Themal Envelope
- Continuous Air Barrier
- Complete Insulation Coverage

Proper Heating & Cooling Systems

Controlled Ventilation

Deal with Moisture!



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HEAT TRANSFER

CONCEPTS

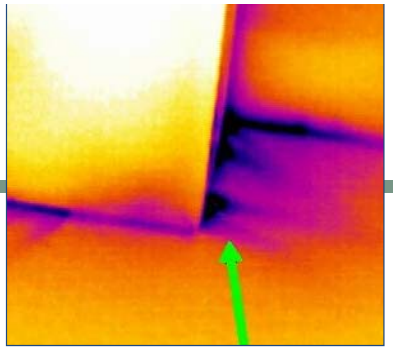
Heat Flow

- Heat always moves from a warmer place to a cooler place

Types of Heat Transfer

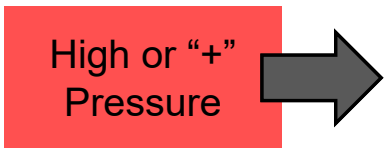
- **Conduction** – heat flow through *solids*
- **Convection** – heat flow through *gas* or *liquid*
- **Radiation** – heat flow from hot *surface* to cool *surface*

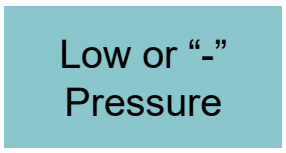
SCIENCE OF AIR MOVEMENT



Basic Principle of Air Leakage

Air will always move from an area of high pressure to an area of low pressure





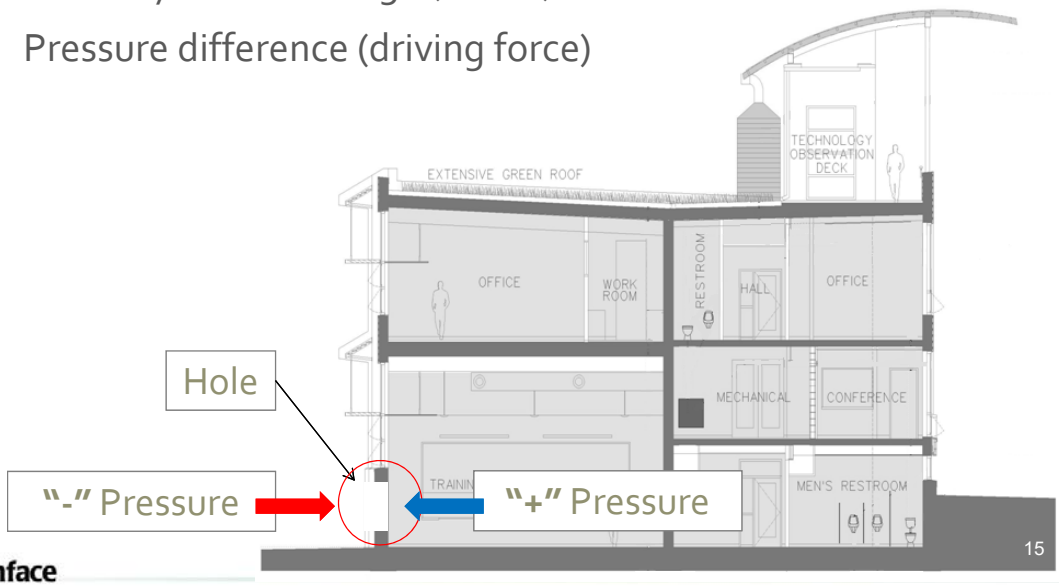
When air moves out of a building, the same amount has to come in and vice-versa

SCIENCE OF AIR FLOW (INFILTRATION)

Basic Principles of Air Infiltration

Two requirements for air movement

1. Pathway for air leakage (a hole)
2. Pressure difference (driving force)



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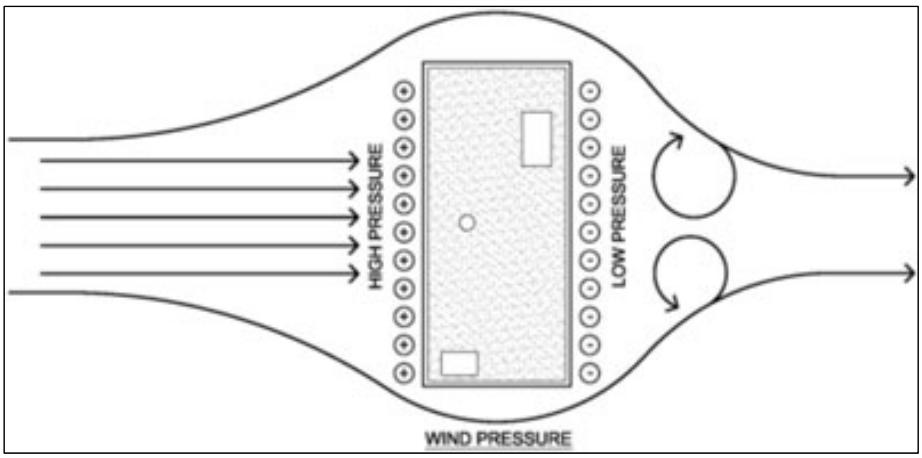
PRESSURES / DRIVING FORCES

Wind

- Air leaks across envelope assemblies driven by the pressure differential due to wind



  - Air enters the building on the windward side (infiltration) and exits on the leeward side (exfiltration)

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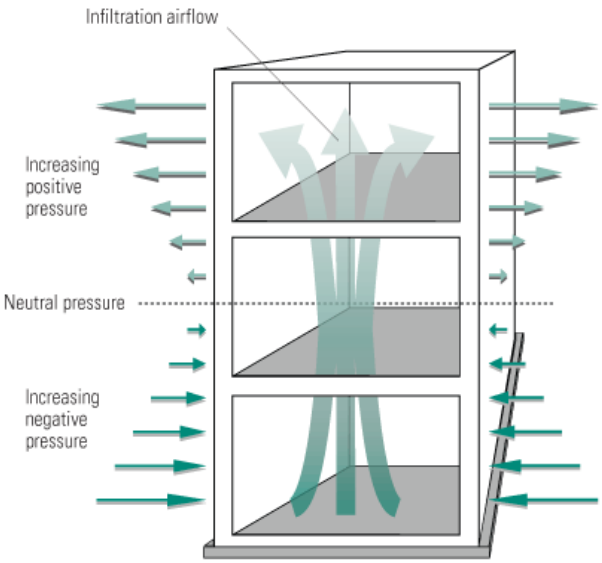
PRESSURES / DRIVING FORCES

Stack Effect (Chimney Effect)

- The stack effect causes air movement due to the buoyancy of heated air
- The greater the thermal difference and the height of the structure, the greater the buoyancy force



Source: E SOURCE

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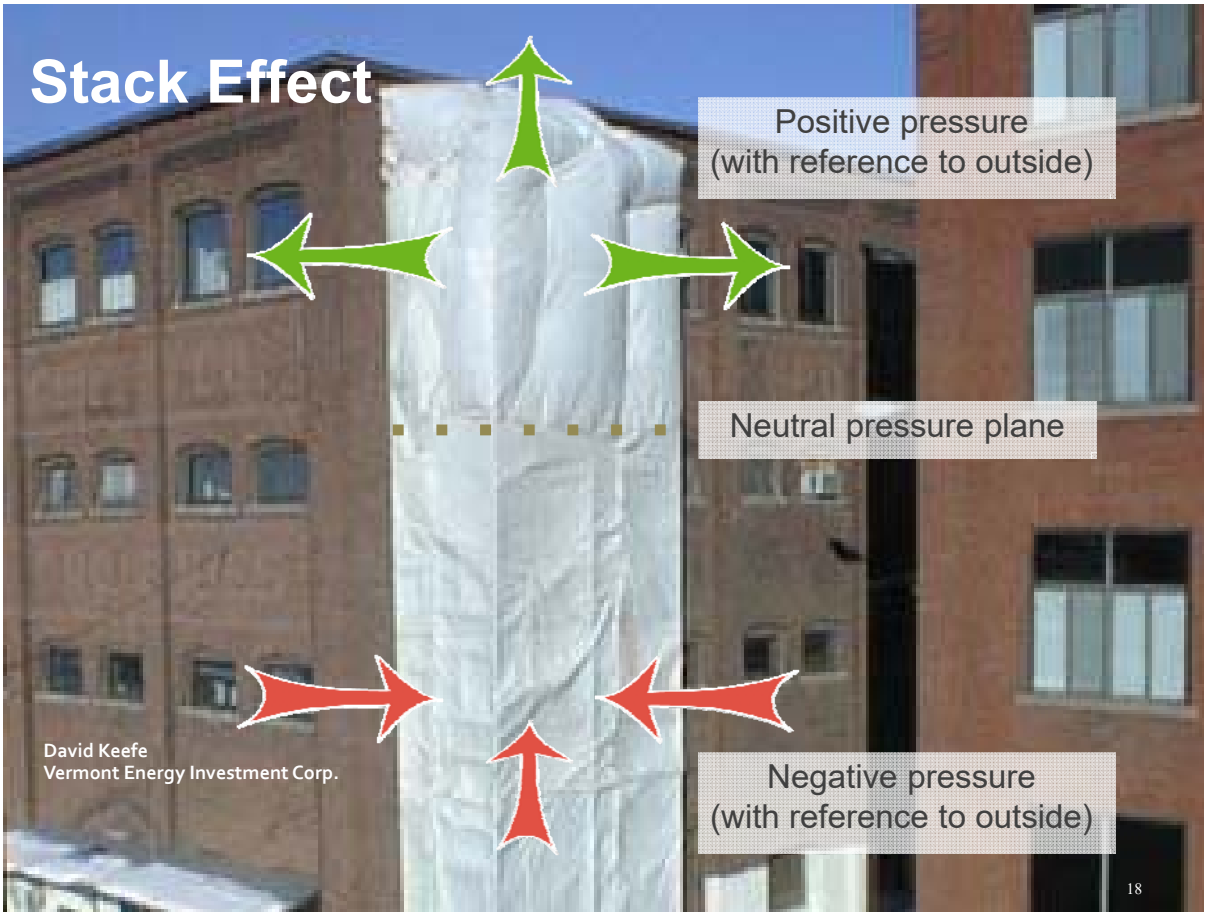

PRESSURES / DRIVING FORCES

Mechanical Fans

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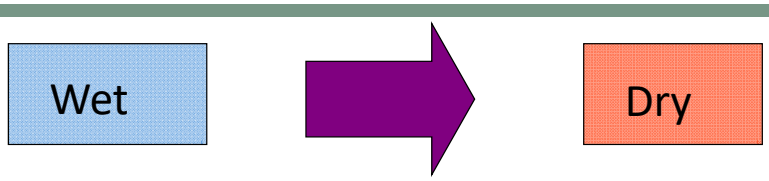
MOISTURE FLOW IN BUILDINGS



Liquid

Bulk

Liquid water (rain, drainage, plumbing leaks)

Capillarity

Wicking through porous materials (concrete, fiberglass and cellulose insulation, wood)

Vapor

Diffusion

Molecules of water moving through porous materials

Infiltration

Moisture laden air brought into or out of the house

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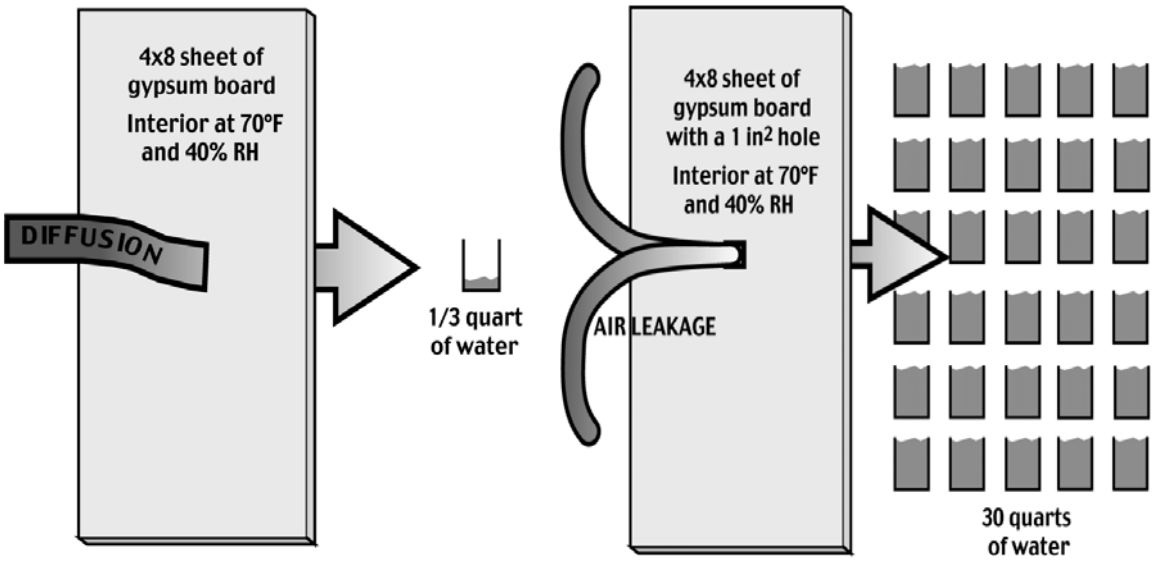
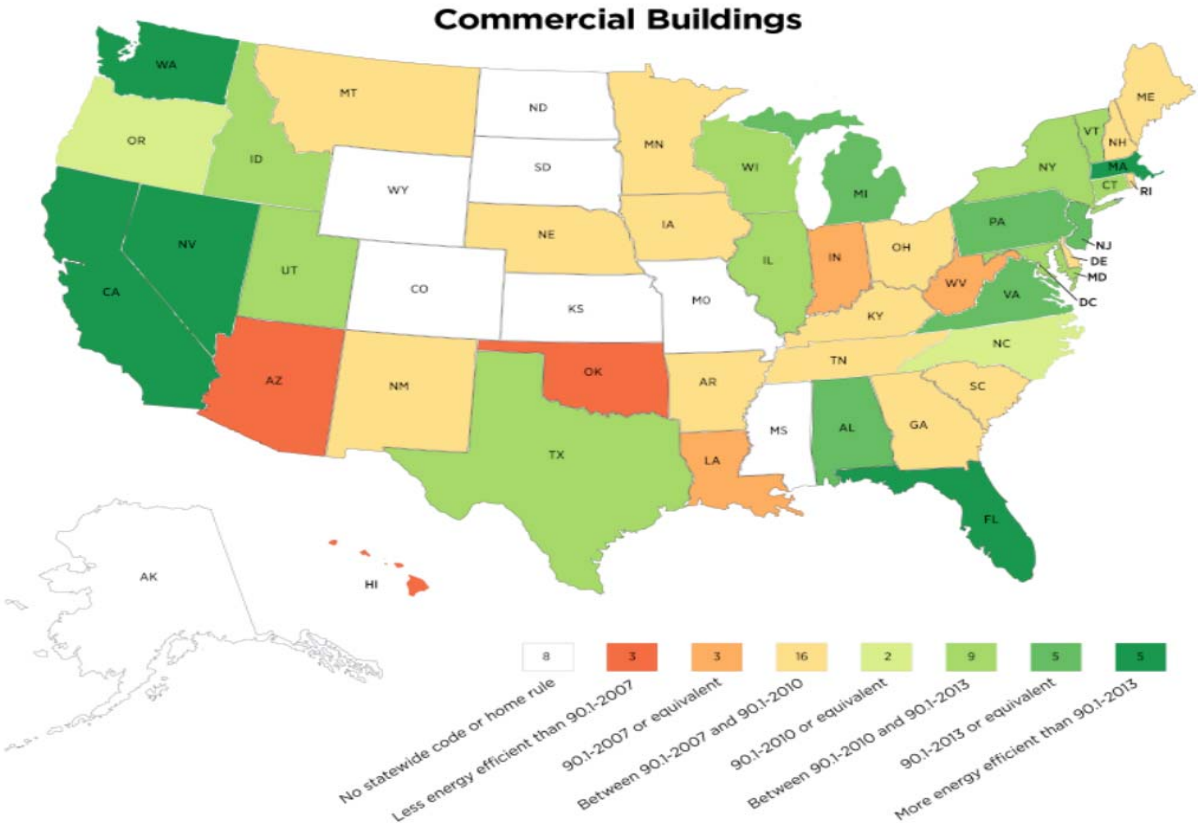
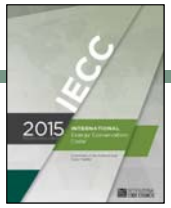
VAPOR DIFFUSION VS. AIR LEAKAGE

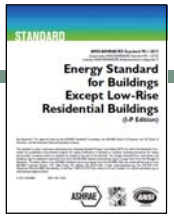


CURRENT COMMERCIAL ENERGY CODES



SUMMARY OF THE COMMERCIAL CODES





IECC 2015 Commercial

C1 – Scope and Admin

C2 – Definitions

C3 – General Requirements

C4 – Comm. Energy Efficiency

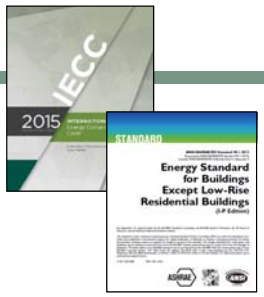
- Building Envelope Requirements
- Building Mechanical Systems
- Service Water Heating
- Lighting
- Total Building Performance

C5 – Referenced Standards

ASHRAE 90.1-2013

- Section 1-4 – General
- Section 5 – Building Envelope
- Section 6 – Heating, Ventilating, & Air Conditioning
- Section 7 – Water Heating
- Section 8-9 – Power & Lighting
- Section 10 – Other Equipment
- Section 11 – Energy Cost Budget Method

ROAD MAP OF COMPLIANCE PATHWAYS



Mandatory Requirements

Envelope, Lighting, and Mechanical Requirements

Prescriptive charts (IECC 2015 Comm.) or (ASHRAE 90.1-2013)

Simple Tradeoff COMCheck for either code (free software)

Building Simulation (IECC 2015 Comm.) or ECB from (ASHRAE 90.1-2013)

Plan Review and Field Inspection

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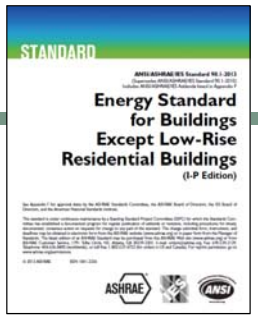
APPLYING THE CODE – 90.1



Conditioned space

- Cooled (>5 Btu/hr-ft2)
- Heated (>10 Btu/hr-ft2 for CZ3)
- Indirectly Conditioned (essentially, reasonably connected to a conditioned space)

Semi-heated space

- for CZ3, heated by system supplying between 3.4 and 10 Btu/h-ft2 (e.g., warehouse with freeze protection)

Unconditioned space

- neither of the above (e.g., crawlspaces, attics, parking garages)

- **ASHRAE space categories** (3 columns in tables)
  - ***Nonresidential*** – most commercial buildings
  - ***Residential*** – hotels, dorms, multifamily buildings over 3 stories
  - ***Semiheated*** – minimal space heating (e.g., freeze protection)

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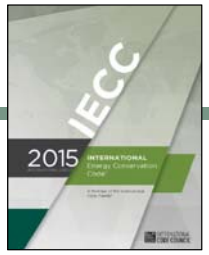
APPLYING THE CODE - IECC



Conditioned space

- An area or room within a building being heated or cooled, containing uninsulated ducts, or with a fixed opening directly into an adjacent conditioned space.

Low energy buildings (exempt from code)

- Design rate energy use less than 3.4 btu/h per ft² or 1.0 watt/ft²
- Buildings that do not contain conditioned space
- Greenhouses

- **IECC Building categories** (2 columns in tables)
  - ***Nonresidential "All Other"*** – most commercial buildings
  - ***Residential "Group R"–*** hotels, dorms, multifamily buildings over 3 stories

SECTION 2: SCOPE

Scope

New buildings and their systems

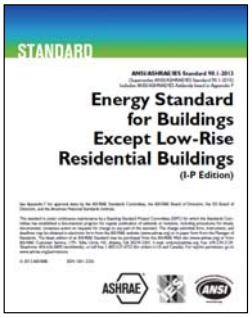
New portions of buildings and their systems

New systems and equipment in existing buildings

ALTERATIONS

- **Alterations** shall comply with code (eight exceptions)

alteration: a replacement or addition to a building or its systems and equipment; routine maintenance, repair, and service or a change in the building's use classification or category shall not constitute an alteration.



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Exceptions: The following alterations need not comply with these requirements, provided such alterations will not increase the energy usage of the building:

1. Installation of storm windows or glazing panels over existing glazing, provided the storm window or glazing panel contains a low-emissivity coating. However, a low-emissivity coating is not required where the existing glazing already has a low-emissivity coating. Installation is permitted to be either on the inside or outside of the existing glazing.
2. Replacement of glazing in existing sash and frame, provided the U-factor and SHGC will be equal to or lower than before the glass replacement.
3. Alterations to roof/ceiling, wall, or floor cavities that are insulated to full depth with insulation having a minimum nominal value of R-3.0/in.
4. Alterations to walls and floors, where the existing structure is without framing cavities and no new framing cavities are created.
5. Roof recovering.
6. Removal and replacement of a roof membrane where there is existing roof insulation integral to or below the roof deck
7. Replacement of existing doors that separate a conditioned space from the exterior shall not require the installation of a vestibule or revolving door, provided that an existing vestibule that separates a conditioned space from the exterior shall not be removed.
8. Replacement of existing fenestration, provided that the area of the replacement fenestration does not exceed 25% of the total fenestration area of an existing building and that the U-factor and SHGC will be equal to or lower than before the fenestration replacement.

