



# Nebraska Commercial Energy Code: Air Infiltration, Lighting and HVAC Controls

Instructor: Matt Belcher

March 15, 2023 | 10 a.m.-11:30 a.m.



# Housekeeping

- Attendees are muted upon entry
- Questions? Enter them in the chat box or unmute
- Webinar is being recorded – slides and recording will be sent to attendees
- CEUs will be provided (ICC and AIA)
- Email [canderson@mwalliance.org](mailto:canderson@mwalliance.org) with questions



# Overview

- Defining the Building Envelope
- Applied Building Science to Envelope Performance (Leakage, Air transfer)
- Energy Code Requirements
  - Air Barrier
- Compliance Paths
- ASHRAE 90.1 as Referenced by IECC
- Testing/Compliance
- Existing Buildings



# Defining the Building Envelope





# Building Envelope

- The building envelope is what ***separates the inside from the outside***
- It is defined as any building element assembly that encloses conditioned space or ***provides a boundary*** between conditioned space and exempt or non-conditioned space
- The building envelope includes: below grade (basement) walls, exterior walls, windows, doors, floors, ceilings, roofs, etc.



# Building Envelope

The building envelope must serve four functions:

1. Keep bulk moisture out.
2. Handle moisture as vapor.
3. Contain air movement.
4. Contain heat.

# Building Envelope

- All of the elements of the envelope and the assembly methods determine how well the building envelope performs.
- The building envelope must be an unbroken boundary surrounding the structure.
- All elements must be in close alignment with each other.



Photo courtesy of U.S. Gypsum

# Building Envelope: Control Layers

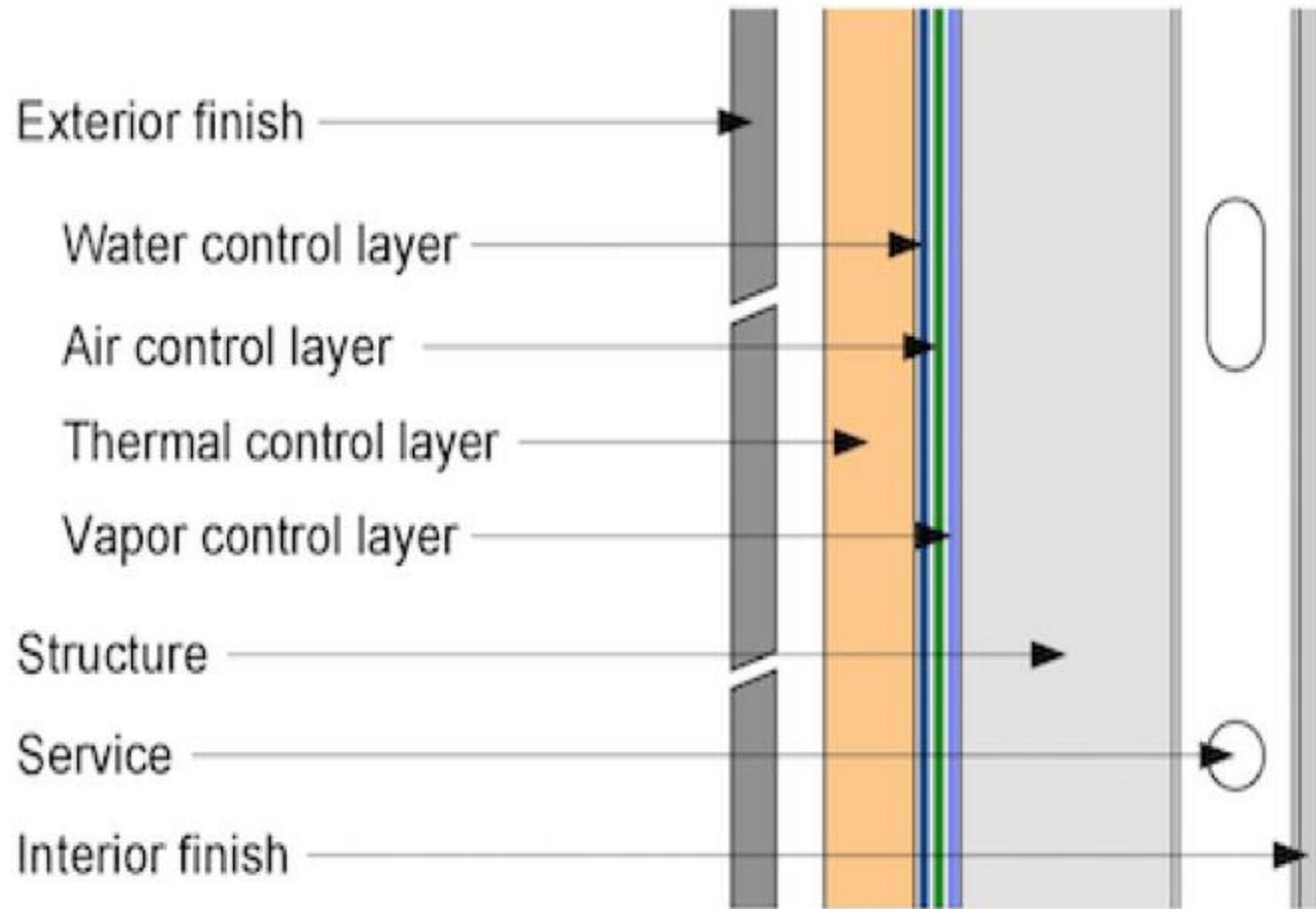
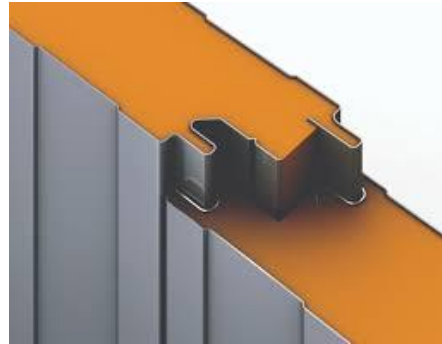


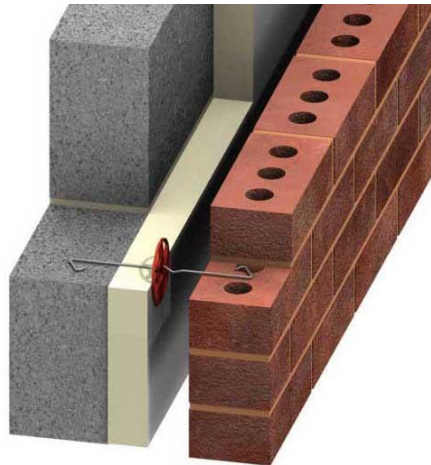
Image: Green Building Solutions



# Building Envelope: Many Wall Types



Insulated Panel



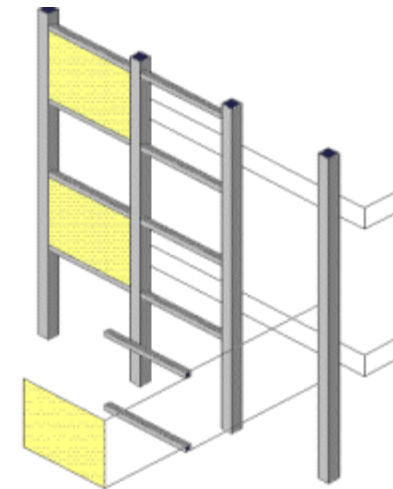
Cavity Wall



Steel Stud/Exterior Sheathing



Mass Timber



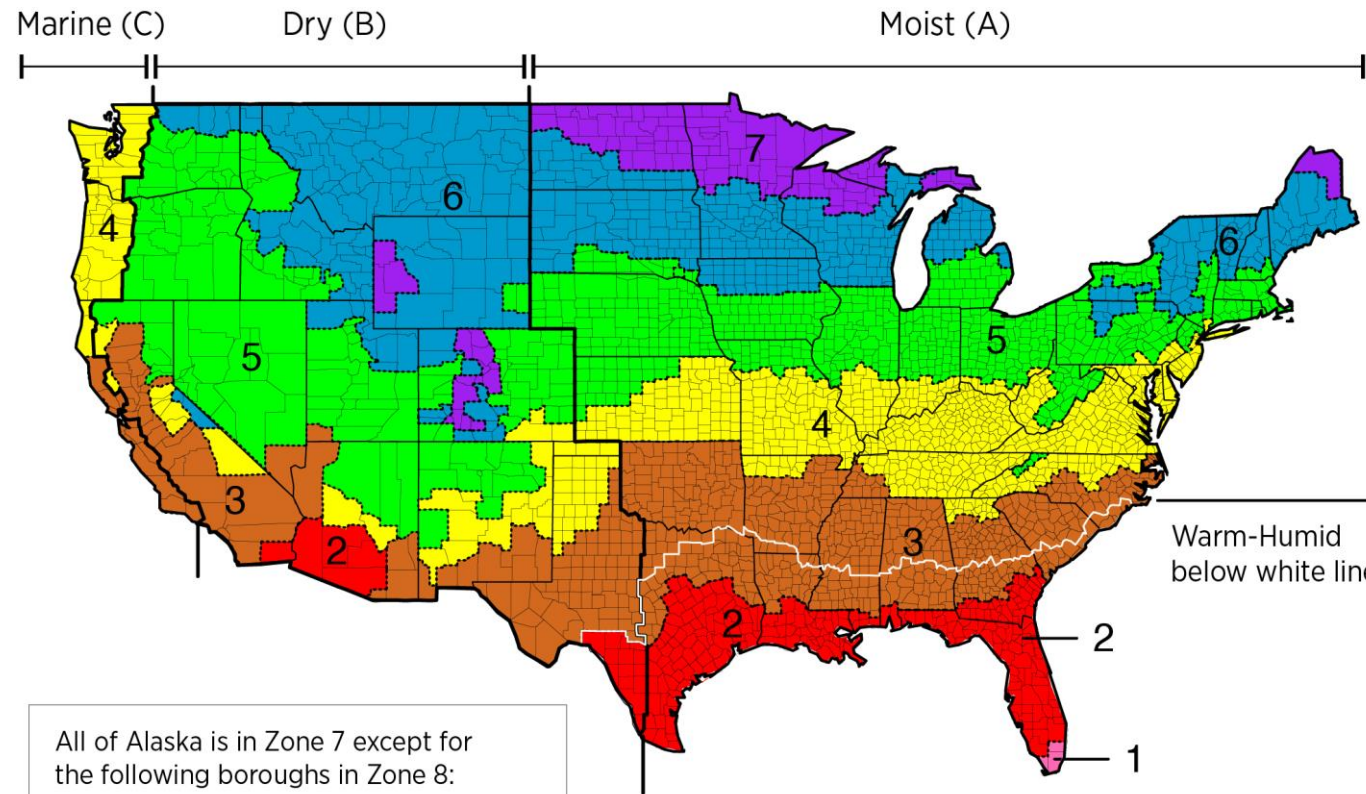
Stick-Built Curtain Wall



# Applied Building Science to the Building Envelope



# 2018 IECC Climate Zones



All of Alaska is in Zone 7 except for the following boroughs in Zone 8:

Bethel, Northwest Arctic, Dellingham, Southeast Fairbanks, Fairbanks N. Star, Wade Hampton, Nome, Yukon-Koyukuk, North Slope

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands



Image Building America Solution Center



# (Not so) Advanced Physics in Building Science

**Heat**

**Hot**



**Cold**

**Moisture**

**Wet**



**Dry**



# Moisture Flows Four Ways

#1 – Bulk water

#2 – Capillary water

**#3 – Air-transported moisture**

#4 – Diffusive moisture movement

# Moisture Flows Four Ways: Air Transported Moisture

- Air movement leads to both energy loss and moisture transmission.
- The air barrier prevents air movement through all parts of the envelope and must be continuous.
- Primary air barrier:
  - Exterior sheathing (e.g. Zip System, etc.)
  - Building wrap (e.g. Tyvek, etc.)
  - Seam sealing
  - Interior drywall
- Penetrations in the primary air barrier create air leaks and must be properly sealed.



Image: westerlyalberta.com



# Moisture Flows Four Ways: Air Transported Moisture

- Uncontrolled / unknown holes that allow air into or out of a building have a negative impact on the building and its occupants.
  - 1/3 quart of water through solid gypsum board but 30 quarts through 1 in<sup>2</sup> hole!
- Minimizing envelope air leakage must be a primary goal of the building envelope.
- Energy efficient buildings have a low leakage rate.
- Controlled ventilation / fresh air intake from a known source improves indoor air quality and contributes to occupant health.



# Building Envelope Code Requirements







# General Requirements

## Section C402.1

Building thermal envelope to comply with the following:


- Specific insulation requirements of Section C402.2
- Thermal requirements of either:
  - R-value-based method of Section C402.1.3
  - U-, C-, and F-factor-based method of Section C402.1.4 **OR**
  - Component performance alternative of Section C402.1.5
- Fenestration in building envelope assemblies
- **Air Leakage of building envelope assemblies**



# Mandatory Requirements

- Air Leakage
- Air barriers
- Fenestration air leakage
- Rooms Containing Fuel-burning Appliances
- Air intakes, exhaust openings, stairways and shafts
- Loading dock weatherseals
- Vestibules
- Recessed lighting





# Air Leakage

## Section C402.5 (Mandatory)

- Envelope air sealing requirements must be met by:
  - Testing (blower door) in accordance with ASTM E 779 at pressure differential of 0.3 inch water gauge or an equivalent method approved by code official when tested air leakage rate  $< 0.40$  cfm/ft<sup>2</sup>

OR

- Compliance with Sections C402.5.1 through 5.8

# Air Barrier Construction

## Section C402.5.1.1 (Mandatory)

- Air barrier placement allowed:
  - Inside of building envelope
  - Outside of building envelope
  - Located within envelope assemblies

**OR**

  - Any combination thereof
- Must be continuous for all assemblies and joints that are part of the envelope



Image: wrmeadows.com

# Vestibules

## Section C402.5.7 (Mandatory)

- Required to reduce infiltration into spaces
- Required for doors leading into spaces  $\geq 3,000 \text{ ft}^2$
- Doors must have self-closing devices
- **Exceptions:**
  - Buildings in Climate Zones 1 and 2
  - Doors from a sleeping unit or dwelling unit
  - Revolving doors (adjacent swing doors are not exempted)
  - Doors that have an air curtain meeting requirements

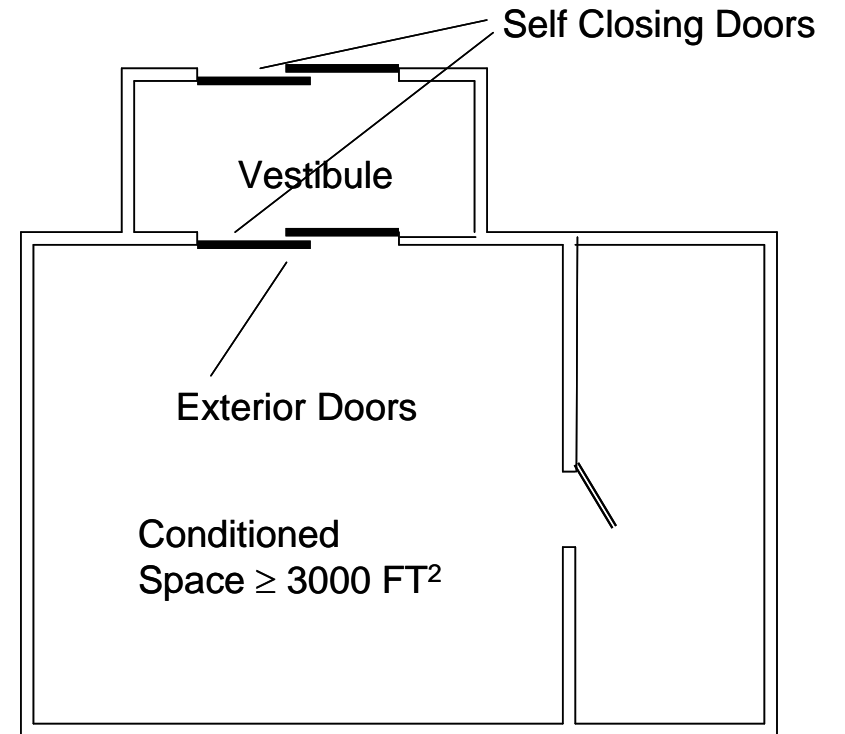


Image: U.S. Dept of Energy



# Additional Efficiency Package Options

## Section C406

- Buildings shall comply with one or more of the following:
  - More efficient HVAC performance
  - Reduced lighting power
  - Enhanced lighting controls
  - On-site renewable energy
  - Dedicated outdoor air system
  - High efficiency water heating
  - **Enhanced envelope performance**
  - **Reduced air infiltration**