Section 5
Building Envelope

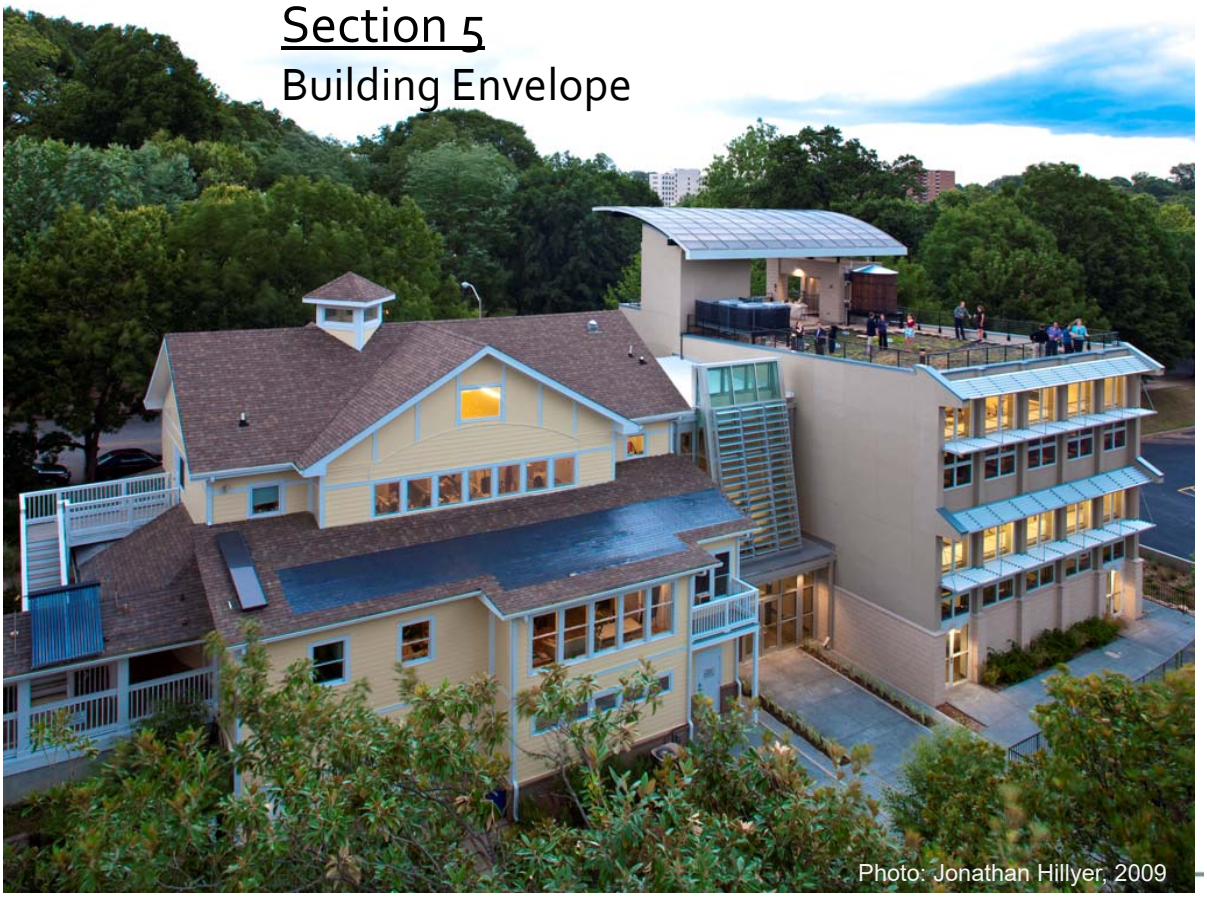


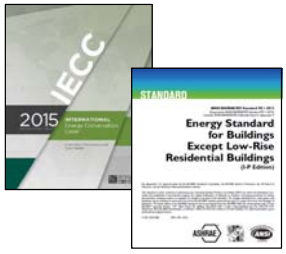
Photo: Jonathan Hillyer, 2009

BUILDING ENVELOPE REQUIREMENTS

Compliance Paths – (choose one)

IECC 2015 – Commercial Section 402

ASHRAE 90.1-2010 – Section 5



Main Elements

Insulation

Fenestration

Air Leakage

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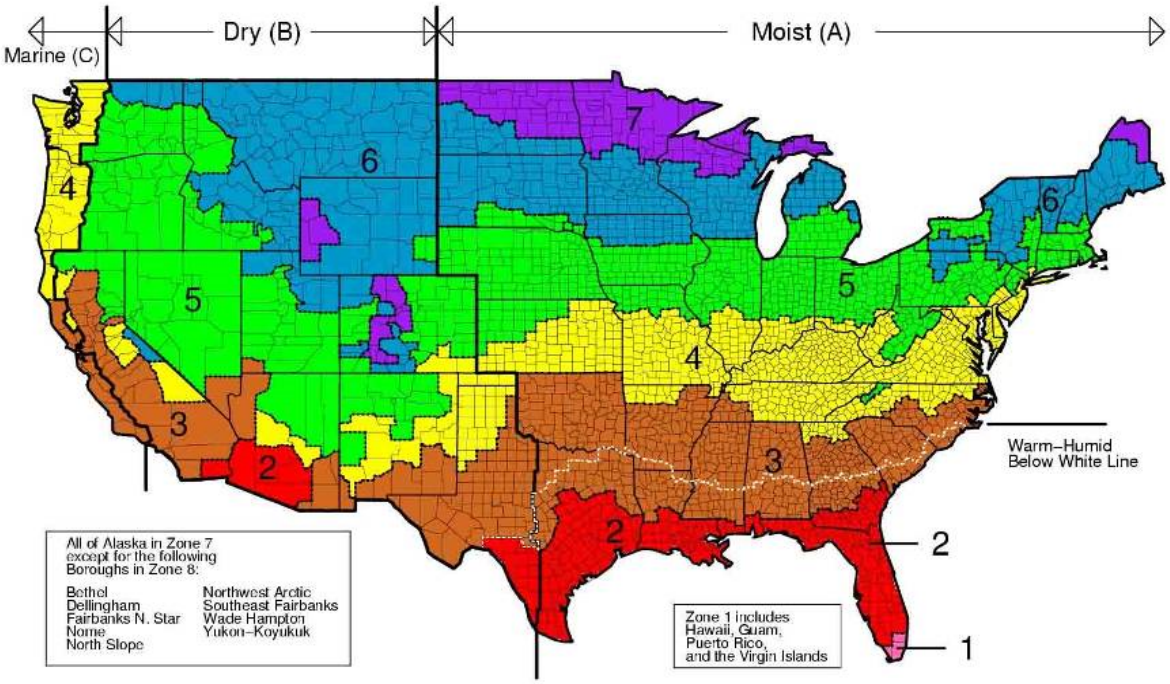
IECC / ASHRAE 90.1 CLIMATE ZONES



Note: GA is Climate Zone (CZ) 2A, 3A and 4A

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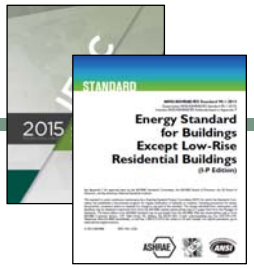
ENVELOPE KEY CONCEPTS



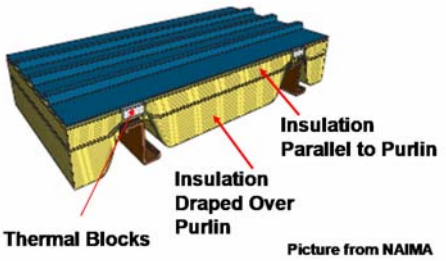
GA is Mixed-Humid Climate

R-values are for components, U-factors for assemblies

R = 1/U
U = 1/R

Metal Buildings

- Walls: R-9.8 c.i. (ASHRAE)
- Or, R-13+R-6.5 c.i. (IECC)
- Roof: R-10+R-19 FC;
  Min. R-3.5 thermal spacer block (ASHRAE)
- Or, R-19+R-11 LS (IECC)



- Buildings Limited to 30%/40% Glass to Wall Area (prescriptive)
- Daylighting required for some buildings

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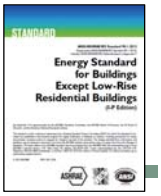
BUILDING ENVELOPE



Important Appendices

Appendix A: Rated R-value of Insulation and Assembly U-, C-, and F-factor Determinations

A2.3 Metal Building Roofs

A2.3.1 General. For the purpose of Section A1.2, the base assembly is a roof with thermal spacer blocks where the insulation is draped over the steel structure (purlins), spaced nominally 5 ft on center and compressed when the metal roof panels are attached to the steel structure (purlins).

A2.3.2 Rated R-Value of Insulation

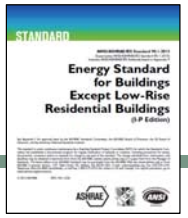
A2.3.2.1 Single Layer. The rated R-value of insulation is for insulation installed perpendicular to and draped over purlins and then compressed when the metal roof panels are attached. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly U-factor.

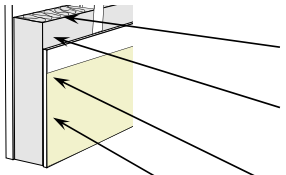
TABLE A2.3.3 Assembly U-Factors for Metal Building Roofs

Insulation System	Rated R-Value of Insulation	Overall U-Factor for Entire Base Roof Assembly	Overall U-Factor for Assembly of Base Roof Plus Continuous Insulation (Uninterrupted by Framing)								
			Rated R-Value of Continuous Insulation								
			R-6.5	R-9.8	R-13	R-15.8	R-19	R-22.1	R-25	R-32	R-38
Standing Seam Roofs with Thermal Spacer Blocks[a, b]											
Single Layer	None	1.280	0.137	0.095	0.073	0.060	0.051	0.044	0.039	0.031	0.026
	R-10	0.115	0.066	0.054	0.046	0.041	0.036	0.032	0.030	0.025	0.021
	R-11	0.107	0.063	0.052	0.045	0.040	0.035	0.032	0.029	0.024	0.021
	R-13	0.101	0.061	0.051	0.044	0.039	0.035	0.031	0.029	0.024	0.021
	R-16	0.096	0.059	0.049	0.043	0.038	0.034	0.031	0.028	0.024	0.021
	R-19	0.082	0.053	0.045	0.040	0.036	0.032	0.029	0.027	0.023	0.020
	R-10 + R-10	0.088	0.056	0.047	0.041	0.037	0.033	0.030	0.028	0.023	0.020
	R-10 + R-11	0.086	0.055	0.047	0.041	0.036	0.033	0.030	0.027	0.023	0.020
	R-11 + R-11	0.085	0.055	0.046	0.040	0.036	0.033	0.030	0.027	0.023	0.020

BUILDING ENVELOPE

Metal Framing (Thermal Bridging) Effects





Outside Air Film

1- inch Exterior foam sheathing (R-3.8) with Stucco

2 x 4 Metal Studs with R-13 in the Cavity

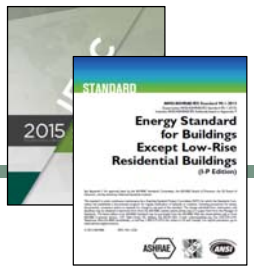
1/2 in. Gypsum Board

Inside Air Film

TABLE A9.2B Effective Insulation/Framing Layer R-Values for Wall Insulation Installed Between Steel Framing

Nominal Depth of Cavity, in.	Actual Depth of Cavity, in.	Rated R-Value of Airspace or Insulation	Effective Framing/Cavity R-Value at 16 in. on Center	Effective Framing/Cavity R-Value at 24 in. on Center
Empty Cavity, No Insulation				
4	3.5	R-0.91	0.79	0.91
Insulated Cavity				
4	3.5	R-11	5.5	6.6
4	3.5	R-13	6.0	7.2
4	3.5	R-15	6.4	7.8

BUILDING ENVELOPE



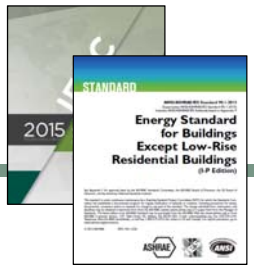
General

Space-Conditioning Categories:

- **Nonresidential** conditioned space (90.1)
- **Commercial** conditioned space (IECC)

"All occupancies other than residential"

BUILDING ENVELOPE



General

Space-Conditioning Categories

- **Residential** conditioned space (90.1)
- **Group R** conditioned space (IECC)

residential: spaces in buildings used primarily for living and sleeping. Residential spaces include, but are not limited to, dwelling units, hotel/motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/ sorority houses, hostels, prisons, and fire stations.

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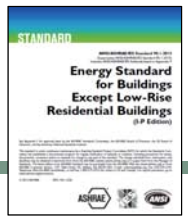
IECC Residential (Group R) - places providing accommodations for overnight stay (excluding Institutional). Examples: houses, apartment buildings, hotels, and motels.

SECTION 5: BUILDING ENVELOPE
(90.1 ONLY)



5.1 - General

Space-Conditioning Categories

– **Semiheated space** *(ASHRAE Only)*

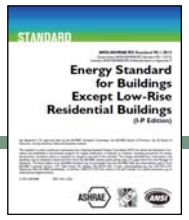
"an enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h·ft² of floor area but is not a conditioned space."

"In climate zones 3 through 8, a space may be designated as either semiheated or unconditioned only if approved by the building official."

TABLE 3.1 Heated Space Criteria

Heating Output (Btu/h·ft²)	Climate Zone
5	1 and 2
10	3
15	4 and 5
20	6 and 7
25	8

SECTION 5.4: MANDATORY ENVELOPE



5.4 - Mandatory Provisions

Insulation

Glazed Fenestration and Doors

Air Leakage

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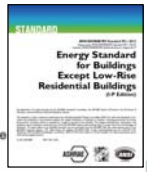
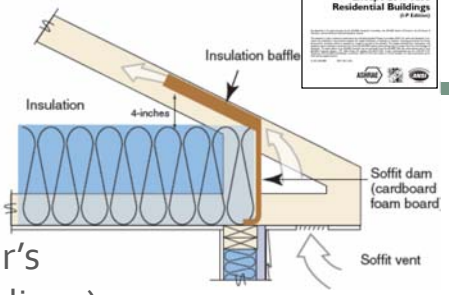
SECTION 5.4: BUILDING ENVELOPE



5.4.1 Mandatory Provisions



Insulation (details 5.8.1)

- Labeling of envelope insulation
- Install in compliance with manufacturer's requirements (exception for metal buildings)
- Insulation in substantial contact with air barrier
- Extent of insulation – full component area
- No loose-fill insulation in attic when ceiling is more than 3:12 slope (baffles at eave vents)
- Recessed equipment – effect on insulation
- Insulation protected from sun, moisture, landscapers, access & maintenance, and wind
- Stagger joints of multilayered rigid insulation

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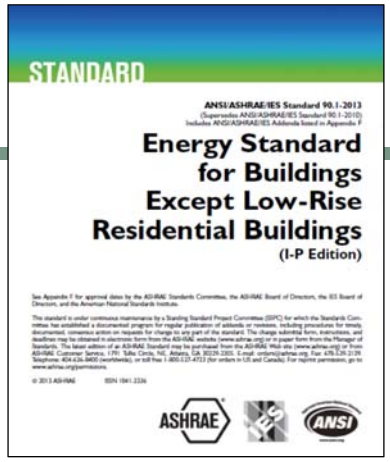
90.1 BUILDING ENVELOPE



Prescriptive Provisions

Opaque Elements

- Roofs
- Walls, above grade
- Walls, below grade
- Floors
- Slab Floors
- Opaque Doors

Opaque Elements Compliance

- Minimum R-value
- Maximum U-Factor, C-Factor or F-Factor for entire assembly

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90.1-2007: **OLD CODE** PRESCRIPTIVE – CZ3

TABLE 5.5-3 Building Envelope Requirements For Climate Zone 3 (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-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.173	R-5.0 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-0.123	R-7.6 c.i.	U-0.104	R-9.5 c.i.	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-0.184	R-6.0
Steel-Framed	U-0.084	R-13.0 + R-3.8 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
Walls, 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 c.i.	U-0.087	R-8.3 c.i.	U-0.322	NR
Steel-Joist	U-0.052	R-19.0	U-0.052	R-19.0	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-0.900	R-10 for 24 in.	F-0.900	R-10 for 24 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-1.450		U-0.500		U-1.450	

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90.1-2013: PRESCRIPTIVE CHART – CZ3

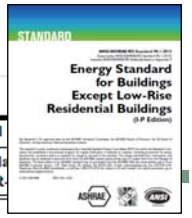


Table 5.5-3 Building Envelope Requirements for Climate Zone 3 (A,B,C)*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insula Min. R-
Roofs						
Insulation Entirely above Deck	U-0.039	R-25 c.i.	U-0.039	R-25 c.i.	U-0.119	R-7.6 c.i.
Metal Building[a]	U-0.041	R-10 + R-19 FC	U-0.041	R-10 + R-19 FC	U-0.096	R-16
Attic and Other	U-0.027	R-38	U-0.027	R-38	U-0.053	R-19
Walls, above Grade						
Mass	U-0.123	R-7.6 c.i.	U-0.104	R-9.5 c.i.	U-0.580	NR
Metal Building	U-0.094	R-0 + R-9.8 c.i.	U-0.072	R-0 + R-13 c.i.	U-0.162	R-13
Steel Framed	U-0.077	R-13 + R-5 c.i.	U-0.064	R-13 + R-7.5 c.i.	U-0.124	R-13
Wood Framed and Other	U-0.089	R-13	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.089	R-13
Wall, below Grade						
Below Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.074	R-10 c.i.	U-0.074	R-10 c.i.	U-0.137	R-4.2 c.i.
Steel Joist	U-0.038	R-30	U-0.038	R-30	U-0.052	R-19
Wood Framed and Other	U-0.033	R-30	U-0.033	R-30	U-0.051	R-19
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	

90.1-2013: PRESCRIPTIVE CHART – CZ2

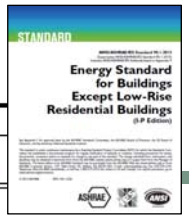


Table 5.5-2 Building Envelope Requirements for Climate Zone 2 (A,B)*

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-0.039	R-25 c.i.	U-0.039	R-25 c.i.	U-0.173	R-5 c.i.
Metal Building[a]	U-0.041	R-10 + R-19 FC	U-0.041	R-10 + R-19 FC	U-0.096	R-16
Attic and Other	U-0.027	R-38	U-0.027	R-38	U-0.053	R-19
Walls, above Grade						
Mass	U-0.151[b]	R-5.7 c.i.[b]	U-0.123	R-7.6 c.i.	U-0.580	NR
Metal Building	U-0.094	R-0 + R-9.8 c.i.	U-0.094	R-0 + R-9.8. c.i.	U-0.162	R-13
Steel Framed	U-0.084	R-13 + R-3.8 c.i.	U-0.064	R-13 + R-7.5 c.i.	U-0.124	R-13
Wood Framed and Other	U-0.089	R-13	U-0.089	R-13	U-0.089	R-13
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 c.i.	U-0.087	R-8.3 c.i.	U-0.322	NR
Steel Joist	U-0.038	R-30	U-0.038	R-30	U-0.069	R-13
Wood Framed and Other	U-0.033	R-30	U-0.033	R-30	U-0.066	R-13
Slab-on-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-0.900	R-10 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	

90.1-2013: PRESCRIPTIVE CHART – CZ4

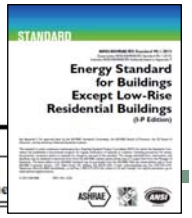


Table 5.5-4 Building Envelope Requirements for Climate Zone 4 (A,B,C)*

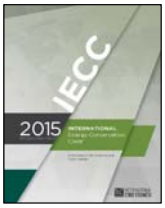
Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.032	R-30 c.i.	U-0.032	R-30 c.i.	U-0.093	R-10 c.i.
Metal Building[a]	U-0.037	R-19 + R-11 Ls or R-25 + R-8 Ls	U-0.037	R-19 + R-11 Ls or R-25 + R-8 Ls	U-0.082	R-19
Attic and Other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
Walls, above Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal Building	U-0.060	R-0 + R-15.8 c.i.	U-0.050	R-0 + R-19 c.i.	U-0.162	R-13
Steel Framed	U-0.064	R-13 + R-7.5 c.i.	U-0.064	R-13 + R-7.5 c.i	U-0.124	R-13
Wood Framed and Other	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.089	R-13
Wall, below Grade						
Below Grade Wall	C-0.119	R-7.5 c.i.	C-0.092	R-10 c.i.	C-1.140	NR
Floors						
Mass	U-0.057	R-14.6 c.i.	U-0.051	R-16.7 c.i.	U-0.107	R-6.3 c.i.
Steel Joist	U-0.038	R-30	U-0.038	R-30	U-0.052	R-19
Wood Framed and Other	U-0.033	R-30	U-0.033	R-30	U-0.051	R-19
Slab-on-Grade Floors						
Unheated	F-0.520	R-15 for 24 in.	F-0.520	R-15 for 24 in.	F-0.730	NR
Heated	F-0.843	R-20 for 24 in.	F-0.688	R-20 for 48 in.	F-0.900	R-10 for 24 in.
Opaque Doors						
Swinging	U-0.500		U-0.500		U-0.700	
Nonswinging	U-0.500		U-0.500		U-1.450	

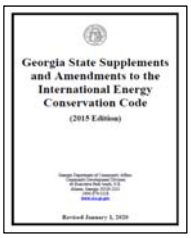
IECC TABLE C402.1.3

2015 INTERNATIONAL ENERGY CONSERVATION CODE®

TABLE C402.1.3
OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, *R*-VALUE METHOD[a]

CLIMATE ZONE	2		3		4 EXCEPT MARINE	
	All other	Group R	All other	Group R	All other	Group R
					Roofs	
Insulation entirely above roof deck	R-25ci	R-25ci	R-25ci	R-25ci	R-30ci	R-30ci
Metal buildings[a, b]	R-19 + R11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS
Attic and other	R-38	R-38	R-38	R-38	R-38	R-38
					Walls, above grade	
Mass	R-5.7ci[c]	R-7.6ci	R-7.6ci	R-9.5ci	R-9.5ci	R-11.4ci
Metal building	R13 + R-6.5ci	R-13 + R-13ci	R-13 + R-6.5ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci
Metal framed	R-13 + R-5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci
Wood framed and other	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20
					Walls, below grade	
Below-grade wall[d]	NR	NR	NR	NR	R-7.5ci	R-7.5ci
					Floors	
Mass[e]	R-6.3ci	R-8.3ci	R-10ci	R-10ci	R-10ci	R-10.4ci
Joist/framing	R-30	R-30	R-30	R-30	R-30	R-30
					Slab-on-grade floors	
Unheated slabs	NR	NR	NR	NR	~~R-10 for 24" below~~	~~R-10 for 24" below~~
Heated slabs[f]	R-7.5 for 12" below	R-7.5 for 12" below	R-10 for 24" below	R-10 for 24" below	R-15 for 24" below	R-15 for 24" below
					Opaque doors	
Nonswinging	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75





*Revise Table C402.1.3 'Opaque Thermal Envelope Insulation Component Minimum Requirements, *R*-Value Method[a]' *Climate Zone* 4 except Marine, for unheated slabs to read as follows:

TABLE C402.1.3
OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, *R*-VALUE METHOD[a]

Climate Zone	4 EXCEPT MARINE	
	All other	Group R
	Slab-on-grade floors	
Unheated slabs	NR	NR

(remainder of table left unchanged)

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ENVELOPE MINIMUM REQUIREMENTS

Poor wall insulation detail

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ENVELOPE MINIMUM REQUIREMENTS

Good wall insulation details

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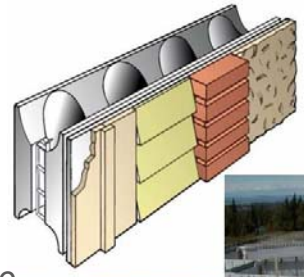
HIGH PERFORMANCE WALLS - ICF'S

CONTINUOUS AIR, THERMAL & MOISTURE BARRIERS

- ICF's are resource efficient & reduce waste
- Cost effective alternative to light gauge steel
- 40% recycled fly ash & slag added to "green" the concrete



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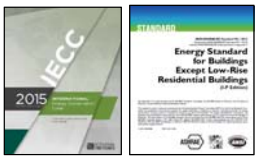
BUILDING ENVELOPE: ROOFS

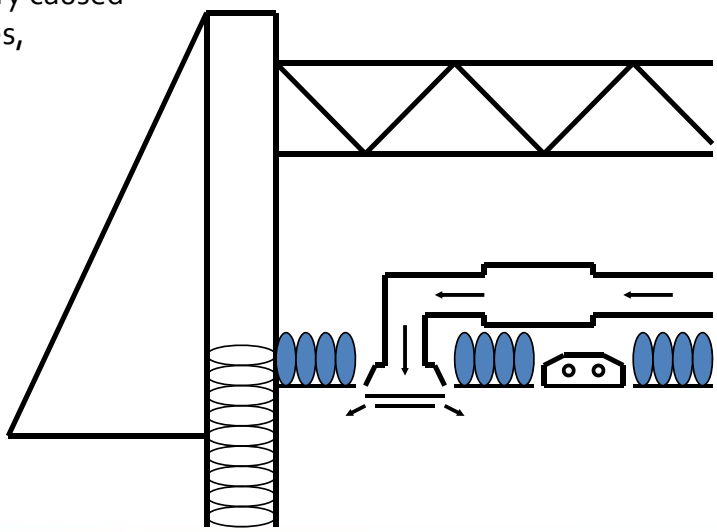


Note: Energy codes ban insulation on top of suspended ceiling (90.1 section 5.8.1.8 ; IECC section C402.2.2)

- **Unacceptable Design:**

  Batts over suspended ceiling tiles

  - Poor pressure boundary caused by tile grid, porous tiles, lighting vent holes
  - Poor durability - maintenance disrupts batts, exposure to fiberglass dust
  - Many thermal breaks due to ductwork, light fixtures, grid, and support wires



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BUILDING ENVELOPE EXAMPLE: ROOFS

- **Unacceptable Design:** Batts over suspended ceiling tiles

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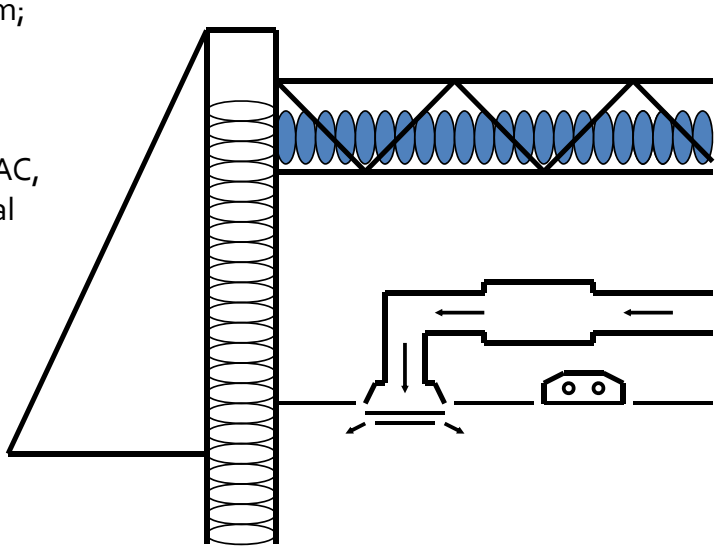
BUILDING ENVELOPE EXAMPLE: ROOFS

- **Okay Design:**

Insulation above hard ceiling

- Example: taped gypsum; similar to residential construction
- Ductwork is inside but must limit and seal HVAC, plumbing, and electrical penetrations through pressure boundary
- Thermal bridging from metal roof trusses



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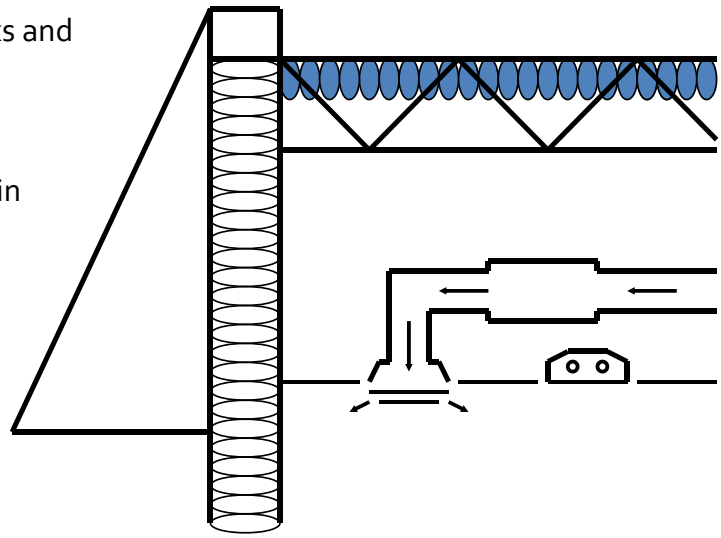
BUILDING ENVELOPE EXAMPLE: ROOFS

- **Very Good Design:**
  Spray foam insulation against underside of roof deck
  - Minimal thermal breaks and continuous pressure boundary
  - HVAC equipment and ductwork located within conditioned space
  - Good durability
  - Retrofit option



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BUILDING ENVELOPE EXAM[LE: ROOFS

Retrofit Option:
Sprayed foam against underside of roof deck

- *Preschool installed new lighting and R-20 foam along roofline*
- *Load reduced from 12 tons to 8*

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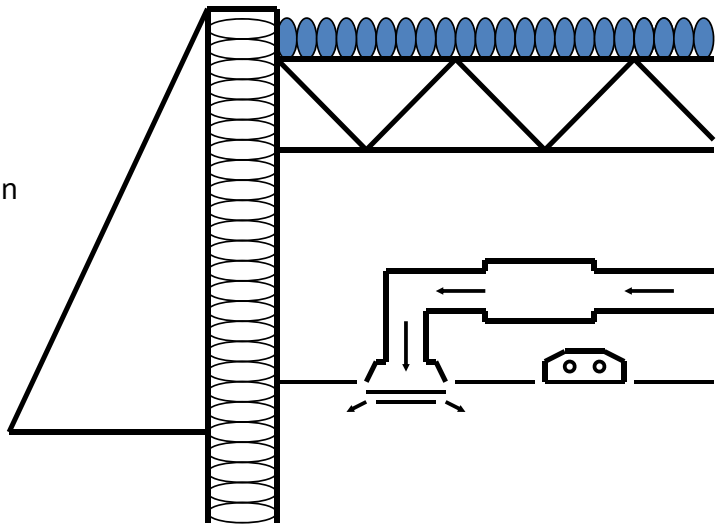
BUILDING ENVELOPE EXAMPLE: ROOFS

- **Best Design:**
  Rigid insulation above roof deck
  - No thermal breaks and continuous pressure boundary
  - HVAC equipment and ductwork located within conditioned space
  - Good durability



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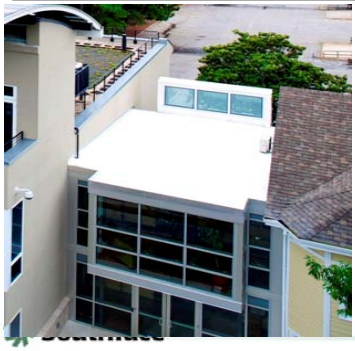
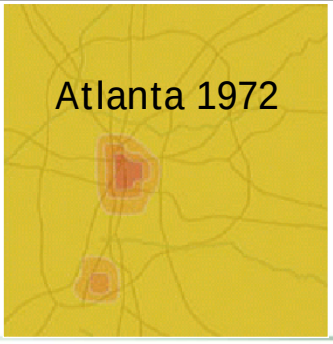
REFLECTIVE ROOF REQUIREMENT

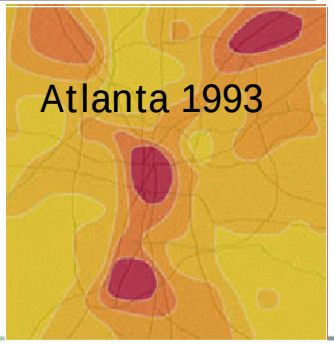
Reflective roofs are now required in CZ 1-3 or else R-value must be increased from R-25 to R-33

Table 5.5.3.1.1 Increased Roof Insulation Levels

Roofs	Nonresidential		Residential	
Opaque Elements	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Insulation entirely above deck	U-0.030	R-33	U-0.029	R-34
Metal buildings	U-0.028	R-35		

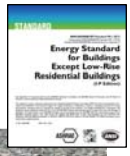






SECTION 5.5.3.1.1: REFLECTIVE ROOF EXCEPTIONS

Cool Roofs required in CZ 1-3



5.5.3.1.1 Roof Solar Reflectance and Thermal Emittance. Roofs in Climate Zones 1 through 3 shall have one of the following:

a. A minimum three-year-aged solar reflectance of 0.55 and a minimum three-year-aged thermal emittance of 0.75 when tested in accordance with CRRC-1 Standard

b. A minimum Solar Reflectance Index of 64 when determined in accordance with the Solar Reflectance Index method in ASTM E1980 using a convection coefficient of 2.1 Btu/h·ft^2·°F, based on three-year-aged solar reflectance and three-year-aged thermal emittance tested in accordance with CRRC-1 Standard

c. Increased roof insulation levels found in Table 5.5.3.1.1

- 3 yr reflectance of ≥ 0.55 and 3 yr thermal emittance ≥ 0.75
- SRI ≥ 64
- R-33-35

Except

a.

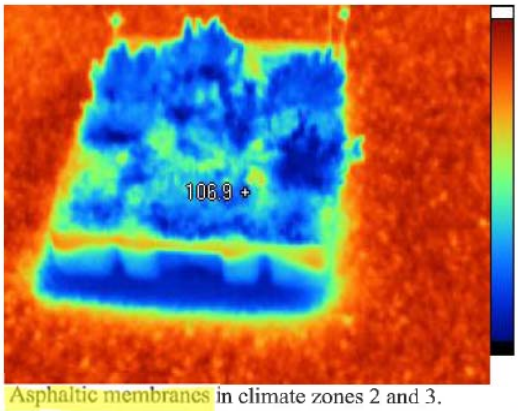
b.

c.

d.

e.

f.



g. Asphaltic membranes in climate zones 2 and 3.

Southface

IECC 402.3 REFLECTIVE ROOFS

Cool Roofs required in CZ 1-3

C402.3 Roof solar reflectance and thermal emittance. Low-sloped roofs directly above cooled conditioned spaces in *Climate Zones* 1, 2 and 3 shall comply with one or more of the options in Table C402.3.

Exceptions: The following roofs and portions of roofs are exempt from the requirements of Table C402.3:

1. Portions of the roof that include or are covered by the following:
   - 1.1. Photovoltaic systems or components.
   - 1.2. Solar air or water-heating systems or components.
   - 1.3. Roof gardens or landscaped roofs.
   - 1.4. Above-roof decks or walkways.
   - 1.5. Skylights.
   - 1.6. HVAC systems and components, and other opaque objects mounted above the roof.
2. Portions of the roof shaded during the peak sun angle on the summer solstice by permanent features of the building or by permanent features of adjacent buildings.
3. Portions of roofs that are ballasted with a minimum stone ballast of 17 pounds per square foot [74 kg/m^2] or 23 psf [117 kg/m^2] pavers.
4. Roofs where not less than 75 percent of the roof area complies with one or more of the exceptions to this section.

- 3 yr reflectance of ≥ 0.55 and 3 yr thermal emittance ≥ 0.75
- SRI ≥ 64

C402.3.1 Aged roof solar reflectance. Where an aged solar reflectance required by Section C402.3 is not available, it shall be determined in accordance with Equation 4-3.

$$R_{aged} = [0.2+0.7(R_{initial}-0.2)] \quad \textbf{(Equation 4-3)}$$

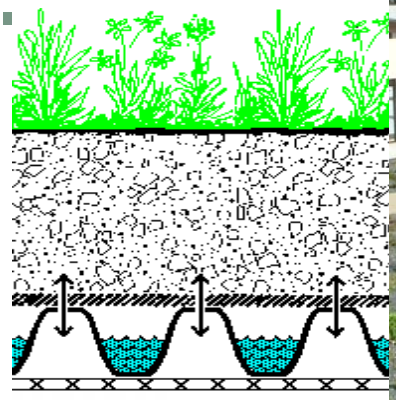
where:

R_{aged} = The aged solar reflectance.

$R_{initial}$ = The initial solar reflectance determined in accordance with CRRC-1.

Southface

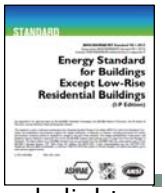
GREEN ROOFS



Green Roof

- reduces heat island
- insulates
- extends life of roof membrane
- absorbs storm water

SECTION 5.5: BUILDING FENESTRATION



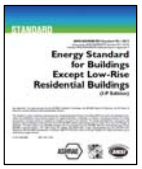
5.5.4 - Prescriptive

- Fenestration
  - Vertical Glazing ≤ 40 (< 30% for IECC)
  - Skylights ≤ 3-6% of roof
  - Daylighting is "required"

Fenestration: All areas (including frames) that let in light, including windows, plastic panels, clerestories, skylights, glass doors that are more than half glass, and glass block walls

Fenestration: Skylights, roof windows, vertical windows (fixed or moveable), "*opaque doors*", glazed doors, glazed block, and combination opaque/glazed doors…

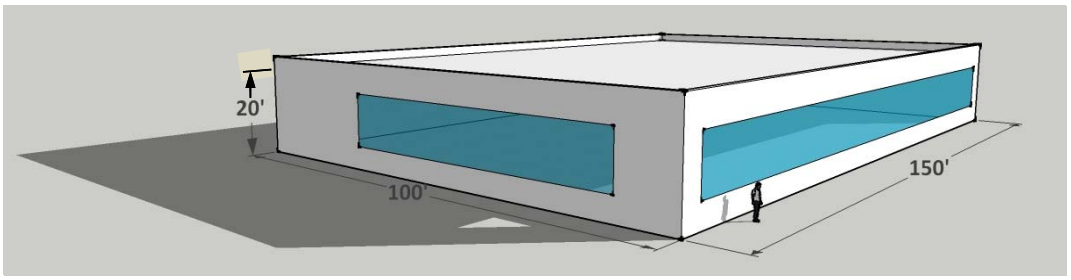
SECTION 5.5.4: FENESTRATION



% Glazing Example

% Glazing = Fenestration Area / Gross Wall Area

What is the % Glazing for a 100'x150' building with 20' high walls and 3,000 sq ft of windows and glass doors?



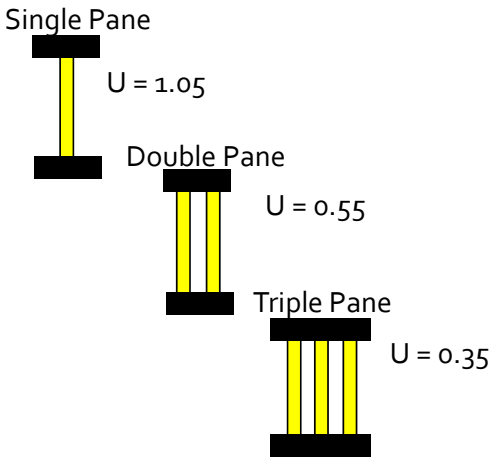
Southface

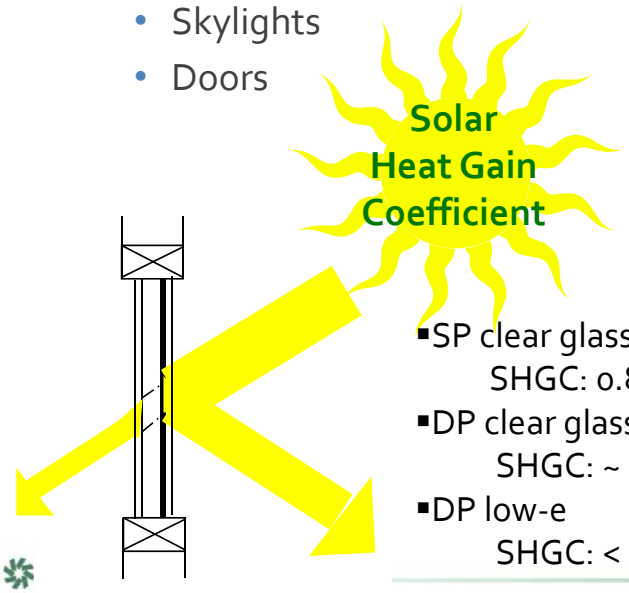
FENESTRATION U-FACTOR & SHGC

Lower **U-factor** = Better insulated (U = 1/R)

U-factor applies to:

- Windows
- Skylights
- Doors



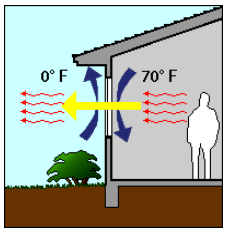


- SP clear glass
  SHGC: 0.8
- DP clear glass
  SHGC: ~ 0.6-0.7
- DP low-e
  SHGC: < 0.2-0.4

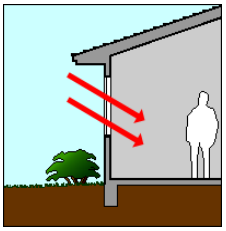
FENESTRATION & DOORS

Energy Performance of Glazing

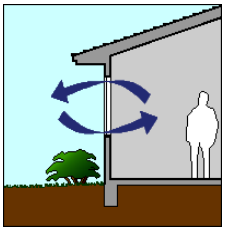
Fenestration Terminology



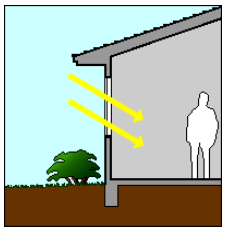
U-Factor



Solar Heat Gain Coefficient (SHGC)



Air Leakage

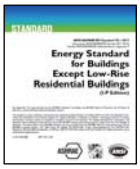


Visible Light Trasmittance (VLT)

- Okay to use weighted average for U-factor and SHGC as long as for a common class of construction or space-conditioning category

Southface

SECTION 5.4.2: FENESTRATION & DOORS



5.8.2 - Mandatory Provisions

Fenestrations and Doors

- Rating, Labeling, & Determination of Fenestration Products: U-factor, SHGC, air leakage, VLT

TABLE A8.2 Assembly U-Factors, Assembly SHGCs, and Assembly Visible Light Transmittances (VLTs) for Unlabeled Vertical Fenestration

Frame Type	Glazing Type	Unlabeled Vertical Fenestration					
		Clear Glass			Tinted Glass		
		U-Factor	SHGC	VLT	U-Factor	SHGC	VLT
All frame types							
	Single glazing	1.25	0.82	0.76	1.25	0.70	0.58
	Glass block	0.60	0.56	0.56	n.a.	n.a.	n.a.
Wood, vinyl, or fiberglass frames							
	Double glazing	0.60	0.59	0.64	0.60	0.42	0.39
	Triple glazing	0.45	0.52	0.57	0.45	0.34	0.21
Metal and other frame types							
	Double glazing	0.90	0.68	0.66	0.90	0.50	0.40
	Triple glazing	0.70	0.60	0.59	0.70	0.42	0.22

Southface

90.1-2013: FENESTRATION – CZ3

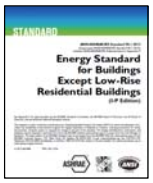


TABLE 5.5-3 Building Envelope Requirements For Climate Zone 3 (A, B, C)*

Fenestration	Nonresidential			Residential			Semiheated		
	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC
Vertical Fenestration, 0%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-0.35			U-0.35			U-0.87		
Metal framing, fixed	U-0.50			U-0.50			U-1.20		
Metal framing, operable	U-0.60	SHGC-0.25	1.10	U-0.60	SHGC-0.25	1.10	U-1.20	NR	NR
Metal framing, entrance door	U-0.77			U-0.68			U-0.77		
Skylight, 0%–3% of Roof									
All types	U-0.55	SHGC-0.35	NR	U-0.55	SHGC-0.35	NR	U-1.70	NR	NR

Southface

90.1-2013: FENESTRATION – CZ2 & 4

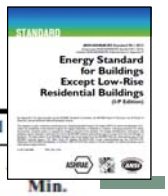


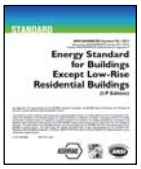
Table 5.5-2 Building Envelope Requirements for Climate Zone 2 (A,B)*