# Additional Efficiency Package Options

## Section C406

- Reduced Air Infiltration
  - Whole building pressurization testing (ASTM E779 or ASTM E1827) by independent third party
  - Measured leakage rate of  $\leq 0.25$  cfm/ft<sup>2</sup> (code minimum is  $\leq 0.40$  cfm/ft<sup>2</sup>)
  - Buildings over 250,000 square feet of conditioned floor area may conduct representative area testing
    - Test not less than 25% of conditioned floor area



# Performance Testing





# Air Leakage & Continuous Air Barrier Testing

## Section C402.5

- Continuous Air Barrier Required
- Two Compliance Options
  1. ASTM E 779 (blower door test)
  2. Compliant assemblies
    - C402.5.1 through C402.5.8



Image: energyconservatory.com



# 2018 IECC vs ASHRAE 90.1-2016



# ASHRAE 90.1 2016 Section 5: Building Envelope Overview

- **ASHRAE 90.1 is an optional compliance path allowed in the 2018 IECC (Section C401.2).**
- Applies to:
  - New, and new portions of, *buildings* and their *systems*
  - *Additions* and *alterations* to existing buildings
  - New *systems* and *equipment* in *existing buildings*
- Does not apply to:
  - Single-family houses, low-rise multi-family  $\leq 3$  stories above *grade*, manufactured houses (mobile or modular)
  - *Buildings* that use neither *electricity* nor *fossil fuel*
- Does not circumvent any safety, health, or environmental requirements

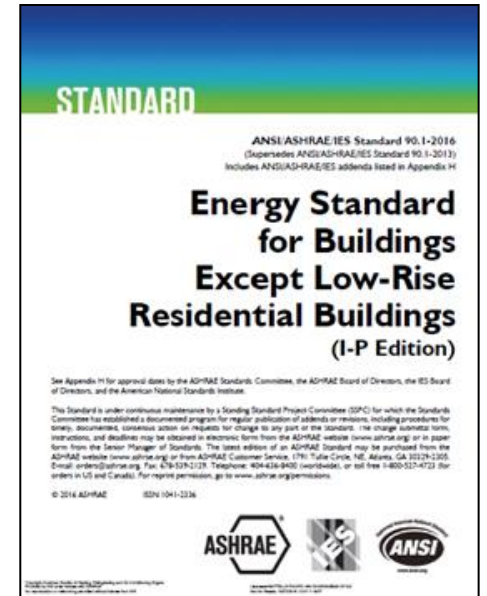


Image: ASHRAE.org



# Structure of Standard 90.1-2016

- Purpose
- Scope
- Definitions, Abbreviations, and Acronyms
- Administration and Enforcement
- Building Envelope
- Heating, Ventilating, and Air Conditioning
- Service Water Heating
- Power
- Lighting
- Other Equipment
- Energy Cost Budget Method
- Normative References
- Normative Appendices A-H
- *Appendix G – is a new compliance path!*

# Some Key Changes

- Major format changes
- New climate maps
- New performance-based compliance path
- Significant energy savings\*
- Increased HVAC equipment efficiency
- Requirements for replacement equipment
  - \*28% more efficient than 90.1 2007 in NE

\*([https://www.energycodes.gov/sites/default/files/2021-07/StateLevelCommercialCodesEnergyUseIndex\\_FY2021Q3.xlsx](https://www.energycodes.gov/sites/default/files/2021-07/StateLevelCommercialCodesEnergyUseIndex_FY2021Q3.xlsx))



# Some Key Changes

- Comprehensive update to the fenestration prescriptive requirements in Tables 5-5-0 through 5-5-8
- Orientation requirements for vertical fenestration were tightened
- SHGC credit for shading by permanent projections was modified to correct how it addressed north-facing fenestration
- Whole building air leakage testing added as an option
- Thresholds for conditioned space were lowered



# Existing Buildings



# Existing Buildings - Scope

## Chapter 5

- Applies to alterations, repairs, additions, and change of occupancy (C501.1)
- Additions must comply with code without requiring unaltered portions to comply (C502.1)
  - Specific requirements for new vertical fenestration and skylights (C502.2.1 and C502.2.2)
- Alterations shall not make building less conforming (C503.1)



Image: MontgomeryCountyMD.gov





# Questions so far?





# Lighting (and a Little Power)



# Commercial Compliance Options

**ASHRAE 90.1-2016**

OR

## **2018 IECC – Prescriptive**

- ✓ C402 – Envelope
- ✓ C403 – Mechanical
- ✓ C404 – SWH
- ✓ C405 – Lighting

**AND Pick at Least One C406:**

- C406.2 – Eff. HVAC Performance
- C406.3 – Reduced Lighting Power**
- C406.4 – Enhanced Lighting Controls
- C406.5 – On-site Supply of Renewable Energy
- C406.6 – Dedicated Outdoor Air System
- C406.7 – High Eff. Service Water Heating
- C406.8 – Enhanced Envelope Performance
- C406.9 – Reduced Air Infiltration

OR

## **2018 IECC – Performance**

- C407 – Total Building Performance
- C402.5 – Air Leakage
- C403 – Mandatory Mechanical Provisions
- C404 – SWH
- **C405 - Lighting**
- Building energy cost to be < 85% of standard reference design building

# When do the Lighting and Power Requirements Apply?

- Original Installed Lighting System in a New Building, Addition, or Tenant Build-out
- Existing Lighting System that is Altered
- Change in Occupancy that Increases Energy
- Change in Occupancy that requires less LPD as shown in the LPD tables

## Exceptions:

- Alterations where less than 10% of the luminaires in a space are replaced and installed interior power lighting is not increased
- Lighting within dwelling units
  - Where  $\geq 75\%$  of permanently installed fixtures (except low-voltage) are fitted for and include high-efficacy lamps

# Electrical Lighting and Power Systems Requirements

- Mandatory Interior Lighting requirements
  - Required Controls
  - Wattage/Efficiency Limits
- Interior Lighting Power Allowances (watts/ft<sup>2</sup>)
- Exterior Lighting Controls
  - Required Controls
  - Lamp Efficiency
- Exterior Lighting Power Allowances (watts/ft<sup>2</sup>)
- Dwelling Electric Meters
- Electrical Transformers and Motors
- Vertical and Horizontal Transportation Systems and Equipment



Image: U.S. Dept of Energy

# Summary of Changes - Interior Lighting Power Density (LPD) Limits

- Interior Power Density limits (LPD) were revised for 90.1-2016 primarily because of improved efficacy of LED lighting.
- All space type models used for LPD development were reviewed and where applicable, LED technology was included as part of the technology mix.
- Space-by-Space LPDs – Most were reduced but a few went up based on revised design criteria and current practice for that space type
- Building area LPDs – Almost all were reduced



# High-Efficacy Lamps: Definition

Compact fluorescent lamps, LED lamps, T8 or smaller diameter linear fluorescent lamps, or other lamps with an efficacy based on lamp wattage

Lamp Wattage	Efficacy
> 40 watts	60 lumens/watt
15-40 watts	50 lumens/watt
< 15 watts	40 lumens/watt

**NOTE:** You can now get a 100w LED equivalent bulb with ~100 lumens/watt





# Interior Lighting Power Allowance

## Section C405.3.2

Two methods to determine Lighting Power Allowance:

- Building Area Method
  - Floor area for each building area type x value for the area
  - “area” defined as all contiguous spaces that accommodate or are associated with a single building area type as per the table
- Space-by-Space Method
  - Floor area of each space x value for the area
  - Then sum the allowances for all the spaces
  - Some tradeoffs among spaces are allowed



# Building Area Compliance Method

Part of Table 9.5.1 shown below.

Complete table in the Standard has 32 different building types

Building Type	Lighting Power Density (W/ft <sup>2</sup> )
Automotive Facility	0.71
Convention Center	0.76
Court House	0.90
Dining: Bar Lounge/Leisure	0.90
Dining: Cafeteria/Fast Food	0.79
Dining: Family	0.78
Dormitory	0.61
Exercise Center	0.65

# Space-by-Space Compliance Method – 9.6.1

There are numerous lighting exceptions that do not have to be included in the installed lighting power calculation!

Table 1 – Gradual Change of Code Lighting Power Densities

Space Type	ASHRAE 90.1 (Space-by-space LPD in W/ft <sup>2</sup> )			
	2016	2013	2010	2007
Conference, multi-purpose and meeting rooms	<b>1.07</b>	1.23	1.23	1.23
Lounge/Breakroom in a healthcare facility	<b>0.78</b>	0.92	1.07	1.07
Healthcare – exam treatment room	<b>1.68</b>	1.66	1.66	1.66
Enclosed offices	<b>0.93</b>	1.11	1.11	1.11
Office open	<b>0.81</b>	0.98	0.98	0.98

# Lighting Power Densities

## Table C405.3.2(1) and Table C405.3.2(2)

Building Area Type	LPD (w/ft <sup>2</sup> )
Automotive facility	0.71
Convention center	0.76
Courthouse	0.90
Dining: bar lounge/leisure	0.90
Dining: cafeteria/fast food	0.79
Dining: family	0.78
Dormitory	0.61
Exercise center	0.65
Fire station	0.53
Gymnasium	0.68

(partial tables)

Common Space Types	LPD (w/ft <sup>2</sup> )
Locker room	0.48
Lounge/breakroom	
In a healthcare facility	0.78
Otherwise	0.62
Office	
Enclosed	0.93
Open plan	0.81
Parking area, interior	0.14
Pharmacy area	1.34

# Lighting Controls

## Section C405.2 (Mandatory)

Lighting systems required to be provided with controls as specified for:

- Occupant sensor controls – C405.2.1
- Time-switch controls – C405.2.2
- Daylight-responsive controls – C405.2.3
- Specific application controls – C405.2.4
- Manual controls – C405.2.5
- Exterior lighting controls – C405.2.6



Image: U.S. Dept of Energy



# Occupant Sensor Controls

## Sections C405.2.1, C405.2.1.1

- Occupancy sensors are required in many spaces, including:
  - Classrooms
  - Conference/multipurpose rooms
  - Lounges/breakrooms
  - Enclosed offices
  - Open plan office areas
  - Restrooms
  - Storage rooms
  - Warehouse storage areas
- Occupancy sensor function (other than for warehouses):
  - Automatically turn lights off within 20 minutes after occupants have left space
  - Incorporate a manual control to allow occupants to turn off lights

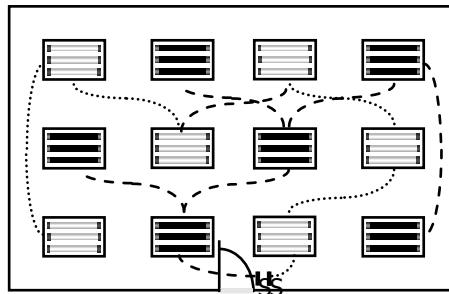
# Light-reduction Control

## Section C405.2.2

- Controlling all lamps or luminaires
- Dual switching of alternate rows of luminaires, alternate luminaires or lamps
- Switching middle lamp luminaires independently from the outer lamps
- Switching each luminaire or each lamp

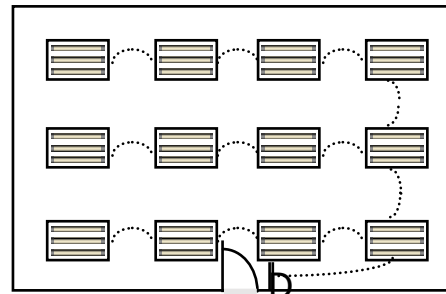
Light Reduction Controls must allow the occupant to reduce connected lighting load

- By not less than 50%
- In a reasonably uniform illumination pattern



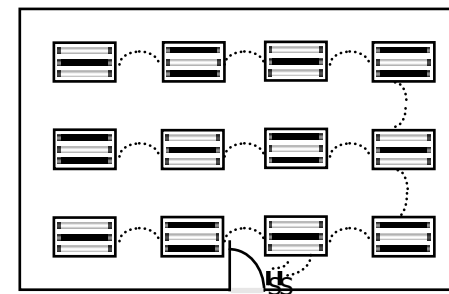
**Alternating Luminaires**

Image: U.S. Dept of Energy



Dimmer Switch

**Dimming**



**Alternating Lamps**



# Daylight-responsive Controls

## Section C405.2.3

- Definition: A device or system that provides automatic control of electric light levels based on the amount of daylight in a space
- Required to control lighting in spaces with  $\leq$  150 watts of general lighting:
  - Sidelit zones
  - Toplit zones