Fenestration	Nonresidential			Residential			Semiheated		
	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Min. VT/SHGC
Vertical Fenestration, 0%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-0.40			U-0.40			U-0.93		
Metal framing, fixed	U-0.57			U-0.57			U-1.20		
Metal framing, operable	U-0.65	SHGC-0.25	1.10	U-0.65	SHGC-0.25	1.10	U-1.20	NR	NR
Metal framing, entrance door	U-0.83			U-0.77			U-0.83		
Skylight, 0%–3% of Roof									
All types	U-0.65	SHGC-0.35	NR	U-0.65	SHGC-0.35	NR	U-1.80	NR	NR

Table 5.5-4 Building Envelope Requirements for Climate Zone 4 (A,B,C)*

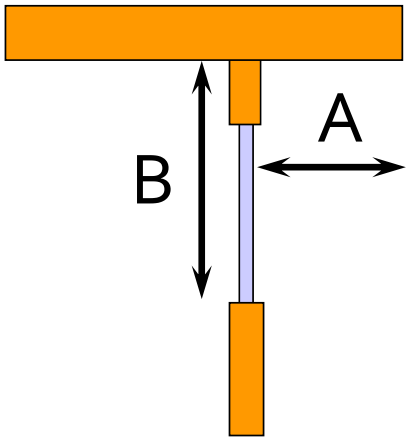
Vertical Fenestration, 0%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-0.35			U-0.35			U-0.51		
Metal framing, fixed	U-0.42			U-0.42			U-0.73		
Metal framing, operable	U-0.50	SHGC-0.40	1.10	U-0.50	SHGC-0.40	1.10	U-0.81	NR	NR
Metal framing, entrance door	U-0.77			U-0.68			U-0.77		
Skylight, 0%–3% of Roof									
All types	U-0.50	SHGC-0.40	NR	U-0.50	SHGC-0.40	NR	U-1.15	NR	NR

SECTION 5.5.4.4.1: OVERHANGS



Projection Factor (PF) and SHGC

PF = Ratio of overhang projection divided by height from window sill to bottom of overhang (must be permanent)



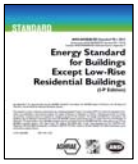
PF = A/B

TABLE 5.5.4.4.1 SHGC Multipliers for Permanent Projections

Projection Factor	SHGC Multiplier (All Other Orientations)	SHGC Multiplier (North-Oriented)
0–0.10	1.00	1.00
>0.10–0.20	0.91	0.95
>0.20–0.30	0.82	0.91
>0.30–0.40	0.74	0.87
>0.40–0.50	0.67	0.84
>0.50–0.60	0.61	0.81
>0.60–0.70	0.56	0.78
>0.70–0.80	0.51	0.76
>0.80–0.90	0.47	0.75
>0.90–1.00	0.44	0.73

Southface

PRESCRIPTIVE GLAZING EXAMPLE



Small Retail Building

All metal curtain-wall glazing is on the Front (East) façade and shaded by a 6′ overhang

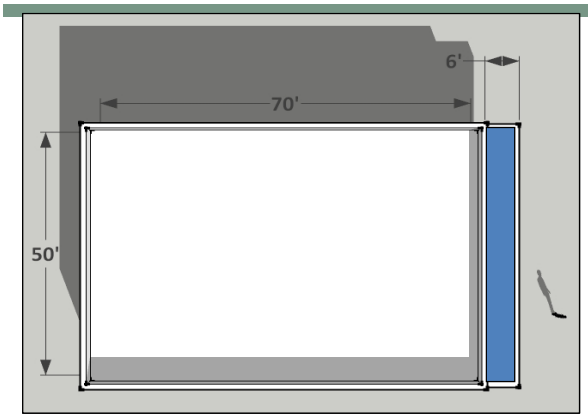
Option 1:

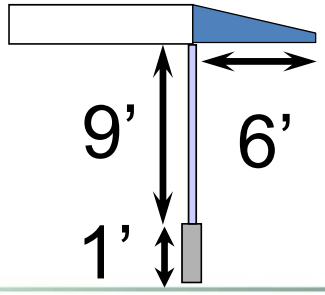
Glazing U = 0.50, SHGC = 0.52

Option 2:

Glazing U = 0.36, SHGC = 0.44

Does either option comply with the CZ3 prescriptive glazing requirements of 90.1?



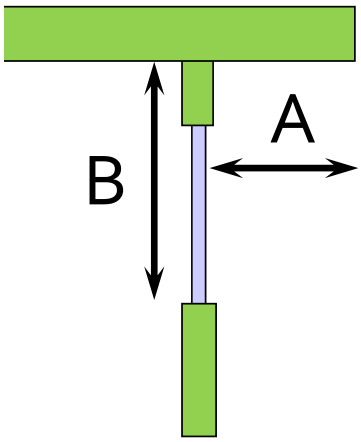


Southface

IECC 402.4 – U_{FACTOR} & SHGC

Projection Factor (PF) and SHGC

PF = Ratio of overhang projection divided by height from window sill to bottom of overhang (must be permanent)



PF = A/B

TABLE C402.4
BUILDING ENVELOPE FENESTRATION MAXIMUM *U*-FACTOR AND SHGC REQUIREMENTS

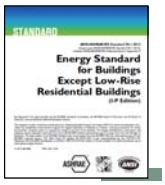
CLIMATE ZONE	2		3		4 EXCEPT MARINE	
Vertical fenestration						
U-factor						
Fixed fenestration	0.50		0.46		0.38	
Operable fenestration	0.65		0.60		0.45	
Entrance doors	0.83		0.77		0.77	
SHGC						
Orientation[a]	SEW	N	SEW	N	SEW	N
PF < 0.2	0.25	0.33	0.25	0.33	0.40	0.53
0.2 ≤ PF < 0.5	0.30	0.37	0.30	0.37	0.48	0.58
PF ≥ 0.5	0.40	0.40	0.40	0.40	0.64	0.64
Skylights						
U-factor	0.65		0.55		0.50	
SHGC	0.35		0.35		0.40	

NR = No requirement, PF = Projection factor.
a. "N" indicates vertical fenestration oriented within 45 degrees of true north. "SEW" indicates orientations other than "N." For buildings in the southern hemisphere, reverse south and north. Buildings located at less than 23.5 degrees latitude shall use SEW for all orientations.

Southface

SECTION 5.5.4.4.1: OVERHANGS

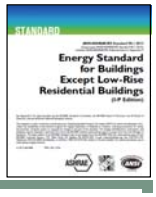
90.1 DAYLIGHTING DETAILS



- 5.5.4.2.2 Max. Skylight Fenestration Area
  - Total skylight area shall not exceed 3% of gross roof area
  - May go to 6% of gross roof area provided design meets all criteria
- 5.5.4.2.3 Minimum Skylight Fenestration Area
  - for any enclosed space in a building (all of the following):
    - ≥2,500 sq. ft.
    - Directly under a roof with ceiling heights greater than 15 feet
    - One of the following space types: office, lobby, atrium, concourse, corridor, warehouse, gym, convention center, courtroom automotive service, fire station engine room, manufacturing, retail, library, distribution/sorting, transportation baggage and seating, or workshop
  - Minimum 50% of floor area is daylit area and either:
    - Provide skylight to daylight area of 3% and VT of 0.4
    - Minimum skylight effective aperture of 1%
  - Many exceptions based on LPD, space type, and side daylighting

Southface

90.1 DAYLIGHTING EXCEPTIONS



5.5.4.2.3 Minimum Skylight Fenestration Area. In any enclosed space in a building that is

a. 2500 ft^2 and greater;
b. directly under a roof with ceiling heights greater than 15 ft; and
c. one of the following space types: office, lobby, atrium, concourse, corridor, storage (including nonrefrigerated warehouse), gymnasium, fitness/exercise area, playing area, gymnasium seating area, convention exhibit/event space, courtroom, automotive service, fire station engine room, manufacturing corridor/transition and bay areas, retail, library reading and stack areas, distribution/sorting area, transportation baggage and seating areas, or workshop,

the total daylight area under skylights shall be a minimum of half the floor area and either

a. provide a minimum skylight area to daylight area under skylights of 3% with a skylight VT of at least 0.40 or
b. provide a minimum skylight effective aperture of at least 1%.

These skylights shall have a glazing material or diffuser with a measured haze value greater than 90% when tested according to ASTM D1003. General lighting in the daylight area shall be controlled as described in Section 9.4.1.1(f).

Exceptions:

1. Enclosed spaces in Climate Zones 6 through 8
2. Enclosed spaces where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed space for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.
3. Enclosed spaces where the daylight area under roof monitors is greater than 50% of the enclosed space floor area
4. Enclosed spaces where it is documented that 90% of the skylight area is shaded on June 21 in the Northern Hemisphere (December 21 in the Southern Hemisphere) at noon by permanent architectural features of the building
5. Enclosed spaces where the total area minus the primary and secondary sidelighted area(s) is less than 2500 ft^2 and where the lighting is controlled according to sidelighting requirements described in Section 9.4.1.1(e)

Southface

DESIGN OF HIGH PERFORMANCE BUILDINGS

Building Siting and Orientation

Sun / Passive Solar Design

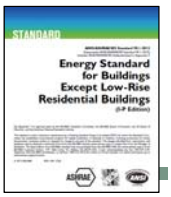
(elongate building on north / south facades)

Wind Orientation

(analyze prevailing winds for natural ventilation / cooling)

Southface

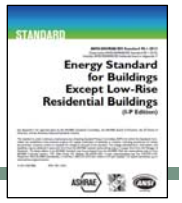
SECTION 5.5.4.4: FENESTRATION SHGC



- Vertical Glazing SHGC shall be ≤ 0.25
  - Exceptions
    - o Opaque and partially opaque permanent projections are credited (calculations)
    - o Glazing using the street-level exception for SHGC
      - – Street level story ≤ 20'
      - – Overhang > 0.5 PF
      - – Fenestration area of street level is < 75% of the gross wall area of the street side
      - – Separate calculations required
    - o Dynamic glazing calculated separately
    - o North oriented glazing allowed 0.05 higher SHGC (0.30)
    - o Separate details for skylight SHGC (with exceptions)

Southface

SECTION 5.5.4.5: FENESTRATION ORIENTATION



- Area of vertical fenestration on east and west facades may not exceed 25% of total area of vertical glazing

5.5.4.5 Fenestration Orientation. The vertical fenestration shall comply with either (a) or (b):

a. $A_W \le (A_T)/4$ and $A_E \le (A_T)/4$

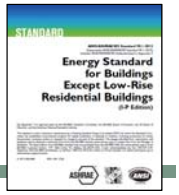
b. $A_W \times \text{SHGC}_W \le (A_T \times \text{SHGC}_C)/4$ and $A_E \times \text{SHGC}_E \le (A_T \times \text{SHGC}_C)/4$

Exceptions:

1. Vertical fenestration that complies with Exception (3) Section 5.5.4.4.1.
2. Buildings that have an existing building or existing permanent infrastructure within 20 ft to the south (north in the southern hemisphere) that is at least half as tall as the proposed building
3. Buildings with shade on 75% of the west- and east-oriented vertical fenestration areas from permanent projections, existing buildings, existing permanent infrastructure, or topography at 9 a.m. and 3 p.m. on the summer solstice (June 21 in the northern hemisphere)
4. Alterations and additions with no increase in vertical fenestration area
5. Buildings where the west-oriented and east-oriented vertical fenestration area (as defined in Section 5.5.4.5) does not exceed 20% of the gross wall area for each of those façades, and SHGC on those facades is no greater than 90% of the criteria in Tables 5.5-1 through 5.5-8

https://vimeo.com/169382048/c973625071

SECTION 5.5.4.6: VT/SHGC RATIO

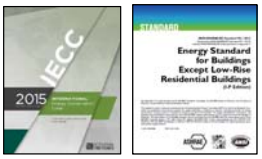


- Where automatic daylighting controls are required, the Visible Transmittance / SHGC ratio shall be $\geq$ 1.1

Exceptions:

1. A light-to-solar-gain ratio (LSG) of not less than 1.25 is allowed to be used as an alternative to VT/SHGC. When using this option, the center-of-glass VT and the center-of-glass SHGC shall be determined in accordance with NFRC 300 and NFRC 301, determined by an independent laboratory or included in a database published by a government agency, and certified by the manufacturer.
2. Fenestration not covered in the scope of the NFRC 200
3. Enclosed spaces where the daylight area under rooftop monitors is greater than 50% of the enclosed space floor area
4. Enclosed spaces with skylight(s) that comply with Section 5.5.4.2.3
5. Enclosed spaces where the sidelighting effective aperture is greater than or equal to 0.15
6. For dynamic glazing, the VT/SHGC ratio and the LSG shall be determined using the maximum VT and maximum SHGC. Dynamic glazing shall be considered separately from other fenestration, and area-weighted averaging with other fenestration that is not dynamic glazing shall not be permitted.

COM*CHECK*™ SOFTWARE



Software evaluates specific designs quickly

Allows trade-offs (web-based or downloadable)

- Building Envelope components
- Lighting and Power components
- Mechanical components

www.energycodes.gov

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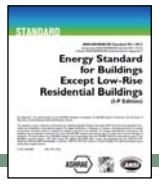
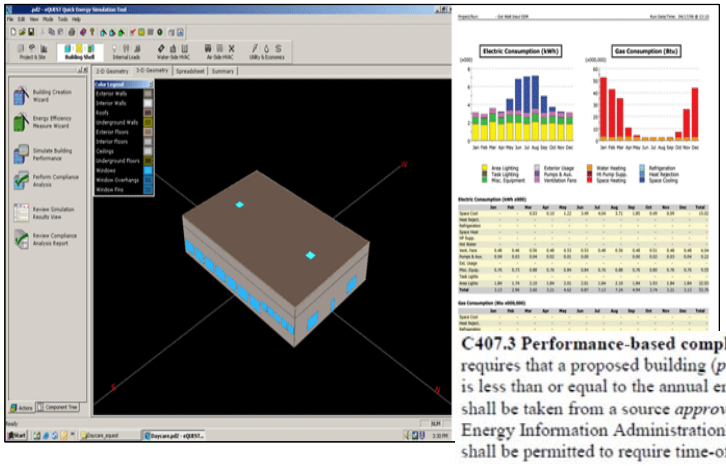
ENVELOPE TRADE-OFFS

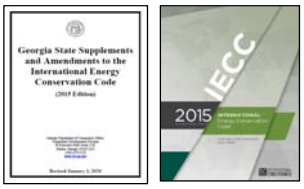


90.1 Section 11 - Energy Cost Budget Method

- Must comply with mandatory provisions



the design energy cost, as calculated in Section 11.5, does not exceed the energy cost budget as calculated by the simulation program described in Section 11.4;



C407.3 Performance-based compliance. Compliance based on total building performance requires that a proposed building *(proposed design)* be shown to have an annual energy cost that is less than or equal to the annual energy cost of the *standard reference design*. Energy prices shall be taken from a source *approved* by the *code official*, such as the Department of Energy, Energy Information Administration's *State Energy Price and Expenditure Report*. *Code officials* shall be permitted to require time-of-use pricing in energy cost calculations.

The reduction in annual energy cost of the *proposed design* associated with *on-site renewable energy* shall be not more than 5% of the total annual energy cost. The amount of renewable energy purchased from off-site sources shall be the same in the *standard reference design* and the *proposed design*.

Exception: Jurisdictions that require site energy (1 kWh = 3413 Btu) rather than energy cost as the metric of comparison.
(Effective January 1, 2020)

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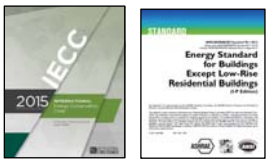
SECTION 5.4: BUILDING ENVELOPE



5.4.3.1.3 Continuous Air Barrier

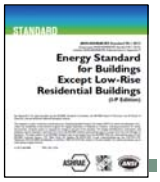
The air barrier shall be designed and noted:

- Air barrier components shall be identified on construction documents
- Joints, interconnections, and penetrations of air barrier including lighting fixtures shall be detailed or otherwise noted
- Air barrier shall extend over all surfaces of the envelope
- Air barrier shall be designed to resist positive and negative pressures from wind, stack effect, and vent fans

Acceptable air barrier materials/assemblies

- 3/8" plywood & OSB
- ½" XPS & poly-iso
- ½" Gyp board
- ½" Cement board
- Built up, modified bit, & adhered single-ply roof membranes
- ½" cement parge, stucco or gyp board
- Concrete
- Sheet metal
- 1" (1.5") Closed cell foam
- 4.5" Open cell foam
- CMU walls – painted/grouted
- Sheet steel/aluminum

SECTION 5.4: BUILDING ENVELOPE

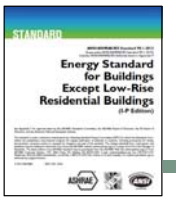


5.4.3.1 - Mandatory Provision – Air Sealing

The following areas of the continuous air barrier in the building envelope shall be wrapped, sealed, caulked, gasketed, or taped to minimize air leakage:

- joints around fenestration and door frames
- envelope component junctions
- at all penetrations
- site-built fenestration and doors
- building assemblies used as ducts or plenums
- joints, seams, and penetrations through air barrier
- changes in air barrier materials

SECTION 5: ENVELOPE AIR SEALING

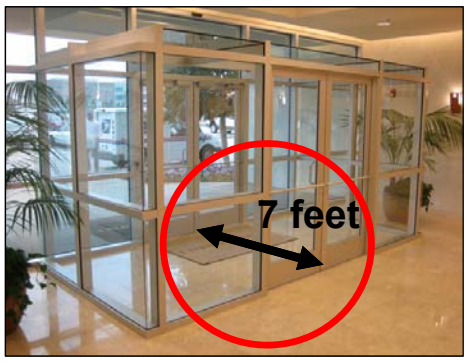


5.4 - Mandatory Provision

- Air Leakage – Vestibules (5.4.3.4)

Vestibules are required in CZ 3-8 for entrances in buildings

- All doors must be equipped with self-closing devices
- Interior and exterior doors at least 7 ft apart
- Floor area of vestibule ≤ 50 s.f. or 2% of gross area of floor
- Envelope of unconditioned vestibule (interior/exterior) meets semi-heated



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Exceptions:

- revolving doors, non-entrance doors, and dwelling unit doors
- not required in CZ 1-2
- Entrances in CZ3 for buildings < 4 stories and < 10,000 s.f.
- Entrances in CZ4-8 for buildings < 1,000 s.f.
- Doors from a space < 3,000 s.f. and separate from the entrance

CONDITIONING VESTIBULES?

C402.4.8: RECESSED LIGHTING

Air Leakage – Recessed Luminaires

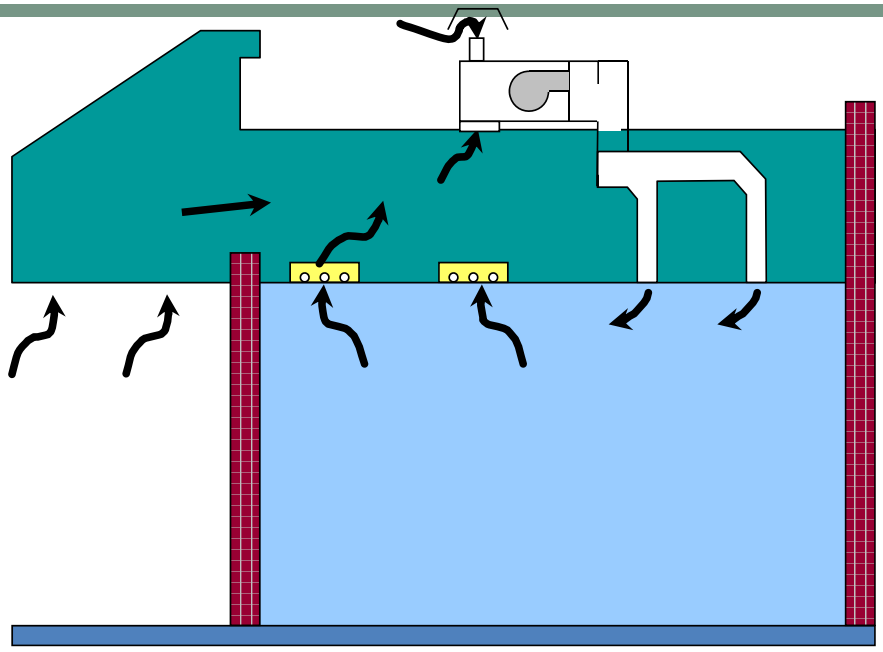
Recessed lights must be air sealed to limit air leakage between conditioned and unconditioned space

- IC-rated
- Air tight (not more than 2.0 cfm leakage at 75 Pa

MAJOR AIR LEAKAGE SITES

- Cavities above suspended ceilings
- Plenum return spaces (Highly depressurized)
- Ventilated walls
- Equipment tunnels and chases
- Mechanical rooms and mezzanines
- Unconditioned adjacent space (storage, plant, warehouse, etc.)

RETURN PLENUM PROBLEMS - CANOPY



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ENVELOPE – AIR SEALING

Air sealing – mandatory requirement and cannot be traded off

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ENERGY EFFICIENT BUILDING ENVELOPE

Blower Door Testing – Recognized by IECC

- Prove Air Sealing
- Envelope Integrity

C402.5 Air leakage—thermal envelope (Mandatory). The *thermal envelope* of buildings shall comply with Sections C402.5.1 through C402.5.8, or the building *thermal envelope* shall be tested in accordance with ASTM E 779 at a pressure differential of 0.3 inch water gauge (75 Pa) or an equivalent method approved by the code official and deemed to comply with the provisions of this section when the tested air leakage rate of the building thermal envelope is not greater than 0.40 cfm/ft² (0.2 L/s · m²). Where compliance is based on such testing, the building shall also comply with Sections C402.5.5, C402.5.6 and C402.5.7.

$$ELR_{75} = \frac{CFM_{75}}{\text{shell area}}$$

$$ELR_{75} \leq 0.40$$

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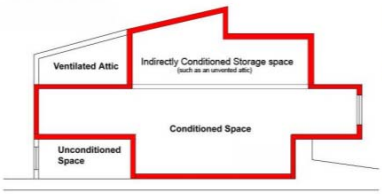
ENVELOPE LEAKAGE RATIO @ 75
ELR75 – A BETTER METRIC

- Leakage occurs through shell of building (not through volume)
- Normalizing leakage at 75Pa (0.3 in w.c.) based on shell area is most common for commercial buildings



Building Thermal Envelope

The building thermal envelope is the portion of the building envelope that is comprised of the continuous air barrier and insulation and separates conditioned space from unconditioned space.