# Sidelit Zone

## Section C405.2.3.2

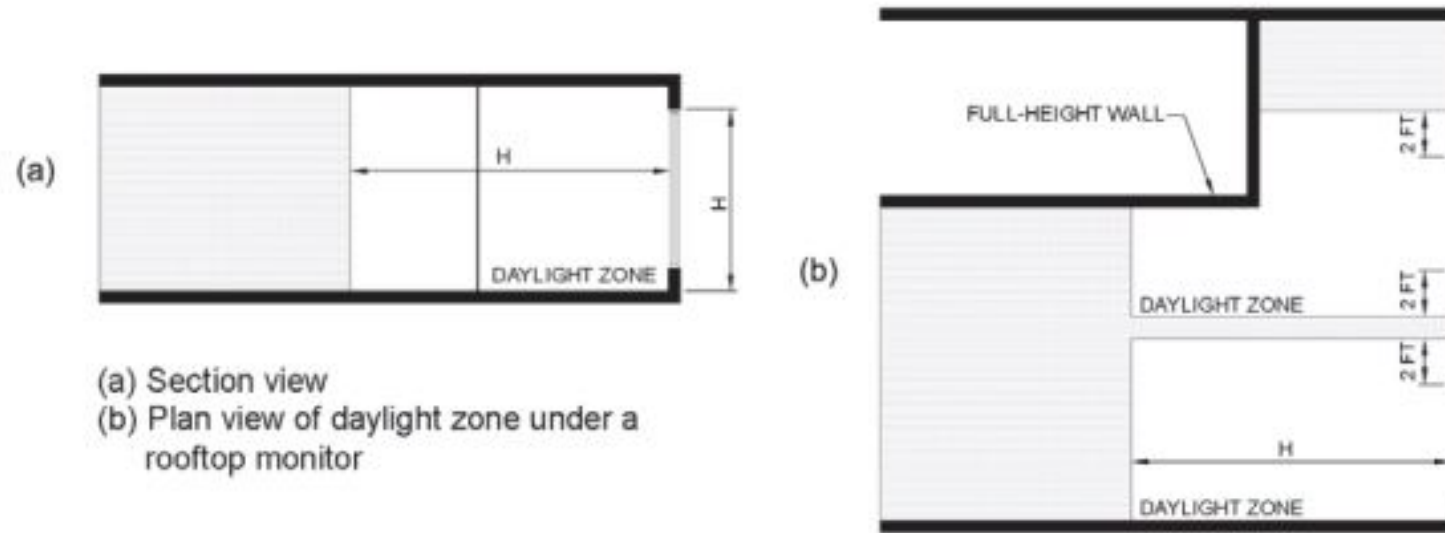


FIGURE C405.2.3.2 SIDELIT ZONE

Image: International Code Council



# Toplit Daylight Zone

## Section C405.2.3.3

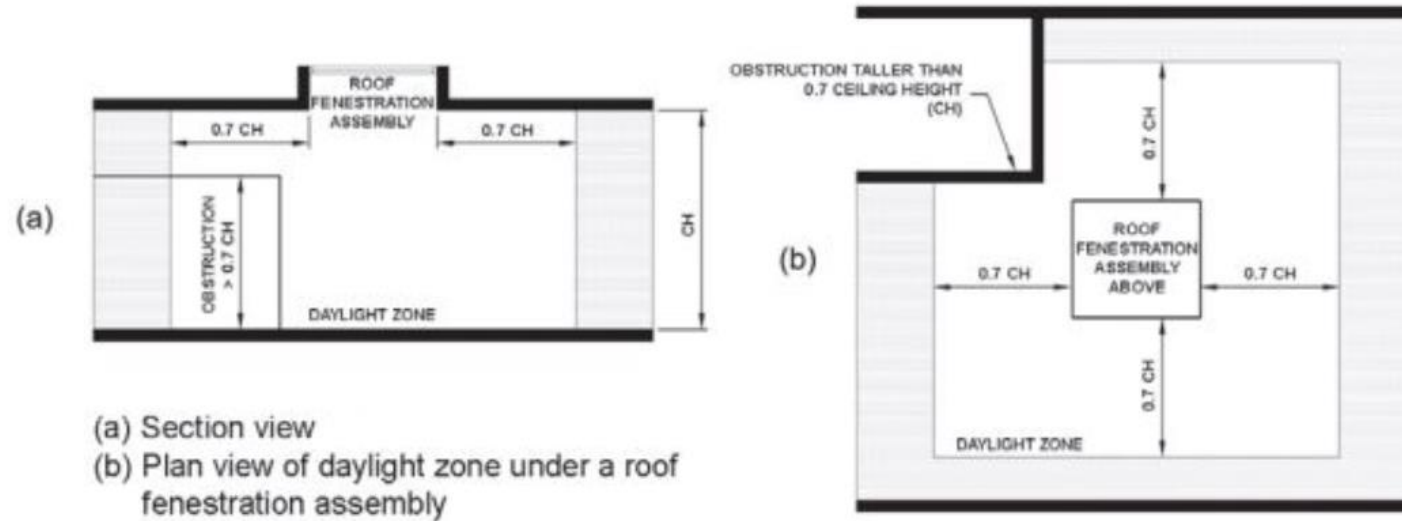


FIGURE C405.2.3.3(1) TOPLIT ZONE

Image: International Code Council

# Daylight Areas– 9.4.1.4

- Documentation to identify daylight areas on floor plans, including:
  - Primary sidelighted areas
  - Secondary sidelighted areas
  - Daylight area under skylight
  - Daylight area under roof monitors

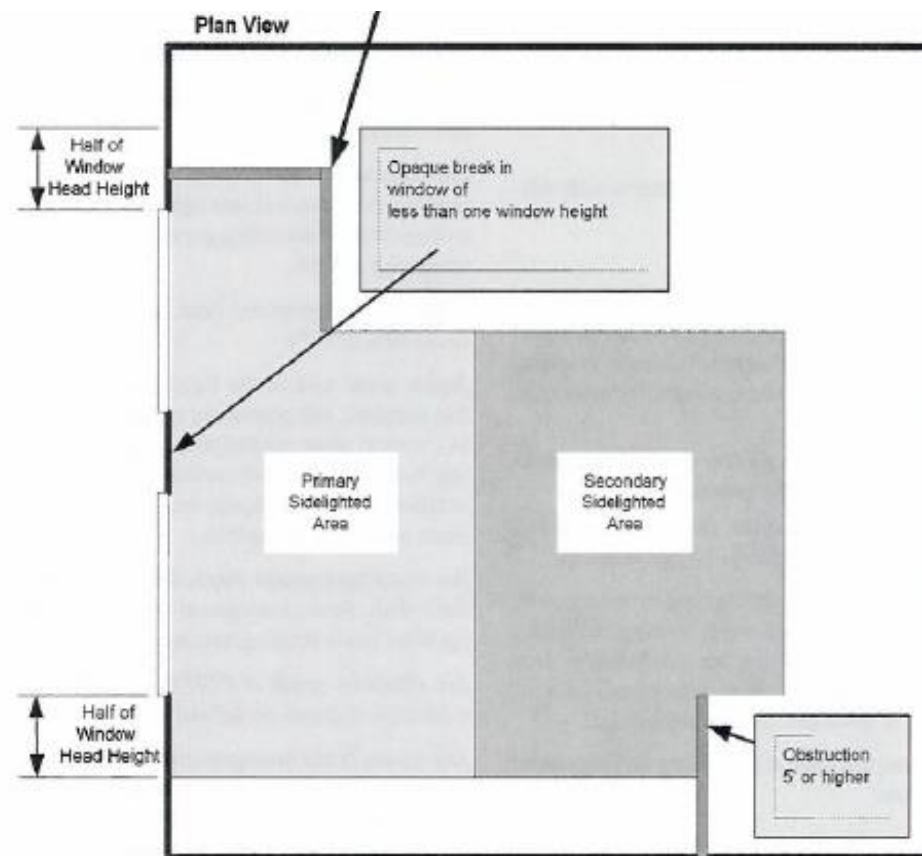



Image: US DOE



# Exterior Lighting and Building Lighting Power

## Sections C405.4, C405.4.1 (Mandatory)

Connected Exterior Lighting Power must not exceed Exterior Lighting Power Allowance except where approved because of historical, safety, signage or emergency considerations:

1. Calculate exterior lighting power allowance
  - Lighting power densities by exterior function and by applicable lighting zone
2. Calculate proposed connected lighting power
  - Wattage calculation “rules”
  - Exempted lighting
3. Compare values: proposed wattage must be less than or equal to allowed wattage



# Lighting Alterations

- Lighting alterations (retrofits) section revised to add interior and exterior controls
  - **Interior** retrofits must now also comply with occupancy and scheduled full and partial shutoff and bi-level switching where specified.
  - **Exterior** retrofits must now also comply with astronomical control and/or scheduled shutoff control where specified for each application.
- Application threshold changed to 20% of lighting load before requirements are applied.
- Lamp plus ballast retrofits and one-for-one fixture replacements need only comply with LPD limits.

# Automatic Receptacle Control – 8.4.2

## Automatically Controlled Receptacles

≥ 50% of all 125 volt 15- and 20-amp receptacles in:

- Private offices
- Conference rooms
- Rooms used primarily for printing and/or copying functions
- Break rooms
- Classrooms
- Individual workstations

≥ 25% of branch circuit feeders installed for modular furniture not shown on construction documents

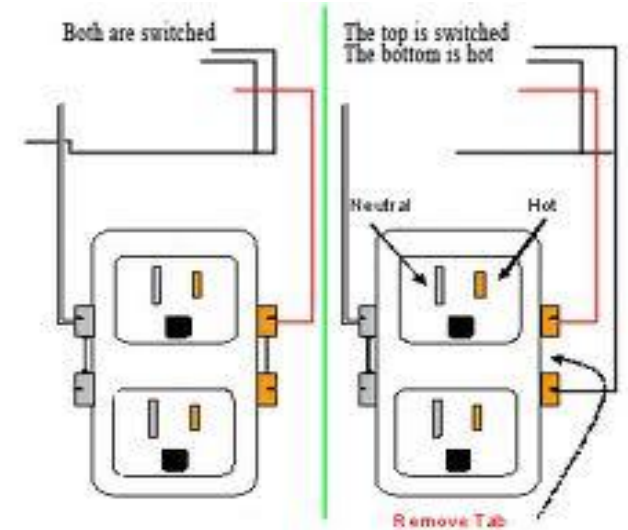
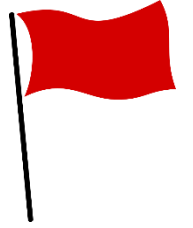


Image: US DOE



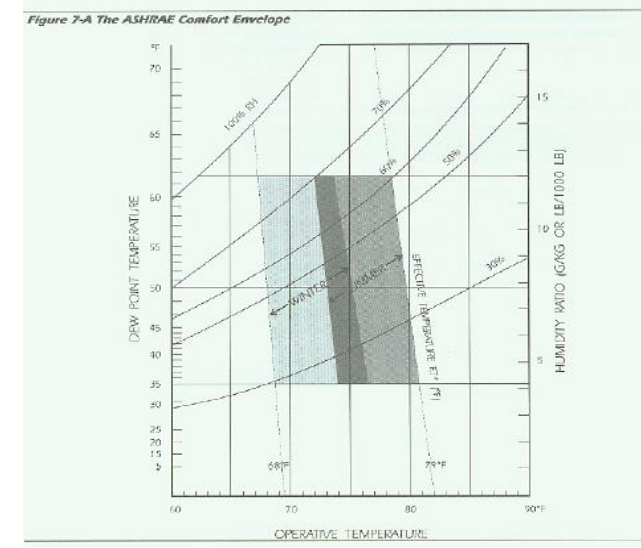
# HVAC (Just a little bit)