Example Calculation

A 7,600 square foot building (First floor: 3,600 square feet and second floor: 4,000 square feet) has a shell area of 13,920 square feet. The blower door test measures a flow of 3,340 CFM_{75}.

What is the Envelope Leakage Ratio at 75 Pa?

ELR75 is calculated by dividing the measured CFM75 by the total shell area of the envelope.

$$\textbf{\textit{Shell Area}} = 4000ft^2 + 4000ft^2 + 5920ft^2 = \mathbf{13{,}920}ft^2$$

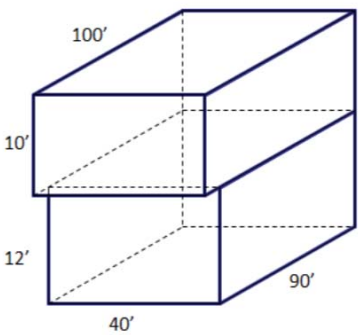
$$\textbf{\textit{BD Fan Flow Measurement}} = \mathbf{3{,}340}\ \textbf{\textit{CFM}}_{75}$$

$$\textbf{\textit{ELR}}_{75} = \frac{\textbf{\textit{CFM}}_{75}}{\textbf{\textit{Shell Area}}}$$

$$\textbf{\textit{ELR}}_{75} = \frac{3{,}340\ CFM_{75}}{13{,}920\ sf}$$

$$\textbf{\textit{ELR}}_{75} = \mathbf{0.24}$$

Envelope passes program requirement and earns additional points



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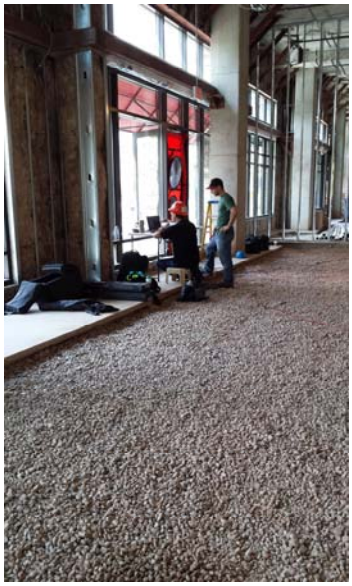
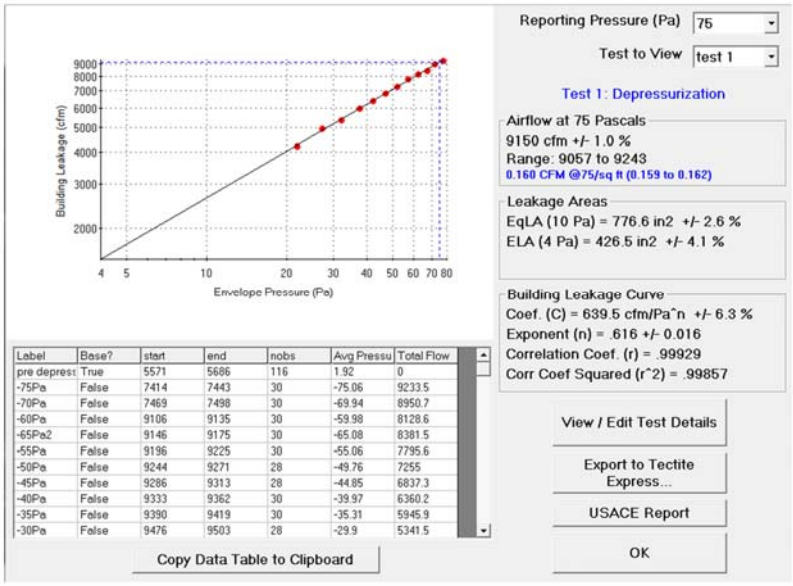
MULTI-BLOWER DOOR – ENVELOPE LEAKAGE TEST





Label	Base?	start	end	nobs	Avg Pressu	Total Flow
pre depress	True	5571	5686	116	1.92	0
-75Pa	False	7414	7443	30	-75.06	9233.5
-70Pa	False	7469	7498	30	-69.94	8950.7
-60Pa	False	9106	9135	30	-59.98	8128.6
-65Pa2	False	9146	9175	30	-65.08	8381.5
-55Pa	False	9196	9225	30	-55.06	7795.6
-50Pa	False	9244	9271	28	-49.76	7255
-45Pa	False	9286	9313	28	-44.85	6837.3
-40Pa	False	9333	9362	30	-39.97	6360.2
-35Pa	False	9390	9419	30	-35.31	5945.9
-30Pa	False	9476	9503	28	-29.9	5341.5

Commercial Envelope Trivia 1

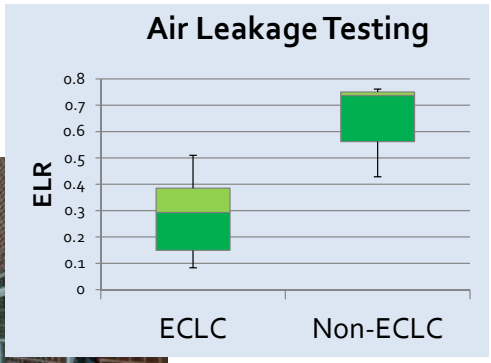
Which of these statements are false?

- LEED Buildings are guaranteed efficient and air tight
- Building age is an indicator of how leaky it is
- The materials chosen for building predict the tightness of the envelope

Commercial Envelope Trivia 2

Based on our testing data, a new commercial building with an intentionally defined air barrier will (on average) be how many times tighter than an standard building?

A. 1.5 times
B. 2 times
C. Over 3 times
D. Over 100 times



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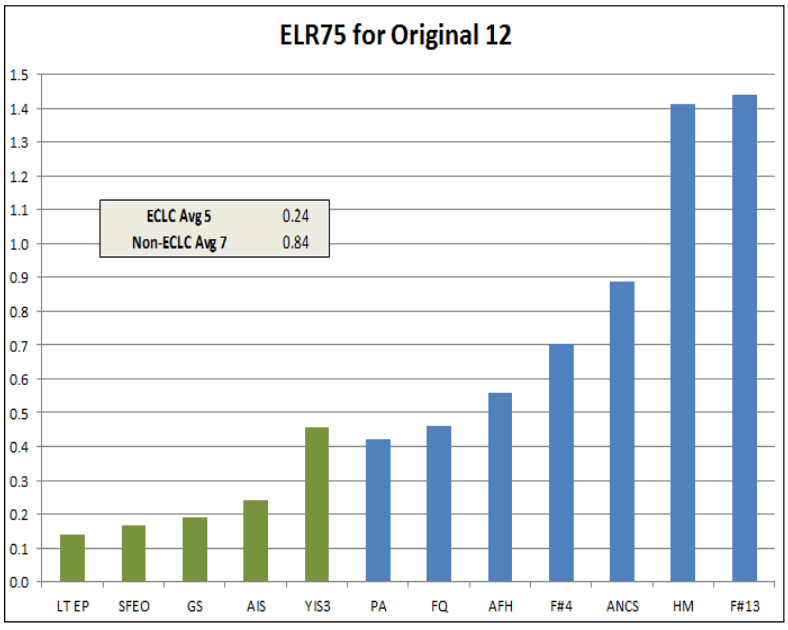
ENVELOPE LEAKAGE RATIOS FOR 12 BUILDINGS



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ADDITIONAL BUILDINGS – SIMILAR RESULTS

Test Buildings	Date of Test	Cond. Floor Area (s.f.)	SFBE	# of Stories	ELR75	Depressurization @-75Pa (masked)	Pressurization @+75Pa (masked)
	11/11/2014	4,261	13,219	1	0.429	5,666	5,518
	11/17/2014	6,692	16,829	2	1.201	20,214	19,589
	12/4/2014	2,128	5,760	1	0.623	3,587	3,628
	12/10/2014	1,081	3,562	1	0.626	2,230	2,269
	12/15/2014	1,480	5,480	1	0.562	3,081	3,501
	12/16/2014	2,207	8,878	1	0.750	6,662	6,745
	12/17/2014	1,586	6,743	1	0.761	5,134	5,134
	12/18/2014	1,895	7,907	1	0.737	5,825	5,662
	12/19/2014	1,561	6,674	1	0.330	2,200	2,181
	1/14/2015	12,142	32,873	1	0.639	21,020	22,286
	2/4/2015	3,416	9,336	1	0.493	4,601	4,672
	2/9/2015	4,236	10,390	1	0.500	5,195	5,194
	11/12/2015	11,417	20,297	3	0.184	3,740	4,738
	1/11/2016	3,020	8,123	1	0.517	4,200	4,553
	1/12/2016	4,315	14,359	1	1.028	14,758	16,428
	1/13/2016	3,900	12,000	1	1.244	14,933	15,513
	8/22/2012	21,628	44,259	2	0.339	15,019	n/a
	5/22/2014	11,202	37,370	1	0.188	7,030	n/a
	6/11/2014	1,634	4,847	2	0.394	1,910	2,352
	6/11/2014	500	2,545	1	0.251	638	791
	7/10/2014	6,082	13,937	1	1.021	14,224	
	7/29/2014	4,615	11,165	1	1.296	14,467	15,824
	8/4/2014	4,615	14,668	1	0.581	8,515	
	8/18/2014	4,615	14,668	1	0.422	6,192	6,402
	8/26/2014	1,135	3,949	1	0.313	1,238	
	8/26/2014	1,680	6,409	1	0.360	2,310	
	10/2/2014	1,135	3,949	1	0.13	514	
	10/2/2014	1,680	6,409	1	0.12	798	

ANALYZING TESTING RESULTS

- **All buildings are created unequal** – no apparent correlation between age, type of construction, location, etc.
- **Air Sealing** – starts at design
- **Existing buildings** – can be retro sealed
- **Designed air barrier** – 0.25 ELR_{75};
  (average existing 0.76 – over 3 times leakier!)
- **Modeling tools** vary significantly in predicted savings from air sealing – approximately~10%

BUILDING ENVELOPE

Case Study Overview

- Dining Hall
  - One Story; 4,615 sf; climate zone 3A
  - SFBE 14,668 sf; CMU with brick veneer

- House of Worship
  - One Story; 12,864 sf; climate zone 3A
  - SFBE 36,845 sf; metal stud with EIFS

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BUILDING ENVELOPE

Findings of Case Study

- Dining Hall
  - VE effort to save on materials led to increased cost and time on new envelope solution
  - Following manufacturer material installation recommendations did not always happen

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BUILDING ENVELOPE



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BUILDING ENVELOPE

Findings of Case Study

- House of Worship
  - Designate materials that will act as air barrier
  - Create material transition location details to link one air barrier material to the next



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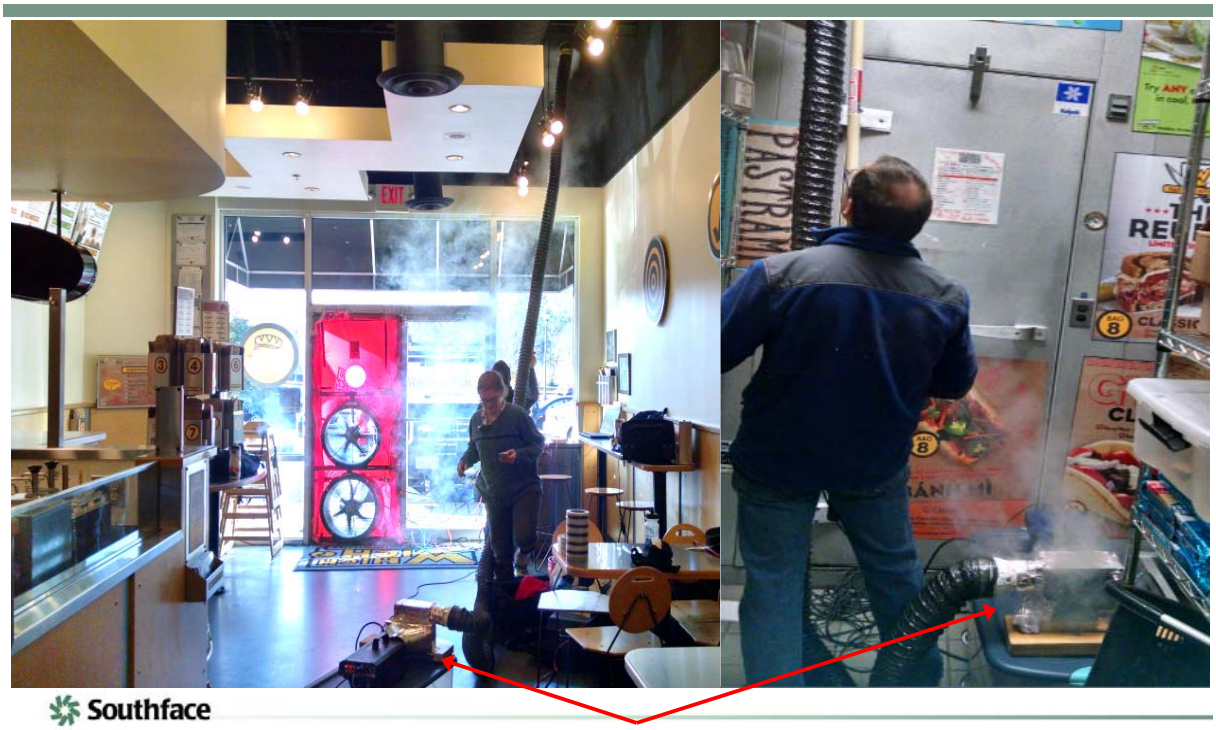
BUILDING ENVELOPE

Case Study Findings

- Inline Retail
  - Envelope Transitions

UTILITY CHASE

HOW TO GET FOG IN THE RIGHT PLACE



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RTU ENVELOPE PENETRATIONS

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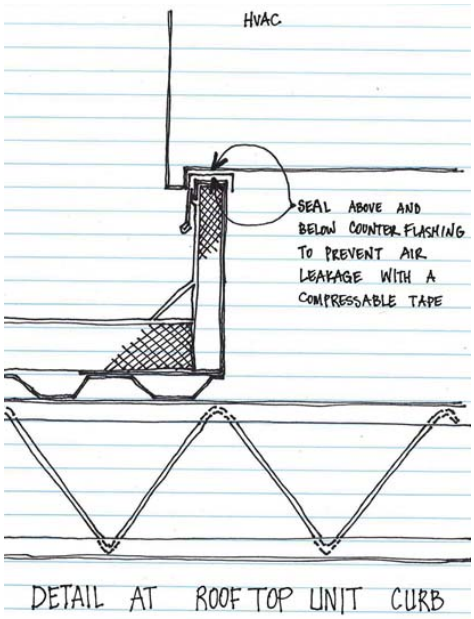
RTU ENVELOPE PENETRATIONS



Wall and roof penetration require sealing at curb and equipment

ROOF MEMBRANE CONNECTIONS

PARAPET LEAK

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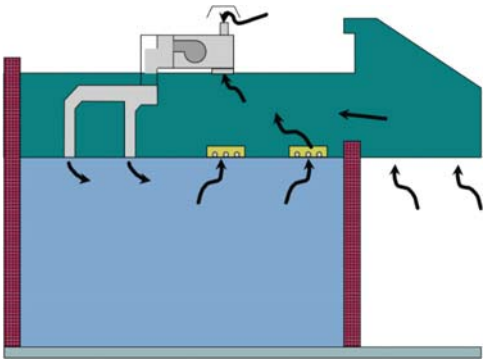
AIR BARRIER CONTINUITY



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Commercial Envelope Trivia 3

"Water stains on dropped ceiling tiles are usually a sign of plumbing/roofing leaks."

- True
- False

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BUILDING ENVELOPE

Dirty carpet on exterior wall indicates leak at wall sill plate; on interior wall indicates wall leaking to attic

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Commercial Envelope Trivia 4

An effective roof insulation strategy is to add fiberglass batts to a drop ceiling assembly.

- True
- False

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Lighting and Appliances Trivia 1

"If you are gone for 20 minutes, it's better to leave the lights on the whole time since turning lights off and then on causes a surge in power consumption."

- True
- False

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Lighting and Appliances Trivia 2

"Lighting retrofit to LED's is typically less than a 7 year payback (ROI)."

- True
- False

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LED RETROFITS OPTIONS FOR TUBE FLUORESCENTS

There are different levels of LED retrofits for fluorescent fixtures

A. Entirely new LED fixture
B. Keep the existing fixture housing - replace the electronics, lens and lighting with LED
C. Keep the existing fixture but upgrade to electronic ballast and install LED tubes
D. Swap the fluorescent tubes with LED tubes

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LED Retrofits – Scenarios Trivia 3

Match the LED Retrofit scenario with a letter (below)

- 100 yr-old Scott Agnes College had recently (3 years ago) upgraded from T-8 fluorescents to T-5 with new electronic ballasts
- 1992 former Storage building with original T-12 fixtures being converted to open retail market
- 2004 Rec Center with well-maintained fixtures wants to upgrade from original T-8 fluorescents
- 1999 Doctor's office with under-lit patient rooms and ugly four-lamp T-8 troffers

A. New LED fixture
B. Keep existing fixture but replace "guts"
C. Keep existing fixture new electron ballasts and LED tubes
D. Swap fluorescent tubes with LED tubes

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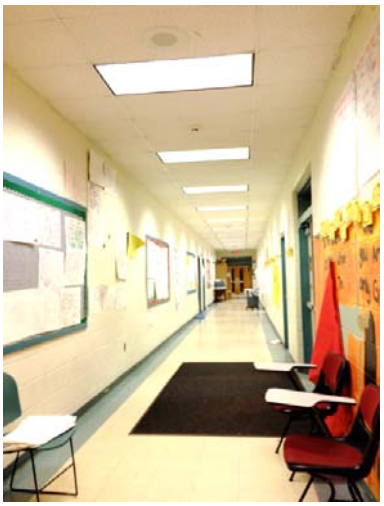
Lighting and Appliances Trivia 4

"New lighting fixture retrofits should be one-for-one in terms of fixture counts."

- True
- False



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Lighting and Appliances Trivia 5

"Vacancy Sensor controls save more energy than Occupancy Sensors."

- True
- False

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INTERIOR & EXTERIOR LIGHTING CONTROLS

Fostering human habits proves to save energy

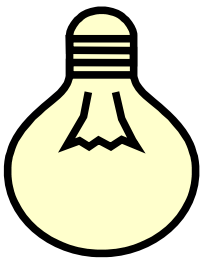
- Vacancy sensors preferred
- Occupancy sensors (no daylight)
- Multi-level controls
- Photosensors for daylit areas
- Automatic shut-offs
- Building automation systems or scheduled auto off
- KISS principle and verify/Cx

SECTION 9: LIGHTING

Key Section Changes 90.1-2007 vs. 2013

Lighting Alterations must meet Lighting Power Density (LPD)

- Now take effect at ≥ 10% replacement
- Include exterior areas
- Include renovations where just the lamp / ballast is replaced
- Require compliance with auto shut off controls



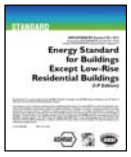
Lighting Power

- LPD tables changes (~ 15% reduction overall)
- Bonus LPD now available for advanced control spaces
- Retail allowances have been reduced
- Exterior LPD now based on 5 lighting zones

Lighting Controls

- Bi-level control requirement added
- Auto shut off now required in all buildings
- Auto shut off required for more spaces
- Functional testing now required
- Daylight harvesting required in certain situations

SECTION 9: LIGHTING



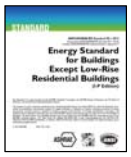
9.1.1 Scope:

- Interior spaces of buildings
- Exterior building features
- Exterior lighting powered through building

Exceptions:

- Emergency lighting that is normally off
- Lighting required by life safety statute
- Lighting within dwelling units of buildings
- Decorative gas lighting

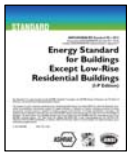
SECTION 9: LIGHTING



How this presentation considers lighting

Interior	**Exterior**
Budget	Budget
Installed Design (exemptions)	Installed Design (exemptions)
Controls	Controls

SECTION 9.5&6: INTERIOR LIGHTING BUDGET



Interior Lighting Power Budget

9.5 Building Area Method

or

9.6 Space by Space Method

- Trade-offs not allowed between different methods
- Actual installed interior lighting fixtures ≤ allowance

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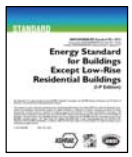
SECTION 9.5: INTERIOR LIGHTING BUDGET



9.5.1 - Building Area Method

Used for projects involving

- An entire building
- A single, independent, and separate occupancy in a multi-occupancy building

Most Building Types listed

- "Selection of a reasonably equivalent type" is permitted

Multiply Gross Lighted Floor Area (measured from the exterior faces of the exterior walls or from the centerline of walls separating buildings) by allowance from Table 9.5.1

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SECTION 9.5: INTERIOR LIGHTING BUDGET

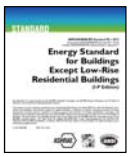

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	LPD, W/ft^2
Automotive facility	0.80
Convention center	1.01
Courthouse	1.01
Dining: Bar lounge/leisure	101
Dining: Cafeteria/fast food	0.90
Dining: Family	0.95
Dormitory	0.57
Exercise center	0.84
Fire station	0.671
Gymnasium	0.94
Health-care clinic	0.90
Hospital	1.05
Hotel/Motel	0.87
Library	1.19

Building Area Type[a]	*LPD* (W/ft^2)
Manufacturing facility	1.17
Motion picture theater	0.76
Multifamily	0.51
Museum	1.02
Office	0.82
Parking garage	0.21
Penitentiary	0.81
Performing arts theater	1.39
Police station	0.87
Post office	0.87
Religious building	1.00
Retail	1.26
School/university	0.87
Sports arena	0.91
Town hall	0.89
Transportation	0.70
Warehouse	0.66
Workshop	1.19

What is "budget" for a 10k office building?