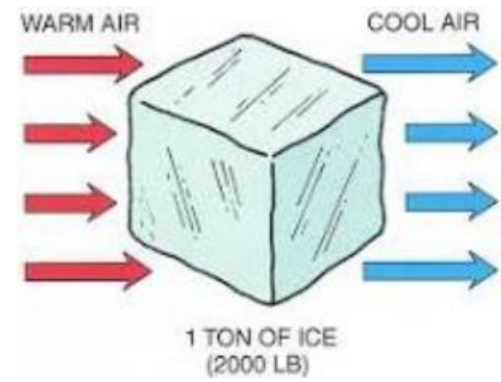


# Load Calculations are Mandatory

- Must calculate heating and cooling system design loads
- Must base calculations on generally accepted engineering standards and handbooks – ASHRAE 7 ACCA 183
- Other approved computation procedures
- Outdoor design conditions
  - Specified by ASHRAE (e.g., Lincoln, NE 2°F winter, 93°F summer)
- Interior design conditions
  - Specified the IECC
  - $\leq 72^{\circ}\text{F}$  for heating load
  - $\geq 75^{\circ}\text{F}$  for cooling load



1 ton = 12,000 Btu/hr



# HVAC 101 - Controls

## Control Devices

- Thermostats
  - Manual
  - Programmable
- DDC Systems
- Automatic Valves and Dampers
- Outdoor Sensors
- Optimum Start
- Variable Speed Drives





# Building Controls are Complicated

- Since 2004, about 30% of all new requirements have been related to building controls
- Control requirements can be difficult to implement, and verification is beyond the expertise of most building code officials
- Assumption is that they are implemented and working correctly
- Source:  
[https://www.pnnl.gov/main/publications/external/technical\\_reports/PNNL-26348.pdf](https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26348.pdf)

# Impacts of Non-Ducted Return Air Plenums

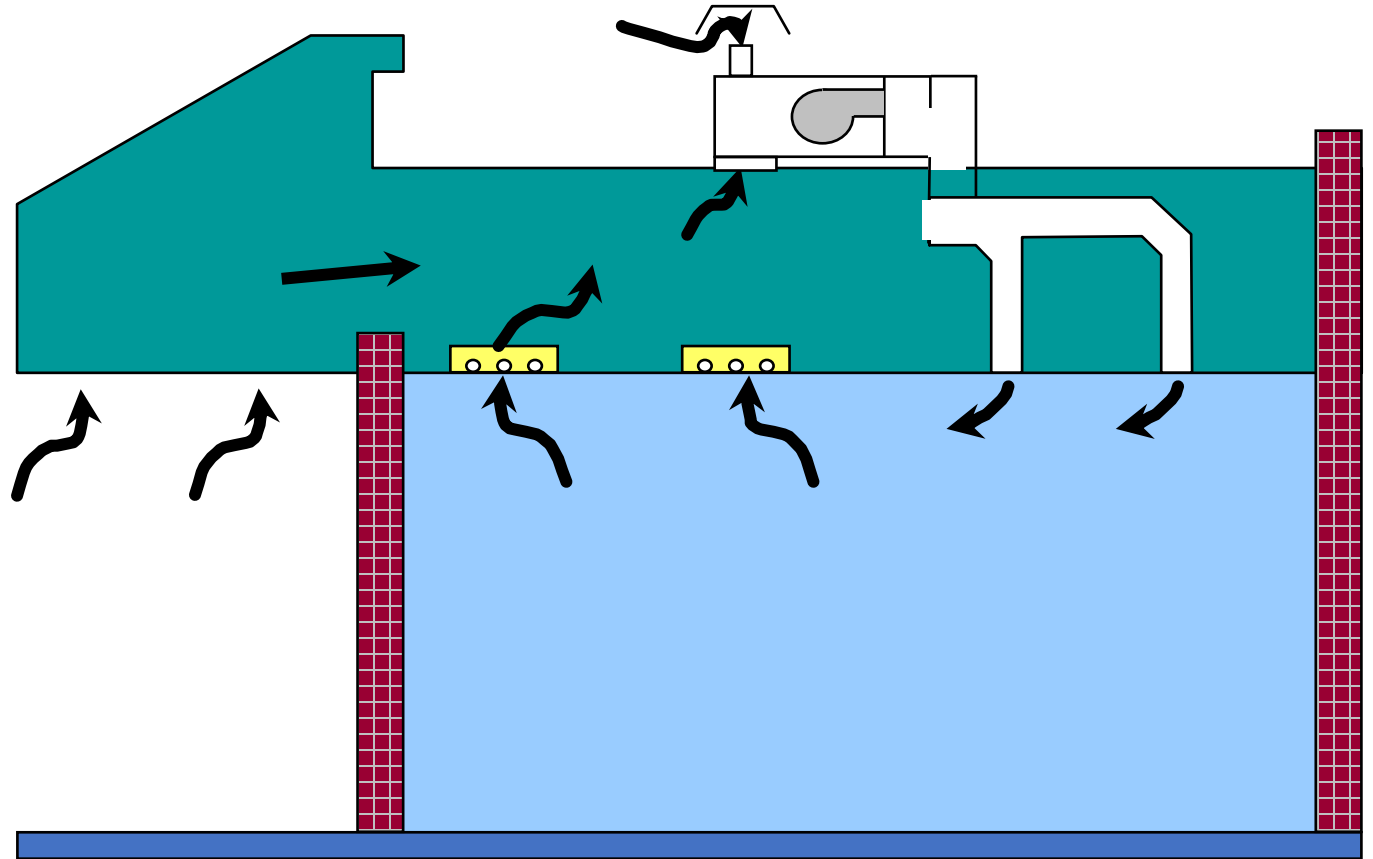
- Reduced HVAC system costs of about 10% to 20% of the total HVAC system cost.
- Reduced efforts for coordination of overhead utilities.
- Assumed reduced fan energy costs due to lower pressure drop of the plenum return system.



Photo by Yuji Sakai

# Problems of Non-Ducted Return Air Plenums

- What could possibly go wrong here?



# Problems of Non-Ducted Return Air Plenums

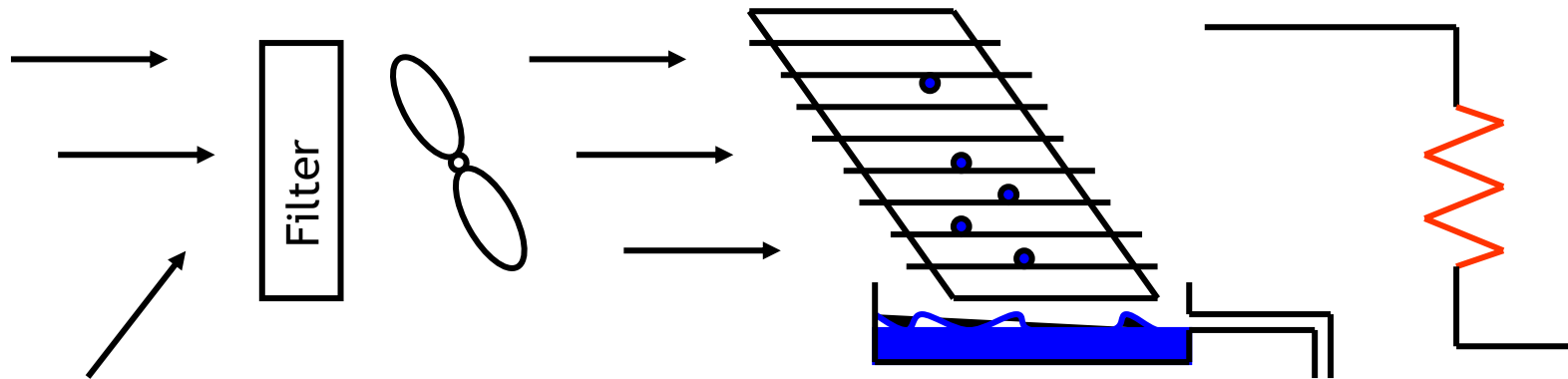
- Cavities above suspended ceilings are used as equipment tunnels and chases causing major air leakage
- These areas are highly (de)pressurized, which exacerbates the air leakage
- They are often adjacent to unconditioned spaces (storage, plant, warehouse, etc.)



# HVAC 101 – Moisture Removal

## Mechanical Dehumidification

- Return air is mixed with ventilation air
- Cold coil condenses moisture
- Heat is sometimes added back (electric or gas) so that room air is not over cooled - Reheat




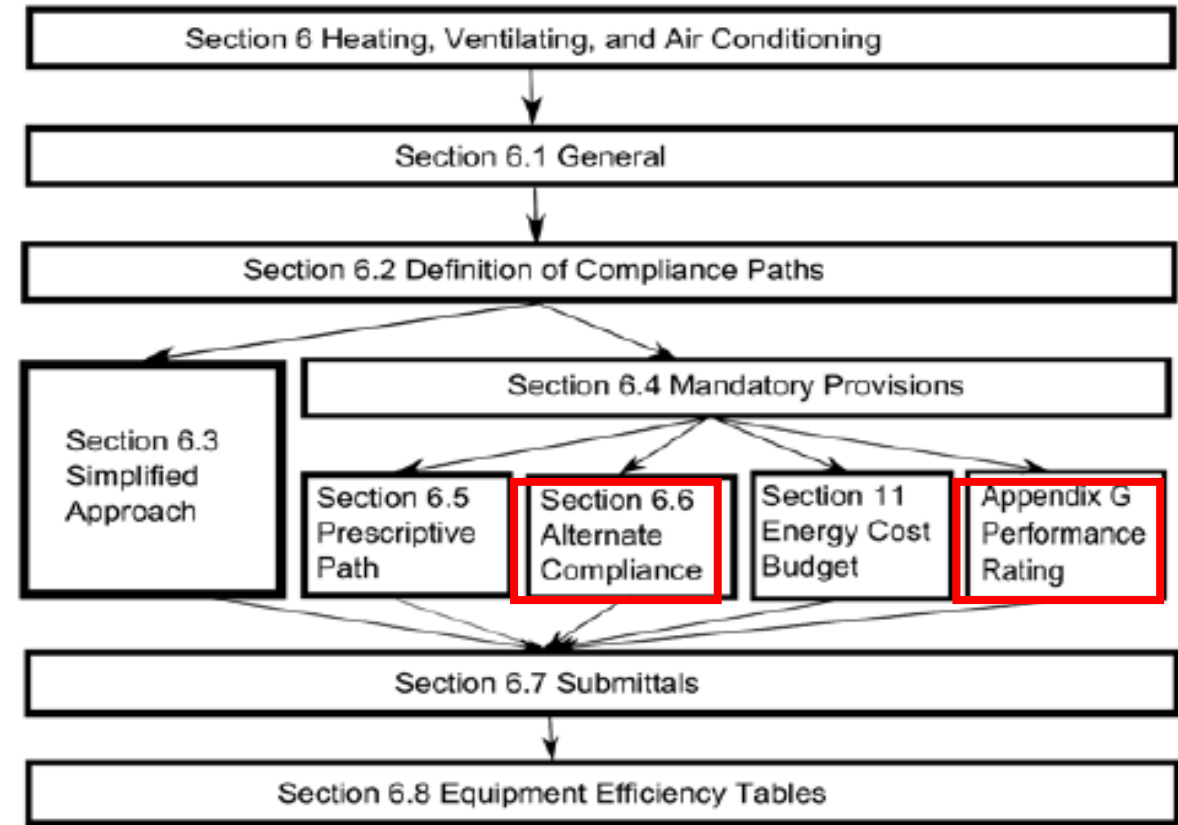
# New Compliance Pathways



## ASHRAE 90.1-2019

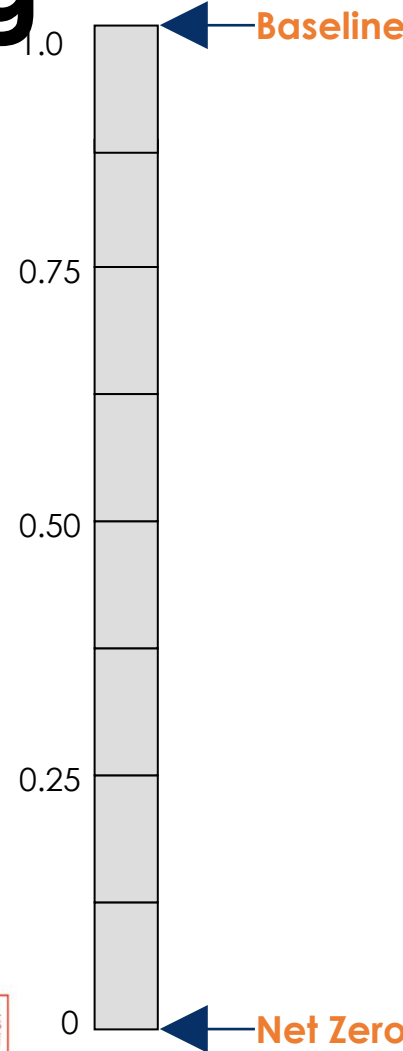
- 6.6 Alternative Compliance Path (for Computer Rooms)
- Appendix G is a new alternative compliance pathway

 2 New Compliance Pathways added in 2016



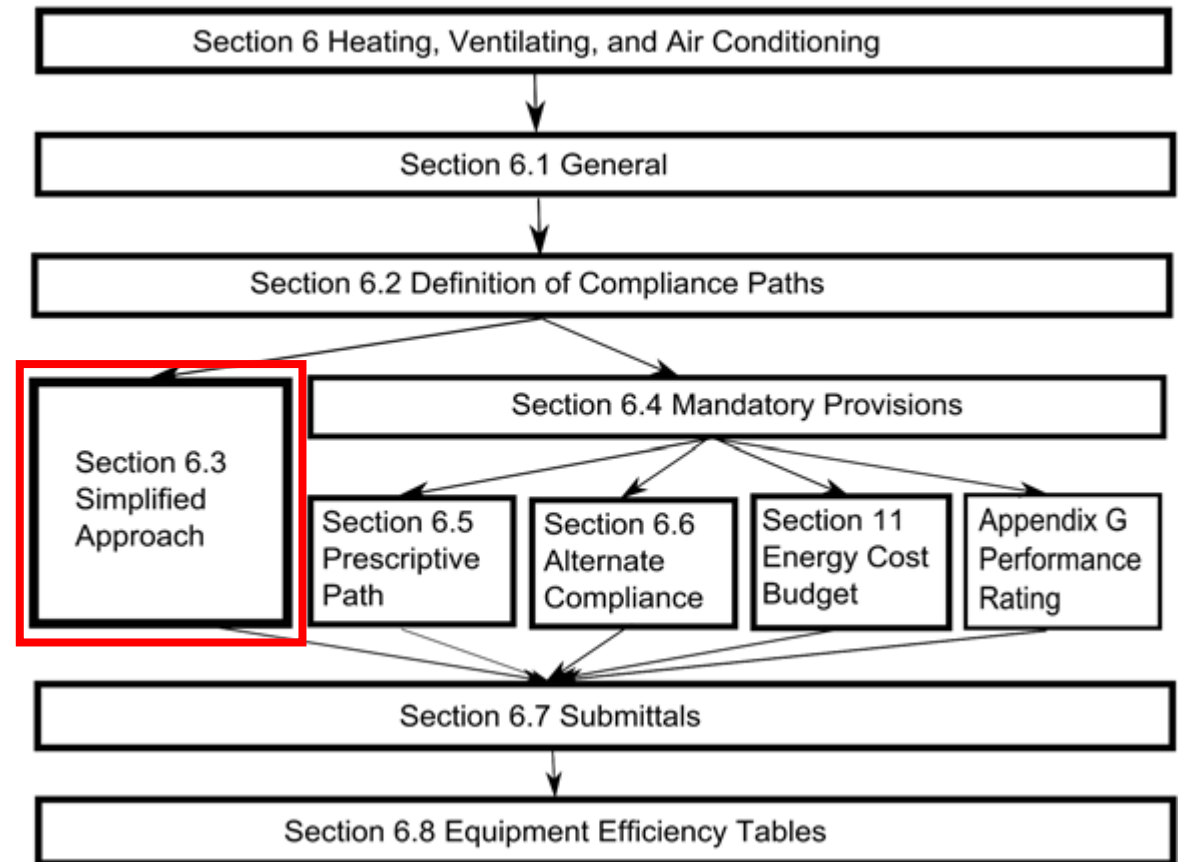
# Appendix G – Performance Rating

- Requires a Performance Cost Index (PCI) specific to building type and climate zone
  - $$PCI = \frac{\text{Proposed Building Performance}}{\text{Baseline Building Performance}}$$
    - PCI of 1.0 = baseline building
    - PCI of 0.0 = zero net energy
    - For compliance,  $PCI < PCI_t$
- $PCI_t$  specified in Standard, and varies by building type, climate zone, and proportion of regulated to unregulated load



# Mechanical Compliance

- Simplified Approach is still the easiest pathway
- According to the Department of Energy, 80 to 85% of the building stock is this type of building.