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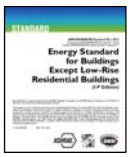
SECTION 9.6: INTERIOR LIGHTING BUDGET



9.6.1 – Space-by-Space Method

Identify different space types in your project

Determine gross lighted area of all space types

Calculate lighting power allowance per LPD table

Sum all the allowances for each space type

Trade-offs between subspaces are permitted

Advantages

- More flexible
- Applicable to more building types
- Opportunity for additional allowances

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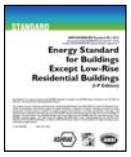
SECTION 9.6: INTERIOR LIGHTING BUDGET



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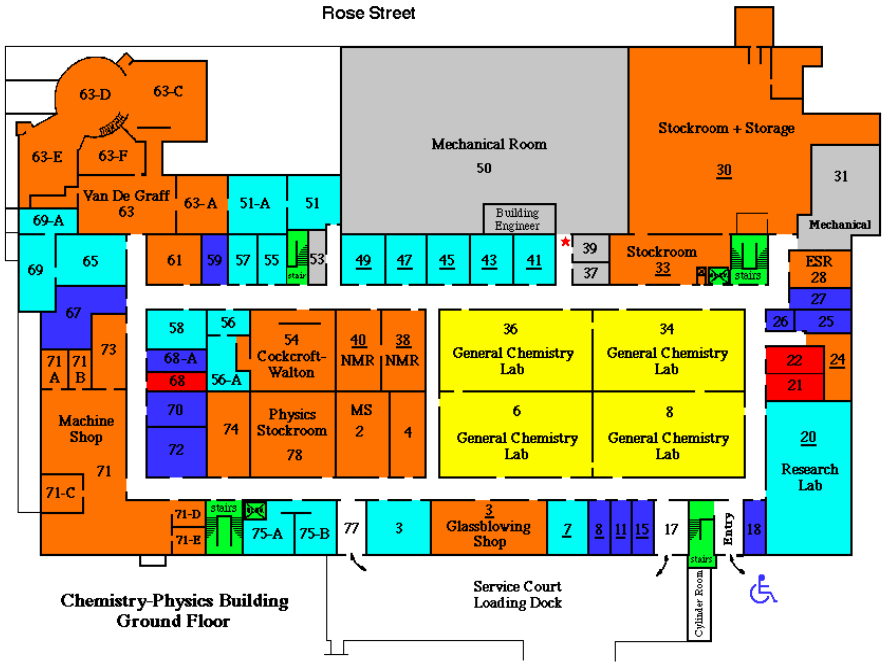

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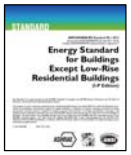
SECTION 9.6.1: SPACE BY SPACE SAMPLE TABLE



Common Space Types[1]	LPD, W/ft^2	RCR Threshold
Office		
… enclosed and ≤250 ft^2	1.11	8
… enclosed and >250 ft^2	1.11	8
… open plan	0.98	4
Parking Area, Interior	0.19	4
Pharmacy Area	1.68	6
Restroom		
… in a facility for the visually impaired (and not used primarily by the staff)[3]	1.21	8
… all other restrooms	0.98	8
Sales Area[4]	1.44	6
Seating Area, General	0.54	4
Stairway		
Stairwell	0.69	10
Storage Room		
… <50 ft^2	1.24	6
… ≥50 ft^2 and ≤ 1000 ft^2	0.63	6
… all other storage rooms	0.63	6
Vehicular Maintenance Area	0.67	4
Workshop	1.59	6

Informative Note: **This table is divided into two sections; this first section covers space types that can be commonly found in multiple building types. The second part of this table covers space types that are typically found in a single building type.**

Building Type Specific/Space Types[1]	LPD W/ft^2	RCR Threshold
… in a nurse's station	0.71	6
… in an operating room	2.48	6
… in a patient room	0.62	6
… in a physical therapy room	0.91	6
… in a recovery room	1.15	6
Library		
… in a reading area	1.06	4
… in the stacks	1.71	4
Manufacturing Facility		
… in a detailed manufacturing area	1.29	4
… in an equipment room	0.74	6
… in an extra high bay area (>50 ft floor-to-ceiling height)	1.05	4
… in a high bay area (25–50 ft floor-to-ceiling height)	1.23	4
… in a low bay area (<25 ft floor-to-ceiling height)	1.19	4
Museum		
… in a general exhibition area	1.05	6
… in a restoration room	1.02	6

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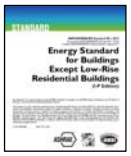
SECTION 9.6: INTERIOR LIGHTING BUDGET



9.6.2 - Space-by-Space Method

Additional Interior Lighting Power

Decorative / highlighting luminaires

- 1.0 W/ft² in space where used

Retail Sales Area (Base 1.68 W/ft²)

Additional Allowance = 1000 watts

+ (Retail Area 1 x .6 W/ft2)

+ (Retail Area 2 x .6 W/ft²)

+ (Retail Area 3 x 1.4 W/ft²)

+ (Retail Area 4 x 2.5 W/ft²)

Retail 1 – All goods not covered in 2, 3, 4
Retail 2 – vehicles, sporting goods, small electronics
Retail 3 – furniture, clothing, cosmetics, artwork
Retail 4 – jewelry, crystal, china

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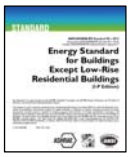
SECTION 9: INTERIOR LIGHTING BUDGET



9.6.3 – Space-by-Space Method

Additional Interior Lighting Power Using Better Controls (5% to 30% bonus)*

*Additional interior lighting control = lighting power under control **X** control factor (per table 9.6.3)

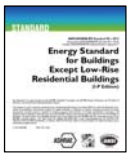
TABLE 9.6.3 Control Factors Used in Calculating Additional Interior Lighting Power Allowance

Additional Control Method (in Addition to Mandatory Requirements)	Space Type				
	Open Office	Private Office	Conference Room, Meeting Room, Classroom (Lecture/ Training)	Retail Sales Area	Lobby, Atrium, Dining Area, Corridors/ Stairways, Gym/ Pool, Mall Concourse, Parking Garage
Manual, continuous dimming control or programmable multilevel dimming control	0.05	0.05	0.10	0.10	0
Programmable multilevel dimming control using programmable time scheduling	0.05	0.05	0.10	0.10	0.10
Occupancy sensors controlling the downlight component of workstation specific luminaires with continuous dimming to off capabilities	0.25[a]	0	0	0	0
Occupancy sensors controlling the downlight component of workstation specific luminaires with continuous dimming to off operation, in combination with personal continuous dimming control of downlight illumination by workstation occupant	0.30[a,b]	0	0	0	0
Automatic continuous daylight dimming in secondary sidelighted areas	0.10[c]	0.10[c]	0.10[c]	0.10[c]	0.10[c]

a. Control factor is limited to workstation-specific luminaires in partitioned single occupant work spaces contained within an open office environment (i.e. direct-indirect luminaires with separately controlled downlight and uplight components, with the downward component providing illumination to a single occupant in an open plan workstation). Within 30 minutes of the occupant leaving the space, the downward component shall continuously dim to off over a minimum of two minutes. Upon the occupant entering the space, the downward component shall turn on at the minimum level and continuously raise the illumination to a preset level over a minimum of 30 seconds. The uplight component of workstation specific luminaire shall comply with Section 9.4.1.1(h) (automatic full off).
b. In addition to the requirements described in footnote (b), the control shall allow the occupant to select their preferred light level via a personal computer, handheld device, or similarly accessible device located within the workstation.
c. Control factors may not be used if controls are used to satisfy exceptions to Section 5.5.4.2.3

SECTION 9: INTERIOR LIGHTING BUDGET

9.6.4 – Space-by-Space Method



Room Geometry Adjustment

(20% LPD bonus if calculated RCR is greater than RCR threshold)

RCR = 2.5 **X** room cavity height* **X** room perimeter length**/** room area

*Room cavity height = luminaire mounting height - workplane

Example: 30'x40' open office with 16.5' fixture height: RCR = 2.5 x 14 x (140/1200) = **4.1**

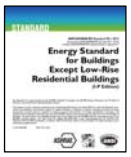
TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method

Common Space Types[a]	LPD, W/ft²	RCR Threshold
Audience Seating Area		
… in an auditorium	0.63	6
… in a convention center	0.82	4
… in a gymnasium	0.65	6
… in a motion picture theater	1.14	4
… in a penitentiary	0.28	4
… in a performing arts theater	2.43	8
… in a religious building	1.53	4
… in a sports arena	0.43	4
… all other audience seating areas	0.43	4
Banking Activity Area	1.01	6

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method *(continued)*

Building-Specific Space Types	*LPD*, W/ft²	RCR Threshold
Office		
… enclosed and ≤250 ft²	1.11	8
… enclosed and >250 ft²	1.11	8
… open plan	0.98	4
Parking Area, Interior	0.19	4
Pharmacy Area	1.68	6
Restroom		
… in a facility for the visually impaired (and not used primarily by the staff)[3]	1.21	8
… all other restrooms	0.98	8
Sales Area[4]	1.44	6
Seating Area, General	0.54	4

SECTION 9.1.3: LIGHTING DESIGN WATTAGE



Installed Interior Lighting Design

1. First, determine interior lighting power allowance (budget) using either the Building Area Method or the Space-by-Space Method
2. Calculate installed interior lighting design
3. Actual installed interior lighting fixture wattage shall not exceed the interior lighting power allowance (budget)

Installed Wattage ≤ Budget Wattage

HOW EFFICIENT IS LIGHTING?

Efficacy – *"miles per gallon"*

The ratio of light output to watts input

- lumens per watt

The higher the efficacy, the more efficient the light source

- 40 watt incandescent = 495 lumens (~12)
- 40 watt fluorescent = 3,150 lumens (~80)

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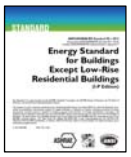
SECTION 9.2.2.3: LIGHTING DESIGN

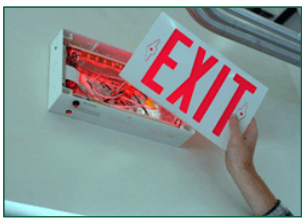


Interior Lighting Power Allowance Exemptions

(often require separate control)

- Display or accent lighting for galleries, museums, and monuments
- Lighting integral to equipment or instrumentation
- Medical and dental procedures
- Refrigerator and freezer cases
- Lighting for food warming
- Life support for non-humans
- Retail display windows (enclosed by ceiling height partitions)
- Registered historic landmarks
- Advertising or directional signage
- Exit signs
- Sale or lighting educational demonstration systems
- Theatrical, stage, film, and video production
- TV broadcasting in sporting activity areas
- Casino gaming areas
- Furniture mounted task lighting
- Mirror lighting in dressing rooms + religious pulpit & choir accent lighting
- Parking garage transition lighting

Lighting exempt from code still offer lots of opportunities for saving energy – make sure it's LED!!!



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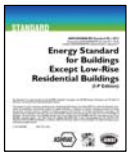
SECTION 9.1.4: LIGHTING DESIGN WATTAGE



Luminaire Wattage – *"the rules"*

Luminaires not containing permanently installed ballasts, transformers, etc. = **max. labeled wattage of the luminaire**

Luminaires with permanently installed or remote ballasts, transformers, etc. = **operating input wattage of the lamp/auxiliary combination***

Line-voltage track =

- **Minimum 30 W per foot**
- **Or limit of system's circuit breaker**
- **Or wattage of other current-limiting device**

Low-voltage track = **transformer wattage**

All others as specified

*based on manufacturer's data, lab results, or max labeled wattage of luminaire (exception for adjustable ballast factors)

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SECTION 9.1.4: LIGHTING DESIGN WATTAGE

Example: Installed Interior Lighting Design

Calculate the total lighting wattage of a room containing the following fixtures:

Eight 4' Fluorescent Fixtures

- Three 4' fluorescent T8 lamps per fixture, 32 Watts
- One three-lamp electronic ballast
- Ballast Input Wattage – 90 Watts

Six Incandescent Downlights

- Specified Lamps – 60 Watt, A-line, Medium Screw Base
- Maximum labeled wattage of fixture – 75 Watts

16 Feet of Line Voltage Track

- Specified – 5 Track Heads
- 90 Watts Halogen PAR38 Lamps

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SECTION 9.1.4: LIGHTING DESIGN WATTAGE

Example: Installed Interior Lighting Design

Eight 4' Fluorescent Fixtures

- Three 4' fluorescent T8 lamps per fixture, 32 Watts
- One three-lamp electronic ballast
- Ballast Input Wattage – 90 Watts

Wrong Way!

8 Fixtures x 3 Lamps x 32 Watts per Lamp = 768 Watts

Right Way!

8 Fixtures x 90 Ballast Input Watts = 720 Watts

"the rules"

Ballasted Luminaires = wattage of the lamp/ballast combination

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SECTION 9.1.4: LIGHTING DESIGN WATTAGE

Example: Installed Interior Lighting Design

Six Incandescent Downlights

- Specified Lamps – 60 Watt, A-line, Medium Screw Base
- Maximum labeled wattage of fixture – 75 Watts

Wrong Way!

6 Downlights x 60 Watts/A-line lamp = 360 Watts

Right Way!

6 Downlights x **75** Watt Labeled fixture = 450 Watts

"the rules"

Standard incandescent = max. labeled wattage of the luminaire

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SECTION 9.1.4: LIGHTING DESIGN WATTAGE

Example: Installed Interior Lighting Design

16 Feet of Line Voltage Track

- Specified – 5 Track Heads
- 90 Watts Halogen PAR38 Lamps

Wrong Way!

5 Track Heads x 90 Watts/Halogen Par Lamp = 450 Watts

Right Way!

16' Track x 30 Watts/Foot = 480 Watts

"the rules"

Line voltage track = min. 30 W per foot

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SECTION 9.1.4: LIGHTING DESIGN WATTAGE

Interior Lighting Wattage Calculation

Wrong Way!

8 Fixtures x 3 Lamps x 32 Watts per Lamp	= 768 Watts
6 Downlights x 60 Watts/A-line lamp	= 360 Watts
5 Track Heads x 90 Watts/Halogen Par Lamp	= 450 Watts
Total Wattage	**= 1,578 Watts**

Right Way!

8 Fixtures x 90 Ballast Input Watts	= 720 Watts
6 Downlights x 75 Watt Labeled A-line	= 450 Watts
16' Track x 30 Watts/Foot	= 480 Watts
Total Wattage	**= 1,650 Watts**

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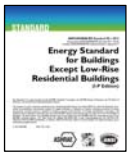
SECTION 9.4.1: LIGHTING CONTROL



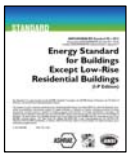
9.4.1.1 Interior Lighting Controls
Minimum Control Requirements (a-i) from Table 9.6.1

Informative Note: This table is divided into two sections; this first section covers space types that can be commonly found in multiple building types. The second part of this table covers space types that are typically found in a single building type.

The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Common Space Types[1]	LPD, W/ft²	RCR Threshold	Local Control (See Section 9.4.1.1[a]) a	Restricted to Manual ON (See Section 9.4.1.1[b]) b	Restricted to Partial Automatic ON (See Section 9.4.1.1[c]) c	Bilevel Lighting Control (See Section 9.4.1.1[d]) d	Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6]) e	Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6]) f	Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies]) g	Automatic Full OFF (See Section 9.4.1.1[h]) h	Scheduled Shutoff (See Section 9.4.1.1[i]) i
Conference/Meeting/Multipurpose Room	1.23	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
Confinement Cells	0.81	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Copy/Print Room	0.72	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
Corridor[2]											
… in a facility for the visually impaired (and not used primarily by the staff)[3]	0.92	width <8 ft	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
… in a hospital	0.99	width <8 ft	REQ	—	—	—	REQ	REQ	ADD2	ADD2	ADD2
… in a manufacturing facility	0.41	width <8 ft	REQ	—	—	—	REQ	REQ	—	ADD2	ADD2
… all other corridors	0.66	width <8 ft	REQ	—	—	—	REQ	REQ	REQ	ADD2	ADD2
Courtroom	1.72	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Computer Room	1.71	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Dining Area											
… in a penitentiary	0.96	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a facility for the visually impaired (and not used primarily by staff)[3]	2.65	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in bar/lounge or leisure dining	1.07	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in cafeteria or fast food dining	0.65	4	REQ	ADD1 OR	ADD1	REQ	REQ	REQ	—	ADD2 OR	ADD2
… in family dining	0.89	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… all other dining areas	0.65	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2

SECTION 9.4.1: LIGHTING CONTROL



9.4.1.1 Interior Lighting Controls

a. Local Controls (for small/big spaces)

Local control – Requires one or more manual control in the space that controls all the lighting in that space.

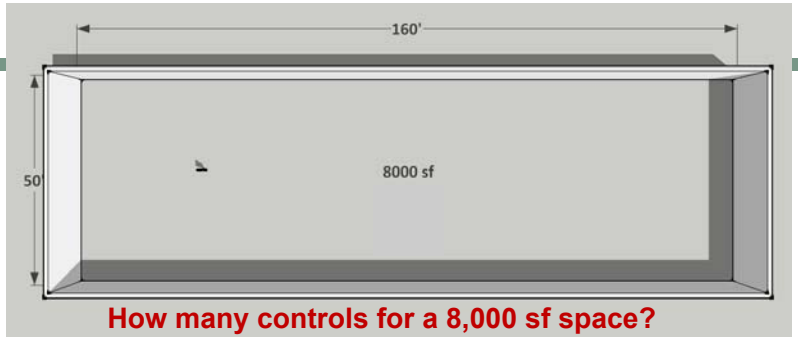
Each control device will control a maximum of:

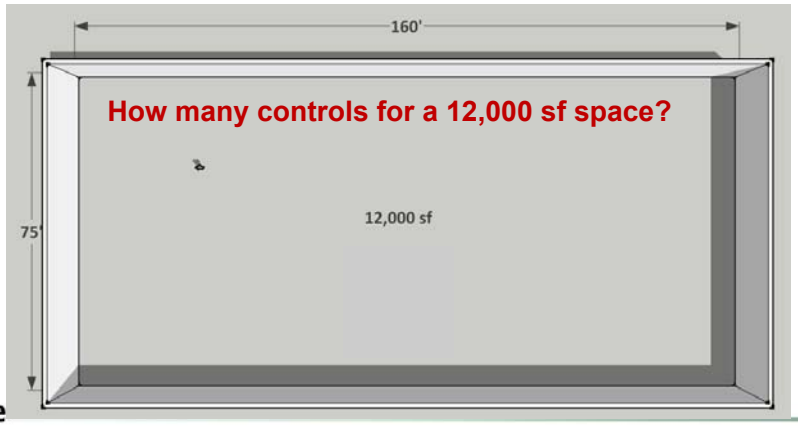
- 2,500 ft² in spaces ≤ 10,000 ft²
- 10,000 ft² in spaces > 10,000 ft²
- Readily accessible so occupants can see the controlled lighting when using the control device

Exceptions:

- Remote location for safety & security (requires pilot indicator and lighting clearly labeled)

SECTION 9.4.1.2: LIGHTING CONTROL





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SECTION 9.4: MANDATORY PROVISIONS

9.4.1.1– Lighting Control

b. Restricted to Manual ON

None of the lighting shall be automatically turned ON

Exceptions: (spaces where full automatic-on is allowed)

Areas where manual-on would endanger safety or security of the room or building occupants

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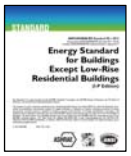
SECTION 9.4: MANDATORY PROVISIONS



9.4.1.1– Lighting Control

c. Restricted to Partial Automatic ON

Maximum of 50% of the lighting power for general lighting is allowed to be automatically turned on and none of the remaining shall be auto ON

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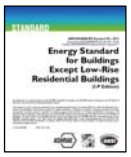
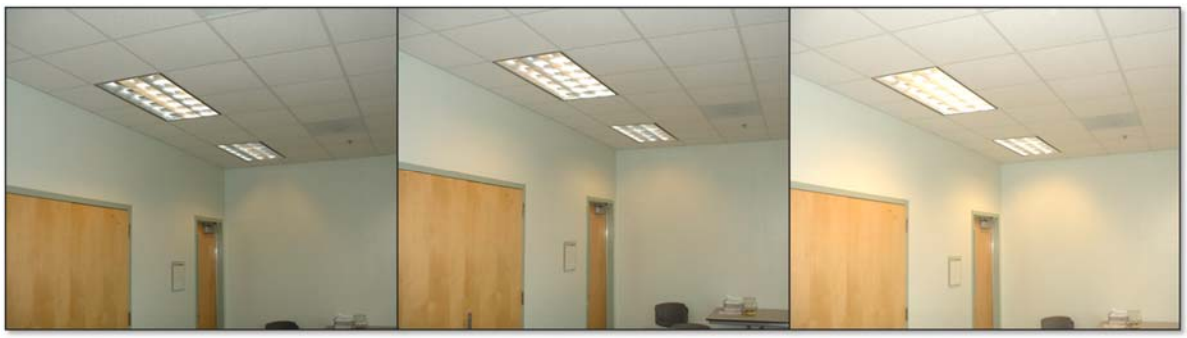
SECTION 9.4.1: LIGHTING CONTROL



9.4.1.1 Lighting Control

d. Bilevel Lighting Controls

The general lighting shall be controlled to have at least one step between 30% and 70% power (in addition to full on / off)



Inboard Only | Outboard Lamps | Full On

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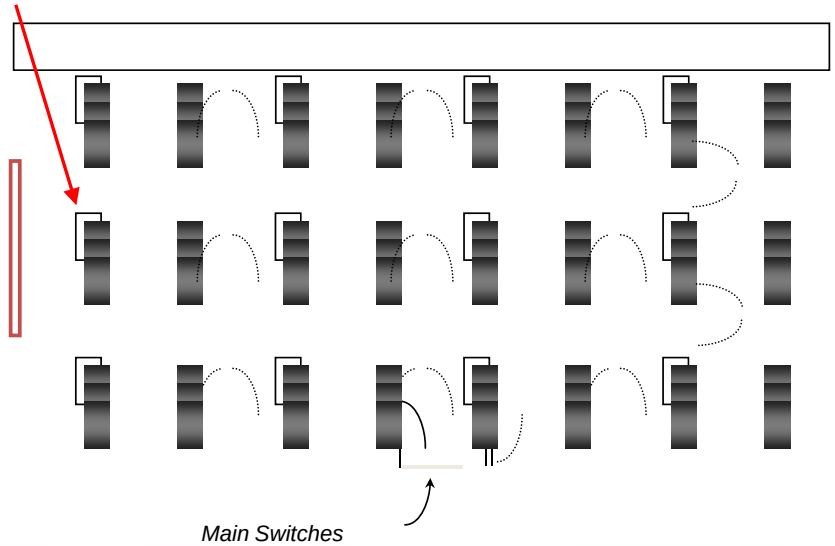
SECTION 9.4.1.2: LIGHTING