# 90.1 Simplified Approach Option for HVAC Systems



- The simplified approach is an optional path for buildings that meet these criteria:
  - Building is two stories or fewer in height.
  - Gross floor area is less than 25,000 sq. ft.
  - System serving single HVAC zone
  - Each HVAC system in the building must comply with all 19 requirements.



# COMcheck



- The COMcheck software and web tools simplify and clarify energy code compliance with the IECC, standard (ASHRAE Standard 90.1)

# Systems Commissioning and Completion Requirements

## Section C408

- Commissioning is critical to ensure that buildings are **working as designed**
- Preliminary and final reports required
- Mechanical and lighting commissioning detailed in section C408

### Benefits of Commissioning



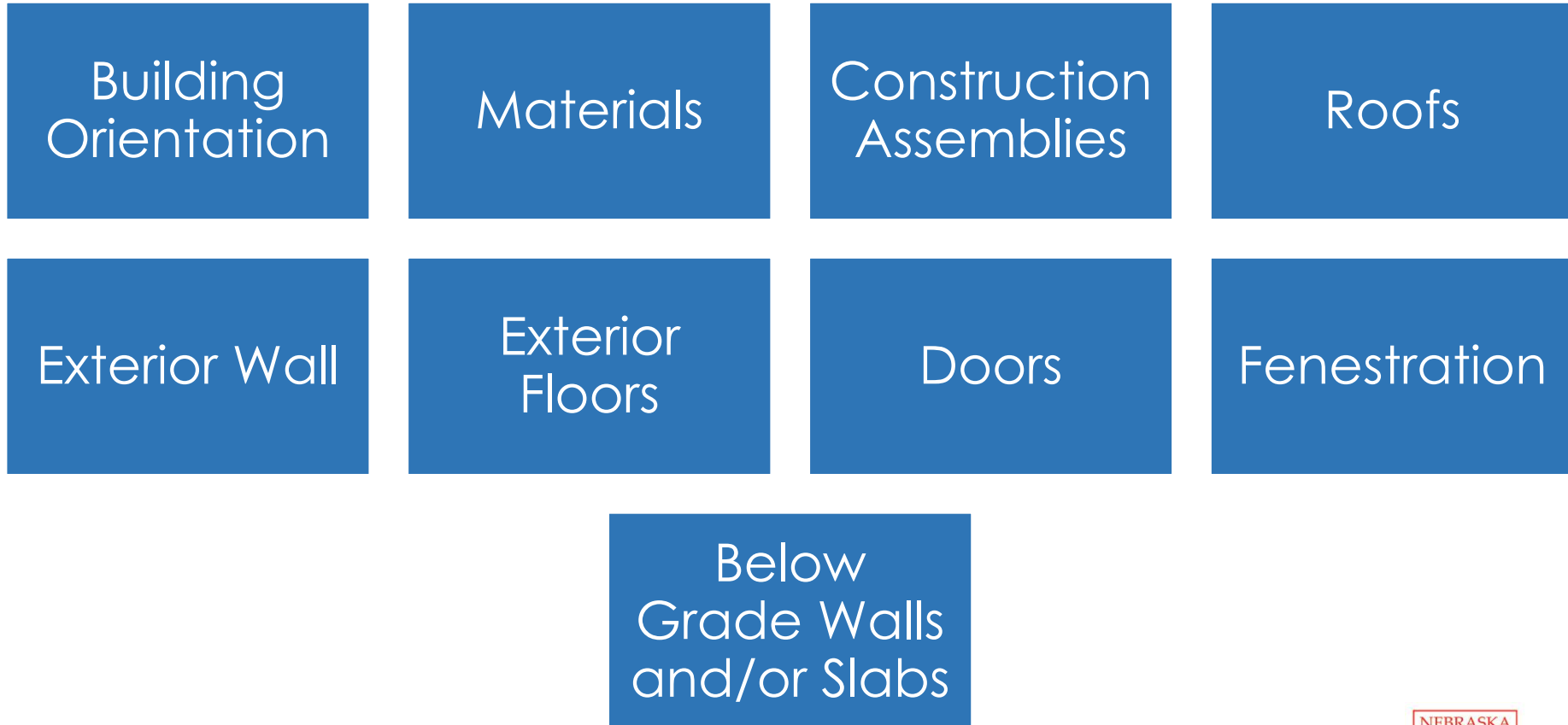


# Functional Testing of Lighting Controls

## Section C408.3.1

- Prior to passing final inspection, registered design professional to provide evidence that lighting control systems:
  - have been tested to ensure that control hardware and software are calibrated, adjusted, programmed and in proper working order per construction documents and manufacturer's installation instructions

# Commissioning: Building Envelope Data Points



# ASHRAE 90.1 2019 Changes

- Building Leakage Rates Update
- Sec 5.9 Verification/Commissioning/Inspections Updates
- Computer rooms & Data centers;
  - Creates definition for Computer Room
  - Directly references Std. 90.4
  - Small Computer rooms still under 90.1

# Resources

- DOE 2018 IECC Presentation: [energycodes.gov/technical-assistance/training/courses/commercial-requirements-2018-iecc](https://energycodes.gov/technical-assistance/training/courses/commercial-requirements-2018-iecc)
- 90.1-2016 Overview: [energy.gov/eere/buildings/articles/new-energy-code-commercial-buildings-standard-901-2016](https://energy.gov/eere/buildings/articles/new-energy-code-commercial-buildings-standard-901-2016)
- DOE 90.1-2016 Presentation: [energycodes.gov/resource-center/training-courses/ansiashraeies-standard-901-2016](https://energycodes.gov/resource-center/training-courses/ansiashraeies-standard-901-2016)
- Performance Rating Method Reference Manual: [pnnl.gov/main/publications/external/technical\\_reports/PNNL-26917.pdf](https://pnnl.gov/main/publications/external/technical_reports/PNNL-26917.pdf)
- 2018 IECC: [codes.iccsafe.org/content/iecc2018/chapter-4-ce-commercial-energy-efficiency#IECC2018\\_CE\\_Ch04\\_SecC408](https://codes.iccsafe.org/content/iecc2018/chapter-4-ce-commercial-energy-efficiency#IECC2018_CE_Ch04_SecC408)
- COMcheck: <https://www.energycodes.gov/comcheck>





# MEEA YouTube Videos

## Commercial Air Infiltration

- <https://www.youtube.com/watch?v=as6l1xEMJes>

## Commercial Lighting and HVAC

- <https://www.youtube.com/watch?v=FroYByTpu7U>





# Questions?



# Upcoming Events

- **Monthly:** Online or in-person trainings on Residential/Commercial Energy Codes and related topics
- **4/25** 2018 IECC Updates and Building Science Basics, in person, 1-2:30 p.m. (at NECA in Omaha)
- **4/26** Nebraska Energy Codes Collaborative, in-person, 9:30-11:30 a.m. (at NDEE in Lincoln)
- **4/26** 4-6 p.m.(ish) Networking/Membership Happy Hour in Lincoln (Location TBD)
- **Late May:** Western Nebraska Code Officials & public seminar (Date/Location TBD)
- **This Fall:** Online MCC Energy Code Certificate 4-Week Course





# Thank you!

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