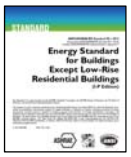
Light Levels Control in Conference / Training Rooms

– "best practice, recognized by 90.1"

Consider separate control for this fixture due to LCD screen



SECTION 9.4.1: LIGHTING CONTROL



9.4.1.1 Lighting Control

e. Auto Daylight Controls - Sidelighting

- Photocontrols required for any space with primary sidelighting ≥ 150 W
- Photocontrols required for any space with combined primary and secondary sidelighting ≥ 300 W

Photocontrols shall:

- Have readily accessible calibration adjustments
- Have secondary sidelighting controls separate from primary sidelighting
- Reduce electric lighting based on available daylight using continuous or 4-step staged dimming

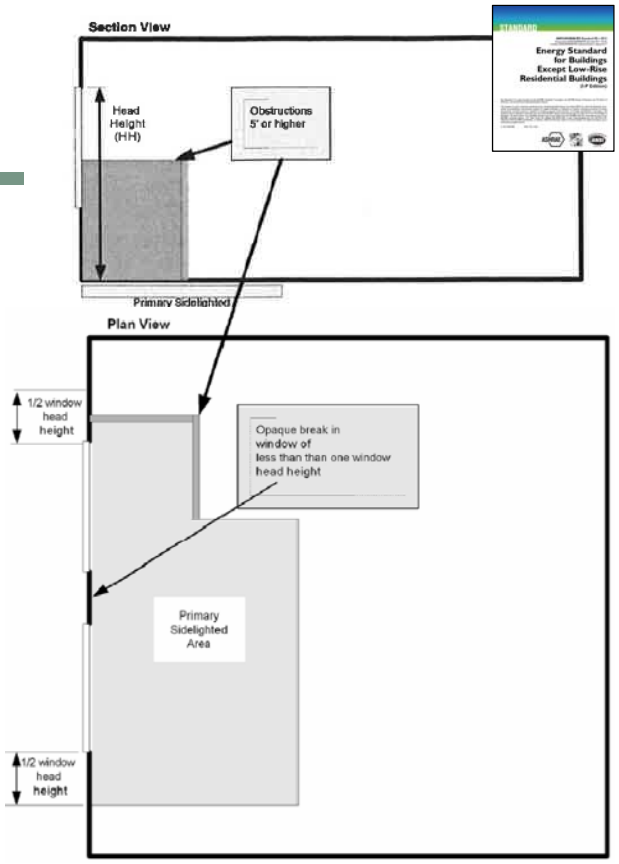
Exceptions for sidelights with tall adjacent structures, < 20 s.f. of glazing, retail spaces

SIDELIGHTED AREA - PRIMARY

primary sidelighted area: the total primary sidelighted area is the combined primary sidelighted area within each space. Each primary sidelighted area is directly adjacent to vertical fenestration below the ceiling (see Figure 3.2-3).

a. The primary sidelighted area width is the width of the vertical fenestration plus, on each side, the smaller of
   1. one half of the vertical fenestration head height (where head height is the distance from the floor to the top of the glazing) or
   2. the distance to any 5 ft or higher opaque vertical obstruction.

b. The primary sidelighted area depth is the horizontal distance perpendicular to the vertical fenestration which is the smaller of
   1. one vertical fenestration head height or
   2. the distance to any 5 ft or higher opaque vertical obstruction.



Southface

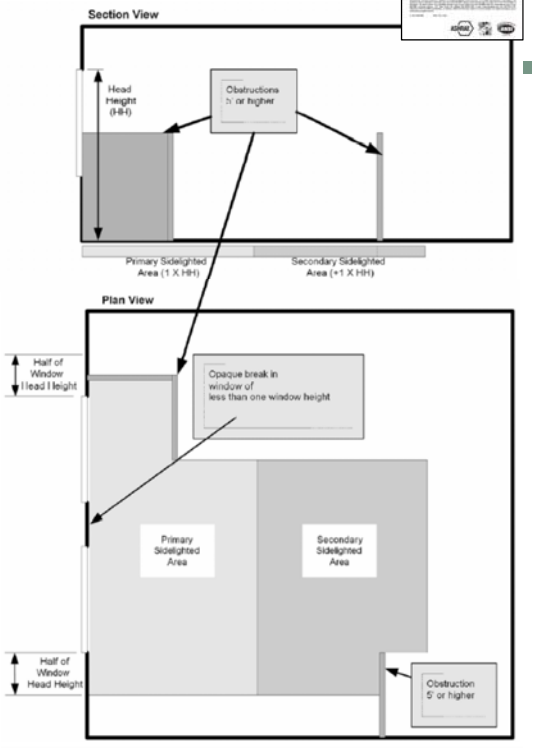
SIDELIGHTED AREA - SECONDARY

secondary sidelighted area: the total secondary sidelighted area is the combined secondary sidelighted area within a space. Each secondary sidelighted area is directly adjacent to a primary sidelighted area (see Figure 3.2-4):

a. The secondary sidelighted area width is the width of the vertical fenestration plus, on each side, the smaller of
   1. one half of the vertical fenestration head height or
   2. the distance to any 5 ft or higher opaque vertical obstruction.

b. The secondary sidelighted area depth is the horizontal distance perpendicular to the vertical fenestration, which begins at the edge of the primary sidelighted area depth and ends at the smaller of
   1. one vertical fenestration head height or
   2. the distance to any 5 ft or higher opaque vertical obstruction.

If the adjacent primary sidelighted area ends at a 5 ftor higher opaque vertical obstruction, there is no secondary sidelighted area beyond such obstruction.



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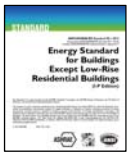
SECTION 9.4.1: LIGHTING CONTROL



9.4.1.1 Lighting Control

f. Auto Daylight Controls - Toplighting

- Photocontrols required for general lighting in any space top-lit by ≥ 150 W

  Photocontrols shall:
  - Have readily accessible calibration adjustments
  - Reduce electric lighting based on available daylight using continuous or 4-step staged dimming
  - Combine controls for overlapping top- and sidelighted areas and lighting shall be controlled by toplighting

Exceptions for Toplighting with tall adjacent shading, skylight VT < 0.4, spaces in CZ 8 < 200 W

Southface

DAYLIGHTED AREA – ROOF MONITORS

daylighted area: the floor area substantially illuminated by daylight.

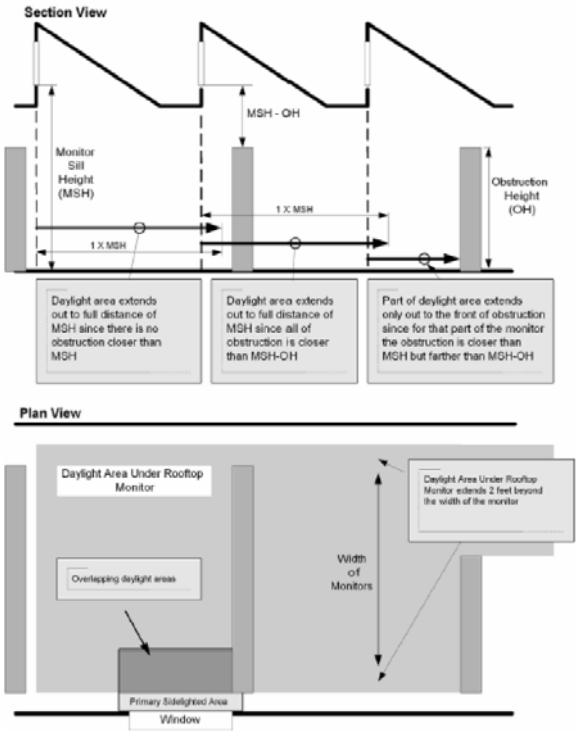
daylight area:

daylight area under roof monitors: the daylight area under roof monitors is the combined daylight area under each roof monitor within each space. The daylight area under each roof monitor is the product of

a. the width of the vertical fenestration above the ceiling level plus, on each side, the smallest of
   1. 2 ft,
   2. the distance to any 5 ft or higher vertical obstruction, or
   3. the distance to the edge of any primary sidelighted area

and

b. the smaller of the following horizontal distances inward from the bottom edge of the vertical fenestration (see Figure 3.2-1):
   1. The monitor sill height (MSH) (the vertical distance from the floor to the bottom edge of the monitor glazing)
   2. The distance to the nearest face of any opaque vertical obstruction, where any part of the obstruction is farther away than the difference between the height of the obstruction and the monitor sill height (MSH – OH).



Rooftop Monitor Daylit Area

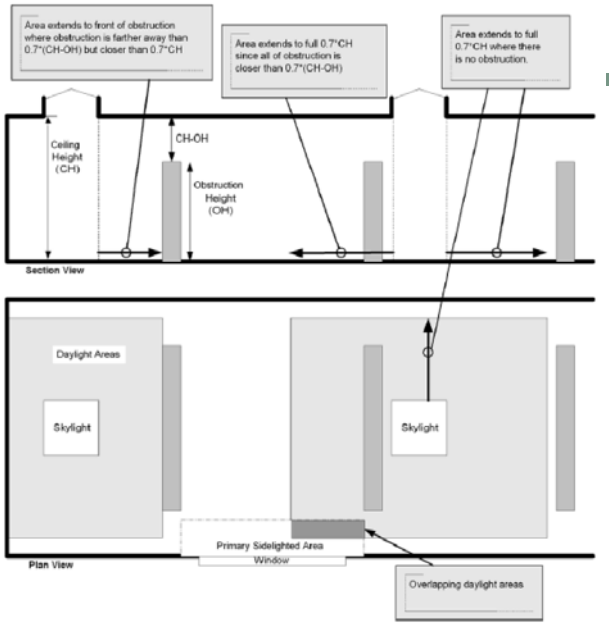
DAYLIGHTED AREA - SKYLIGHTS

daylighted area: the floor area substantially illuminated by daylight.

daylight area under skylights: the daylight area under skylights is the combined daylight area under each skylight within a space. The daylight area under each skylight is bounded by the opening beneath the skylight and horizontally in each direction (see Figure 3.2-2), the smaller of

a. 70% of the ceiling height (0.7 × CH), or
b. the distance to the nearest face of any opaque vertical obstruction, where any part of the obstruction is farther away than 70% of the distance between the top of the obstruction and the ceiling (0.7 × [CH – OH],

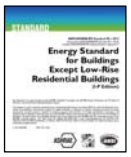
where CH = the height of the ceiling at the lowest edge of the skylight and OH = the height to the top of the obstruction).



Skylight Daylit Area

Southface

SECTION 9.4.1: LIGHTING CONTROL



9.4.1.1 Lighting Control

g. Auto Partial OFF- (full OFF complies)

- General lighting shall be auto reduced by at least half within 20 minutes of being unoccupied

HID exception if meet all:
Space LPD is ≤ 0.8 W/s.f., only HID fixtures are used in the space, and general lighting is reduced at least 30% within 20 minutes of unoccupied

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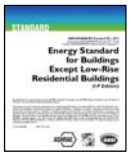
SECTION 9.4.1: LIGHTING CONTROL



9.4.1.1 Lighting Control

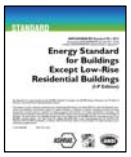
h. Auto Full OFF

- All lighting shall be auto shut off within 20 minutes of being unoccupied
  - Maximum control device area served is 5000 s.f.

Exceptions:

- General and task lighting in shop and lab classrooms
- General and task lighting where it would endanger safety or security of the room or building occupants
- Lighting for 24/7 operation

SECTION 9.4.1: LIGHTING CONTROL



9.4.1.1 Lighting Control

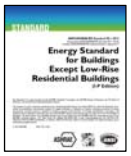
i. Scheduled Shutoff

- All non-exempt lighting shall be auto shut off during periods when space is scheduled to be unoccupied
- Options include:
  - Time of day controller
  - Signal from other such as alarm/security
  - Max area of 25,000 s.f. on one floor, account for weekends and holidays, max. 2 hour override

Exceptions:

- Lighting for 24/7 operation
- Patient care spaces
- General and task lighting where it would endanger safety or security of the room or building occupants

SPECIAL APPLICATIONS



9.4.1.3 Special Applications

a. The following lighting shall be separately controlled from the general lighting in all spaces:
   1. Display or accent lighting
   2. Lighting in display cases
   3. Nonvisual lighting, such as for plant growth or food warming
   4. Lighting equipment that is for sale or used for demonstrations in lighting education

b. Guestrooms
   1. All lighting and all switched receptacles in guestrooms and suites in hotels, motels, boarding houses, or similar buildings shall be automatically controlled such that the power to the lighting and switched receptacles in each enclosed space will be turned off within 20 minutes after all occupants leave that space.

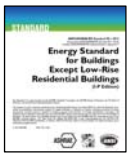
   Exception: Enclosed spaces where the lighting and switched receptacles are controlled by captive key systems and bathrooms are exempt.

   2. Bathrooms shall have a separate control device installed to automatically turn off the bathroom lighting within 30 minutes after all occupants have left the bathroom.

   Exception: Night lighting of up to 5 W per bathroom is exempt.

c. All supplemental task lighting, including permanently installed undershelf or undercabinet lighting, shall be controlled from either (1) a control device integral to the luminaires or (2) by a wall-mounted control device that is readily accessible and located so that the occupant can see the controlled lighting.

9.4.2: EXTERIOR LIGHTING POWER



9.4.2 Exterior Building Lighting Power

Exterior Building Lighting Power Budget:

Sum of the base site allowance

+

Individual allowances from the exterior LPD table (9.4.2.2)
based on lighting zone

TABLE 9.4.2-1 Exterior Lighting Zones

Lighting Zone	Description
0	Undeveloped areas within national parks, state parks, forest land, rural areas, and other undeveloped areas as defined by the authority having jurisdiction
1	Developed areas of national parks, state parks, forest land, and rural areas
2	Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas
3	All other areas
4	High-activity commercial districts in major metropolitan areas as designated by the local jurisdiction

Installed power shall not exceed budget
Trade-offs are allowed only among "tradable surfaces"
Lighting zone is determined per table 9.4.2.1

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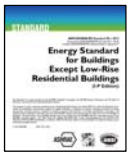
9.4.2: EXTERIOR LIGHTING POWER



9.4.2 Exterior Building Lighting Power

Exterior lighting used for the following applications equipped with a dedicated control device is exempt:

Exceptions:

1. Lighting used for the following exterior applications is exempt when equipped with a control device that complies with the requirements of Section 9.4.1.4 and is independent of the control of the nonexempt lighting:
   a. Lighting that is integral to signage and installed in the signage by the manufacturer
   b. Lighting for athletic playing areas
   c. Lighting for industrial production, material handling, transportation sites, and associated storage areas
   d. Theme elements in theme/amusement parks
   e. Lighting used to highlight features of public monuments and registered historic landmark structures or buildings.
   f. Lighting for water features
2. Lighting used for the following exterior applications is exempt when controlled separately:
   a. Specialized signal, directional, and marker lighting associated with transportation
   b. Lighting integral to equipment or instrumentation and installed by its manufacturer
   c. Lighting for theatrical purposes, including performance, stage, film production, and video production
   d. Temporary lighting
   e. Lighting for hazardous locations
   f. Lighting for swimming pools
   g. Searchlights

9.4.2: EXTERIOR LIGHTING POWER

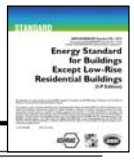
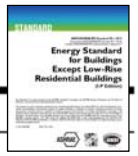


TABLE 9.4.2-2 Individual Lighting Power Allowances for Building Exteriors

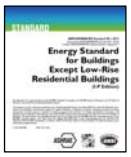
	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (base allowance may be used in tradable or non-tradable surfaces)					
	No base site in Zone 0	500 W	600 W	750 W	1300 W
Tradable Surfaces (LPDs for uncovered parking areas, building grounds, building entrances, exits and loading docks, canopies and overhangs, and outdoor sales areas may be traded.)					
Uncovered Parking Areas					
Parking areas and drives	No allowance	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2	0.13 W/ft^2
Building Grounds					
Walkways less than 10 ft wide	No allowance	0.7 W/linear foot	0.7 W/linear foot	0.8 W/linear foot	1.0 W/linear foot
Walkways 10 ft wide or greater Plaza areas Special feature areas	No allowance	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2	0.2 W/ft^2
Stairways	No allowance	0.75 W/ft^2	1.0 W/ft^2	1.0 W/ft^2	1.0 W/ft^2
Pedestrian tunnels	No allowance	0.15 W/ft^2	0.15 W/ft^2	0.2 W/ft^2	0.3 W/ft^2
Landscaping	No allowance	0.04 W/ft^2	0.05 W/ft^2	0.05 W/ft^2	0.05 W/ft^2
Building Entrances, Exits, and Loading Docks					
Main entries	No allowance	20 W/lin ft of door width	20 W/lin ft of door width	30 W/lin ft of door width	30 W/lin ft of door width
Other doors	No allowance	20 W/lin ft of door width	20 W/lin ft of door width	20 W/lin ft of door width	20 W/lin ft of door width
Entry canopies	No allowance	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2	0.4 W/ft^2
Loading docks	No allowance	0.5 W/ft^2	0.5 W/ft^2	0.5 W/ft^2	0.5 W/ft^2
Sales Canopies					
Free standing and attached	No allowance	0.6 W/ft^2	0.6 W/ft^2	0.8 W/ft^2	1.0 W/ft^2
Outdoor Sales					
Open areas (including vehicle sales lots)	No allowance	0.25 W/ft^2	0.25 W/ft^2	0.5 W/ft^2	0.7 W/ft^2
Street frontage for vehicle sales lots in addition to "open area" allowance	No allowance	No allowance	10 W/linear foot	10 W/linear foot	30 W/linear foot

9.4.2: EXTERIOR LIGHTING BUDGET



	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Nontradable Surfaces (LPD calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.)					
Building facades	No allowance	No allowance	0.1 W/ft^2 for each illuminated wall or surface or 2.5 W/ linear foot for each illuminated wall or surface length	0.15 W/ft^2 for each illuminated wall or surface or 3.75 W/ linear foot for each illuminated wall or surface length	0.2 W/ft^2 for each illuminated wall or surface or 5.0 W/ linear foot for each illuminated wall or surface length
Automated teller machines and night depositories	No allowance	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location
Entrances and gatehouse inspection stations at guarded facilities	No allowance	0.75 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.75 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.75 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.75 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
Loading areas for law enforcement, fire, ambulance, and other emergency service vehicles	No allowance	0.5 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.5 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.5 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")	0.5 W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
Drive-through windows/ doors	No allowance	400 W per drive-through	400 W per drive-through	400 W per drive-through	400 W per drive-through
Parking near 24-hour retail entrances	No allowance	800 W per main entry	800 W per main entry	800 W per main entry	800 W per main entry

SECTION 9.4.1.4: LIGHTING CONTROLS



9.4.1.4 – Exterior Lighting Control

Three requirements:

a. Automatic off control when daylight is available

b. Curfew hours for façade and landscape lighting (midnight – 6am or close to open)

c. Other exterior lighting (including advertising) must automatically reduce power by a minimum of 30% either:

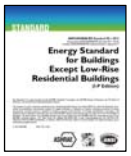
   1. Midnight – 6am (or 1 hour after business close until open)
   2. Motion sensor control (any period of inactivity greater than 15 min)

Note: controls must retain settings during power outage

Exceptions:

- Lighting for covered vehicle entrances or exits where required for safety, security or eye adaptation
- Lighting integral to signage

SECTION 9.4.1: LIGHTING CONTROLS



9.4.1.2 – Parking Garage Control

a) Automatic shut off is required per 9.4.1 (i)

b) Lighting must auto step-back to a minimum 30% power after 20 minutes (max zone 3,600 ft²)
Daylight "transition zones" and ramps without parking exempt

c) Covered vehicle entrance and exit lighting must have separate auto-control to reduce lighting by ≥ 50% from sunset to sunrise

d) Daylight sensor control required to auto reduce power for luminaires within 20 ft of any perimeter wall with net opening to wall ratio ≥ 40% or more and no exterior obstructions within 20 ft

Exceptions:

- Daylight transition zones and ramps without parking

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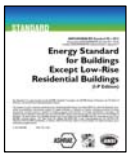
SECTION 9.4.3: FUNCTIONAL TESTING



Control devices and systems must be tested to ensure hardware and software are calibrated, adjusted, programmed, and in proper working condition in accordance with CD's and manufacturer's instructions

Must be independent from design & construction team

Must provide documentation that the controls meet performance requirements

The following controls require detailed functional testing as per 9.4.3 and proper operation must be confirmed and documented:

- Occupant sensors
- Auto Time switches and programmable schedule devices
- Photo-sensor controls

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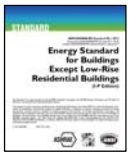
SECTION 9.7: SUBMITTALS

Required to be provided to owner within 90 days of system acceptance:



9.7 Submittals

9.7.1 General. Where required by the authority having jurisdiction, the submittal of compliance documentation and supplemental information shall be in accordance with Section 4.2.2.

9.7.2 Completion requirements. The following requirements are mandatory provisions and are necessary for compliance with this standard.

9.7.2.1 Drawings. Construction documents shall require that within 90 days after the date of system acceptance, record drawings of the actual installation be provided to the building owner or the designated representative of the building owner. Record drawings shall include, as a minimum, the location, luminaire identifier, control, and circuiting for each piece of lighting equipment.

9.7.2.2 Manuals. Construction documents shall require for all lighting equipment and lighting controls, an operating and maintenance manual be provided to the building owner or the designated representative of the building owner within 90 days after the date of system acceptance. These manuals shall include, at a minimum, the following:

a. Submittal data indicating all selected options for each piece of lighting equipment, including but not limited to lamps, ballasts, drivers, and lighting controls.

b. Operation and maintenance manuals for each piece of lighting equipment and lighting controls with routine maintenance clearly identified including, as a minimum, a recommended relamping/cleaning program and a schedule for inspecting and recalibrating all lighting controls.

c. A complete narrative of how each lighting control system is intended to operate including recommended settings.

9.7.2.3 Daylighting Documentation. The design documents shall identify all luminaires for general lighting that are located within daylight areas under skylights, daylight areas under roof monitors as well as primary sidelighted areas and secondary sidelighted areas.

SECTION 9: LIGHTING

- COMcheck is the easiest way to show lighting compliance – it is 100% identical to 90.1
  - Determines budget – Interior & Exterior
  - Creates lighting fixture schedule
  - Provides checklist of mandatory items

COMcheck™

C405: LIGHTING SYSTEMS

Major Items of Note

- Dwelling units *may* comply by having 75% of permanently installed fixtures be high efficacy — C405.1
- Lighting control requirements are similar to 90.1 but worded very differently — C405.2
- Occupancy sensor controls required in 12 spaces — C405.2.1

C405.2.1 Occupant sensor controls. Occupant *sensor controls* shall be installed to control lights in the following space types:

1. Classrooms/lecture/training rooms.
2. Conference/meeting/multipurpose rooms.
3. Copy/print rooms.
4. Lounges.
5. Employee lunch and break rooms.
6. Private offices.
7. Restrooms.
8. Storage rooms.
9. Janitorial closets.
10. Locker rooms.
11. Other spaces 300 square feet (28 m^2) or less that are enclosed by floor-to-ceiling height partitions.
12. Warehouses.

C405.2.1.1

- Auto shut-off within 30 minutes
- Limits to all on %
- Manual override
- Warehouse aisles

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C405: LIGHTING SYSTEMS

Major Items of Note (cont.)

Time-switch controls required: — C405.2.2.1

- 7-day clock with seven different daily programs
- automatic holiday "shutoff"
- 10 hour power backup for settings
- 2-hour manual override for up to 5,000 s.f. area

Exceptions for: — C405.5.2

- sleeping units,
- patient care,
- safety or security,
- continuous operation lighting,
- shop and laboratory classrooms

Light-reduction controls required — C405.2.2.2

Exception for daylit zones (with compliant daylight responsive controls):

- 50% power reduction
- dimming or alternate lamp switching

Manual Controls: — C405.2.2.3

- Readily accessible,
- Located in space with fixture or status indicator required,

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C405: LIGHTING SYSTEMS

Major Items of Note (cont.)

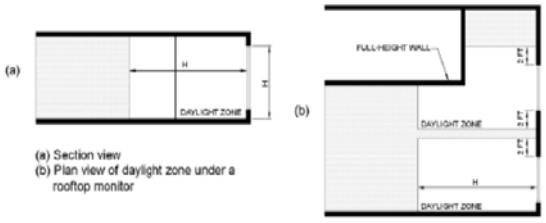
Daylight responsive controls required:

C405.2.3

- Electric general lighting > 150 Watts in daylit zones
- Sidelight daylit zones separate from Toplight zones

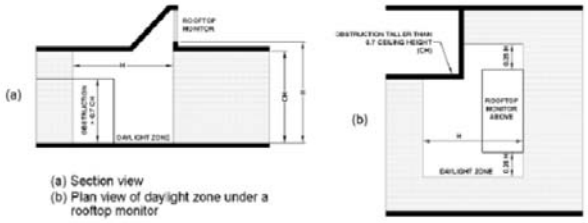
Exceptions for:

- Sleeping units,
- Patient care,
- Exempted lighting



(a) Section view
(b) Plan view of daylight zone under a rooftop monitor

FIGURE C405.2.3.2(1)
DAYLIGHT ZONE ADJACENT TO FENESTRATION IN A WALL



(a) Section view
(b) Plan view of daylight zone under a rooftop monitor

FIGURE C405.2.3.2(3)
DAYLIGHT ZONE UNDER A SLOPED ROOFTOP MONITOR

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C405: LIGHTING SYSTEMS

Major Items of Note (cont.)

Specific application controls required:

C405.2.4

- Display & Accent Lighting
- Case lighting
- Hotel/motel sleeping unit master control for luminaires and switched receptacles
  - Exceptions for captive key system
- Supplemental task lighting
- Non-visual lighting (plant growth and food warming)
- Lighting sales demonstration

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C405: LIGHTING SYSTEMS

Major Items of Note (cont.)

Exterior Lighting controls — C405.2.5

- Auto-off when available daylight
- Façade or landscape light controls dawn/dusk and opening/closing time
- Curfew lighting for other exterior fixtures (minimum 30% reduction)

Exit signs – max 5 W per side — C405.3

Connected lighting may not exceed budget — C405.4

- List of exempt lighting

Lighting power budget (Building Area vs. Space-by-Space) — C405.4.2

Additional lighting power for retail & decorative lighting — C405.4.2.2.1

- No RCR or Additional Control wattage allowance

C405: LIGHTING SYSTEMS

Major Items of Note (cont.)

Exterior Lighting budget — C405.5.1

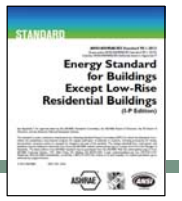
- Exempt outdoor lighting (providing separately controlled)
  - Special signal and transportation directional light
  - Advertising or directional signage
  - Integral to equipment
  - Theatrical lighting
  - Athletic playing areas
  - Temporary lighting
  - Industrial production lighting
  - Theme lighting in amusement parks
  - Public monument lighting
- No zone 0 for Exterior Lighting Zone — C405.5.2(1)

Commercial HVAC Trivia 4

"For typical HVAC systems, setback (shutting equipment off or setting it back when unoccupied) offers negligible savings opportunity."

- True
- False

THE BIG CHANGES TO 90.1-2013



The most significant changes included are as follows:

a. ***Building Envelope.*** *Opaque elements and fenestration requirements have been revised to increase stringency while maintaining a reasonable level of cost-effectiveness. Opaque and fenestration assemblies in Tables 5.5-1 through 5.5-8 are revised in most climates. These changes include*
1. criteria requiring double-glazed fenestration in many climates;
2. minimum VT/SHGC ratio to enable good daylighting with minimum solar gain, while not restricting triple and quadruple glazing; and
3. simplification of the skylighting criteria.

b. ***Lighting.*** *These changes include improvements to daylighting and daylighting controls, space-by-space lighting power density limits, thresholds for toplighting, and revised controls requirements and format. LPD's changed in the 2010 version*
.

c. ***Mechanical.*** *Equipment efficiencies were revised upward for heat pumps, packaged terminal air conditioners (PTAC), single-package vertical heat pumps and air conditioners (SPVHP and SPVAC), and evaporative condensers. Also, fan efficiency requirements were introduced for the first time. Additional provisions that have been included address commercial refrigeration equipment, improved controls on heat rejection and boiler equipment, requirements for expanded use of energy recovery, small motor efficiencies, and fan power control and credits. Control revision requirements were added to the standard, such as DDC controls in many applications. Finally, the 2013 edition completes the work that was begun on equipment efficiencies for chillers in the 2010 edition.*

d. ***Energy Cost Budget (ECB) and Modeling.*** *Improvements were made to the ECB and Appendix G provisions in the standard to clarify the use of the prescriptive provisions when performing building-energy-use modeling. In addition, these sections were revised to enhance capturing daylighting when performing the modeling calculations.*

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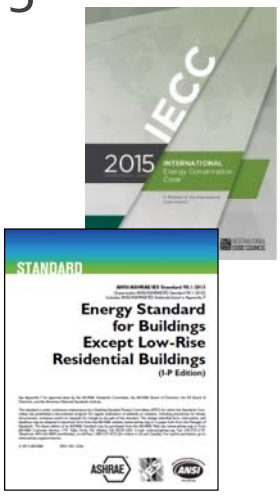
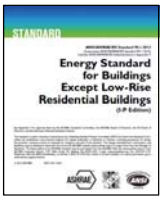
HVAC: 90.1 SECTION 6 / IECC C403



Key Code Concepts:

- Load calcs are required
- All equipment has a minimum efficiency
- Ductwork must be sealed and insulated and balanced
- Fan motor power must be under a certain limit
- All systems must be capable of automatic setback/up during unoccupied times
- Some degree of Commissioning (CX)

90.1 SECTION 6.3: HVAC



6.3 - Simplified Approach

Applies to 80-85% of all commercial buildings

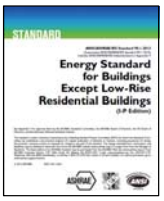
If the 18 requirements are met, the building complies

More restrictive,
but simpler

Limited to:

- 1 or 2 story buildings
- Buildings less than 25,000 sq. ft.
- Each HVAC system must comply

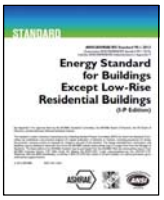
90.1 SECTION 6.3: HVAC



6.3.2 - Simplified Approach

a. Each system must serve a single zone
b. Variable airflow requirements must be met (6.5.3.2.1)
c. Cooling shall be packaged or split system either air or evaporative cooled (and meet min. efficiencies, 6.8.1)
d. Economizers required in most circumstances (6.5.1)
e. Heating shall be packaged or split system heat pump, gas, electric, or hot water (and meet min. efficiencies, 6.8.1)
f. System shall meet exhaust air energy recovery requirements (6.5.6.1)

90.1 SECTION 6.3: HVAC



6.3.2 - Simplified Approach *(Economizer Details)*

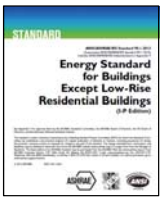
- For systems ≥ 5 tons, economizers required everywhere except CZ1 (Ten exceptions, 6.5.1-1)
- Computer room economizers never required in CZ 2a, 3a, and 4a (Table 6.5.1-2)
- Economizers may be traded off with more efficient equipment
- Not all control options allowed in all CZ's
- List of 10 exceptions (supermarkets, etc.)

Table 6.5.1-3 Eliminate Required Economizer for Comfort Cooling by Increasing Cooling Efficiency

Climate Zone	Efficiency Improvement[a]
2a	17%
2b	21%
3a	27%
3b	32%
3c	65%
4a	42%

a. If a unit is rated with an IPLV, IEER, or SEER then to eliminate the required air or water economizer, the minimum cooling efficiency of the HVAC unit must be increased by the percentage shown. If the HVAC unit is only rated with a full-load metric like EER cooling then these must be increased by the percentage shown.

90.1 SECTION 6.3: HVAC



6.3.2 - Simplified Approach

g. Requires manual changeover or dual set point thermostat

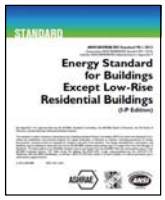
h. When possible, heat pump feature will always provide heating (minimal resistance backup, <40°F lockout)

i. No reheat or simultaneous heating and cooling

j. Control for systems larger than 15k Btu/h and ¾ HP fan motor requires a 7-day / week time clock with 10 hr power loss programming backup, 2-hr override plus temperature setback to 55°F and setup to 90°F (exception for guest rooms and continuously operating systems)

k. Piping insulation and weather protection (6.8.3)

90.1 SECTION 6.3: HVAC



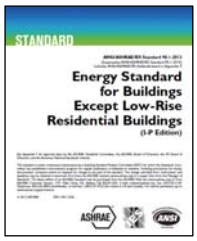
6.3.2 - Simplified Approach

l. Ductwork / plenums insulated (6.8.2) & sealed (6.4.4.2.1)
m. CD's show ducted systems must be air balanced to industry standards (~10% of design)
n. Outdoor air and exhausts shall comply with motorized dampers & controls (some exceptions, 6.4.3.4)
o. Separate thermostats interlocked to prevent simultaneous heating and cooling
p. System greater than 10,000 cfm shall have optimum start controls
q. Demand control ventilation required in high occupancy situations (6.4.3.8)
r. Door switch requirements complied with (6.5.10)

SECTION 6.4: HVAC – MANDATORY ITEMS

6.4 – Mandatory Provisions

(for non-simple HVAC systems)



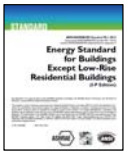
Overview

Must be met whether using prescriptive or performance (ECB method) path

Mandates include:

- 6.4.1 - Equipment efficiency
- 6.4.2 - Calculations (loads, pump sizing)
- 6.4.3 – Controls (zone T-stat, deadband, overlap, off-hour, automatic shutdown, setback, optimum start, zone isolation, ventilation, HP auxiliary heat, humidification & dehumidification, freeze protection & snow melt, demand control ventilation, vestibule heating, DDC)
- 6.4.4 - Construction and insulation (duct & plenum, piping, site built walk-in coolers, refrigerated display cases)
- Submittals and Completion documentation

90.1 SECTION 6.5: HVAC – PRESCRIPTIVE



6.5 – Prescriptive Items

- Economizers – (6.5.1)
- Simultaneous heating & cooling – (6.5.2)
- Air system design and control – (6.5.3)
- Hydronic design & control – (6.5.4)
- Heat rejection equipment – (6.5.5)
- Energy recovery – (6.5.6)
- Exhaust systems – (6.5.7)
- Radiant heating – (6.5.8)
- Hot gas bypass limitation – (6.5.9)
- Door switches– (6.5.10)
- Refrigeration systems– (6.5.11)

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IECC C403 BUILDING MECHANICAL SYSTEMS

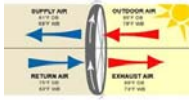
Mandatory Requirements

- Load calcs & equipment sizing
- HVAC equipment minimum efficiency
- Controls (Tstat, HP, Deadband, Overlap, Off-hour, Setback, Automatic shutdown & startup),
- Dampers, Zone isolation, Snow/ice melt & freeze protection,
- Economizer Fault Detection & Diagnostic (FDD), Boiler reset,
- Ventilation (DCV, Parking garage, ERV, kitchen exhaust),
- Duct/plenum insulation and sealing, Piping, CX (Functional Performance Testing),
- Fan motors over 5 hp must meet fan power limitations and minimum efficiency
- Outdoor heating must be radiant (controls)
- Refrigeration equipment, walk-in coolers, refrigerated warehouses, display cases

IECC C406

Additional Efficiency

- Projects must comply with at least one option
- Two are HVAC related
  - More efficient equipment (10%)
  - DOAS



C406.6 Dedicated outdoor air system. Buildings covered by Section C403.4 shall be equipped with an independent ventilation system designed to provide not less than the minimum 100-percent outdoor air to each individual occupied space, as specified by the *International Mechanical Code*. The ventilation system shall be capable of total energy recovery. The HVAC system shall include supply-air temperature controls that automatically reset the supply-air temperature in response to representative building loads, or to outdoor air temperatures. The controls shall reset the supply-air temperature at least 25 percent of the difference between the design supply-air temperature and the design room-air temperature.

SECTION C406
ADDITIONAL EFFICIENCY PACKAGE OPTIONS

C406.1 Requirements. Buildings shall comply with at least one of the following:

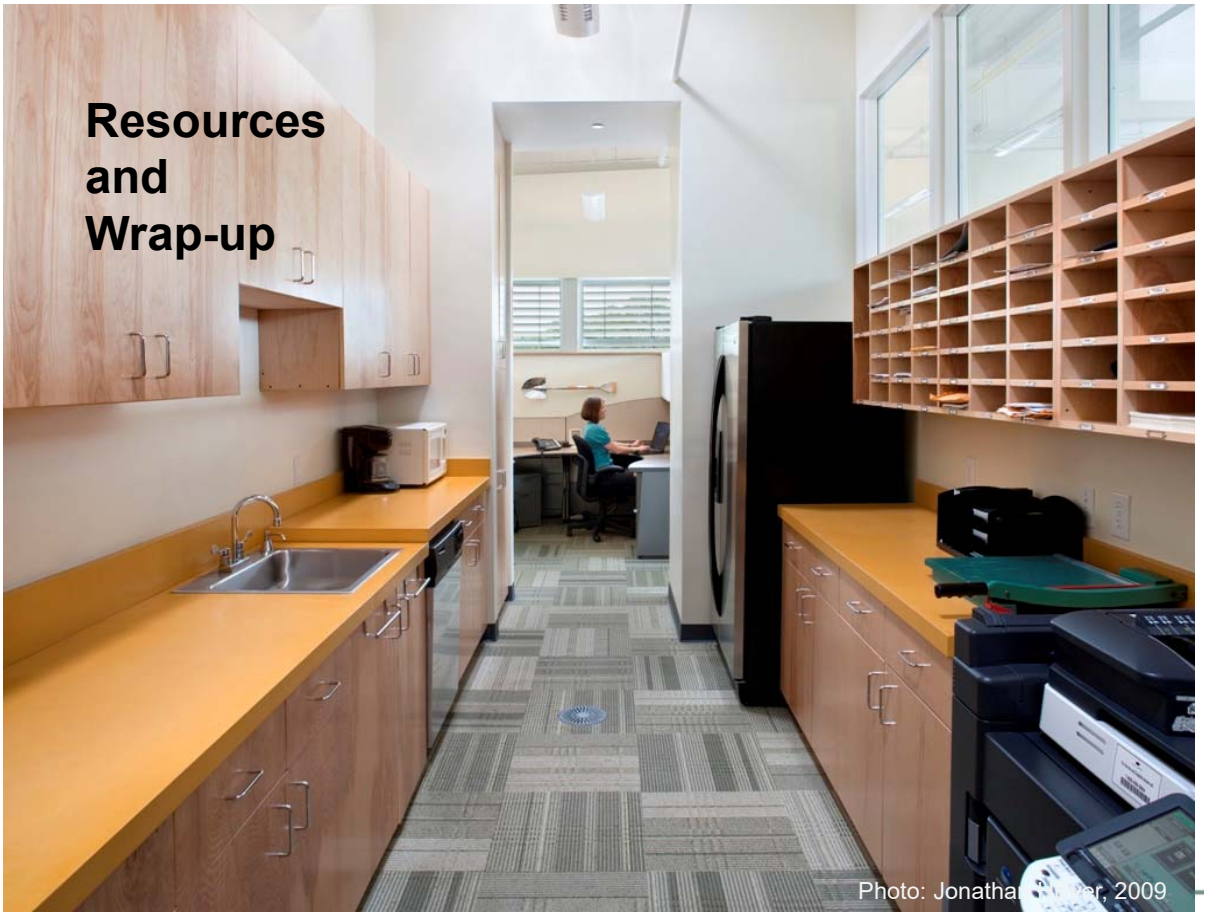
1. More efficient HVAC performance in accordance with Section C406.2.
2. Reduced lighting power density system in accordance with Section C406.3.
3. Enhanced lighting controls in accordance with Section C406.4.
4. On-site supply of renewable energy in accordance with Section C406.5.
5. Provision of a dedicated outdoor air system for certain HVAC equipment in accordance with Section C406.6.
6. High-efficiency service water heating in accordance with Section C406.7.

IECC C402 & C403 – GA AMENDMENTS

Commercial Amendments to IECC only!

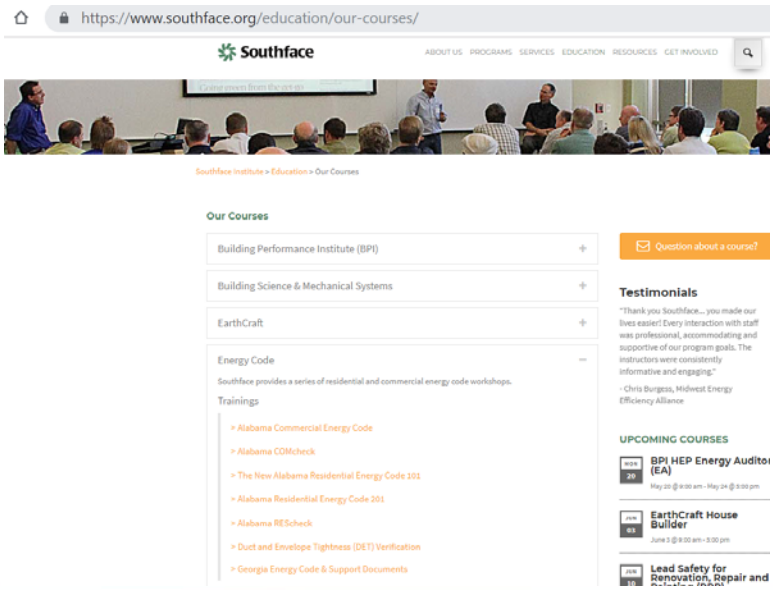
- 403.2.3 -Equipment efficiencies shall use 90.1-2013 tables
- 403.2.8 - Kitchen exhaust hood requirements deleted
- 403.2.9 - Duct and plenum insulation and sealing (revised to allow spray foam as sealant)
  (Joints, seams and connections shall be sealed with mastic and spray foam is allowed option)
- 403.3 - Economizer exception added for computer rooms (aligns with 90.1 exception)
- 403.4.2.6 - Revised Pump isolation details
- 407.3 - Energy simulation compliance –limits renewables to maximum of 5% credit in model
- 408 - Substitute word "Commissioning" with "Functional Performance Testing"

Resources and Wrap-up



RESOURCES

- www.ashrae.org
- www.energycodes.gov
- www.iesna.org
- www.dca.ga.gov
- www.iccsafe.org
- www.southface.org



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WANT TO LEARN MORE?

Mike Barcik

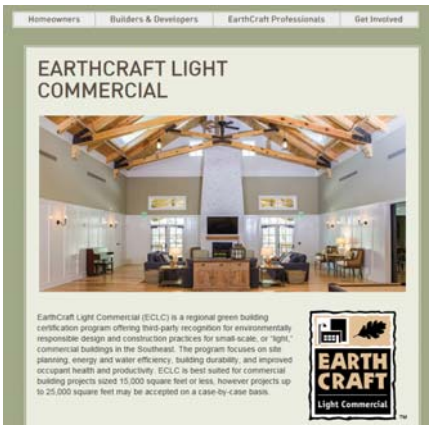
mikeb@southface.org

- Senior Engineer / Technical Principal, Southface

Jenna Grygier

jgrygier@southface.org

- Engineer / Technical Project Manager, Southface



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