



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

Instructor: Matt Belcher

September 19, 2024 | 11:30 a.m.-1:30 p.m.



Housekeeping



Attendees are muted upon entry



Questions? Enter them in the chat box, or simply unmute yourself and ask



Webinar is being recorded – slides and recording will be sent to attendees



CEU's will be available upon request (ICC and AIA)

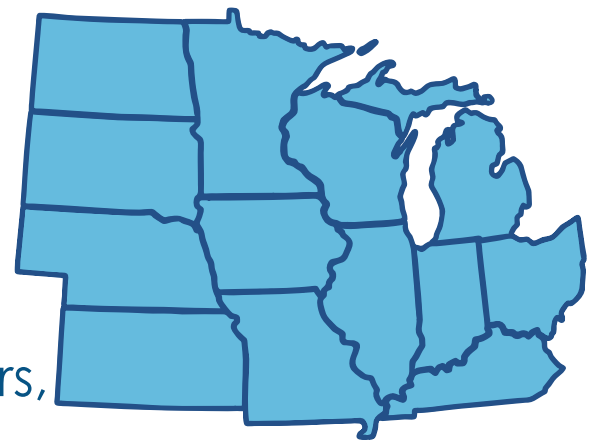


Email: jgossman@mwalliance.org with questions



Who We Are

The Midwest Energy Efficiency Alliance (MEEA) is a collaborative network, promoting energy efficiency to optimize energy generation, reduce consumption, create jobs and decrease carbon emissions in all Midwest communities.



MEEA is a non-profit membership organization with 170+ members, including:



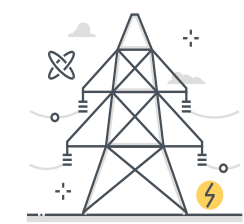
Energy Service Companies & Contractors



State & Local Governments



Academic & Research Institutions



Electric & Gas Utilities



Community-based Organizations

About the Nebraska Training Program



Goal: **prepare** the Nebraska workforce for changes in construction best practices



Focused on **providing training** to builders, code officials, design professionals, public officials and students



For more information, visit:

<https://www.mwalliance.org/nebraska-energy-codes-training-program>

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

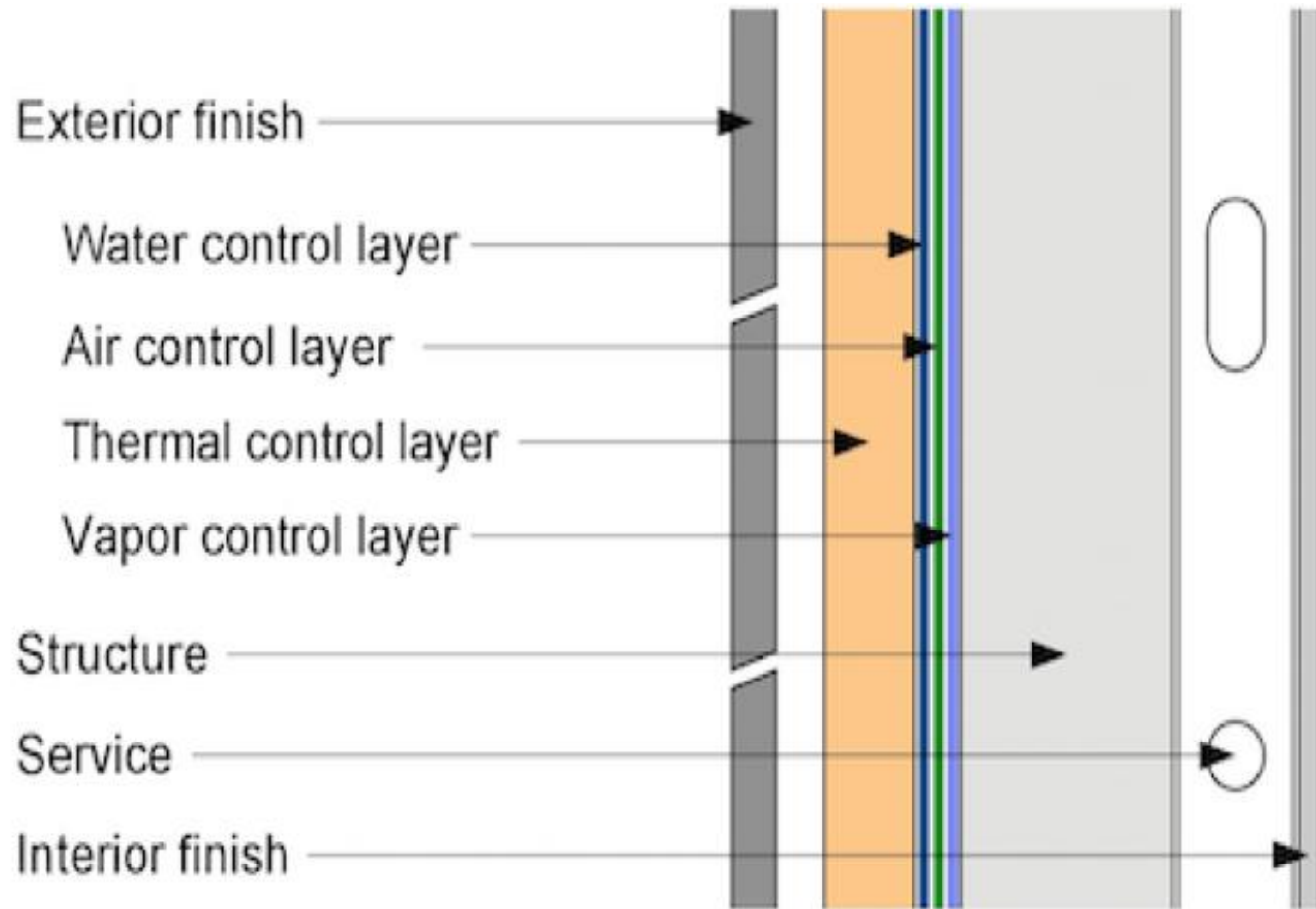
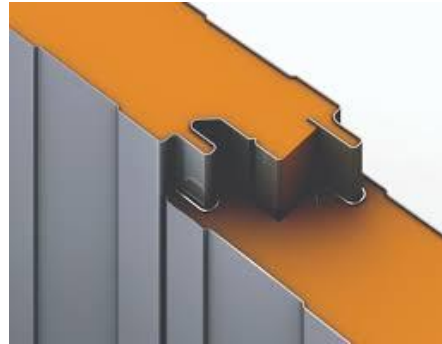
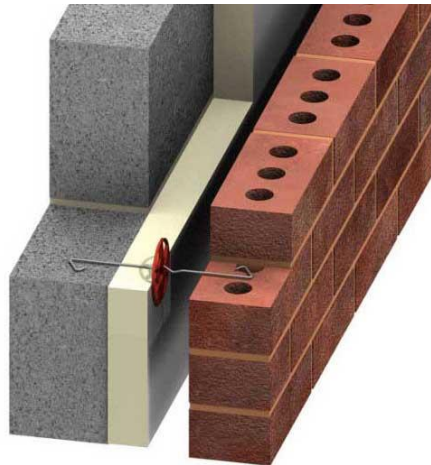


Image: Green Building Solutions

Building Envelope: Many Wall Types



Insulated Panel



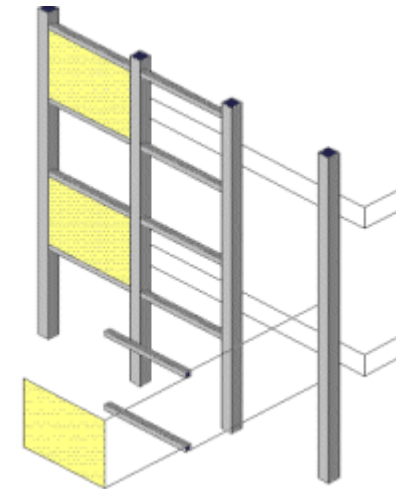
Cavity Wall



Steel Stud/Exterior Sheathing



Mass Timber



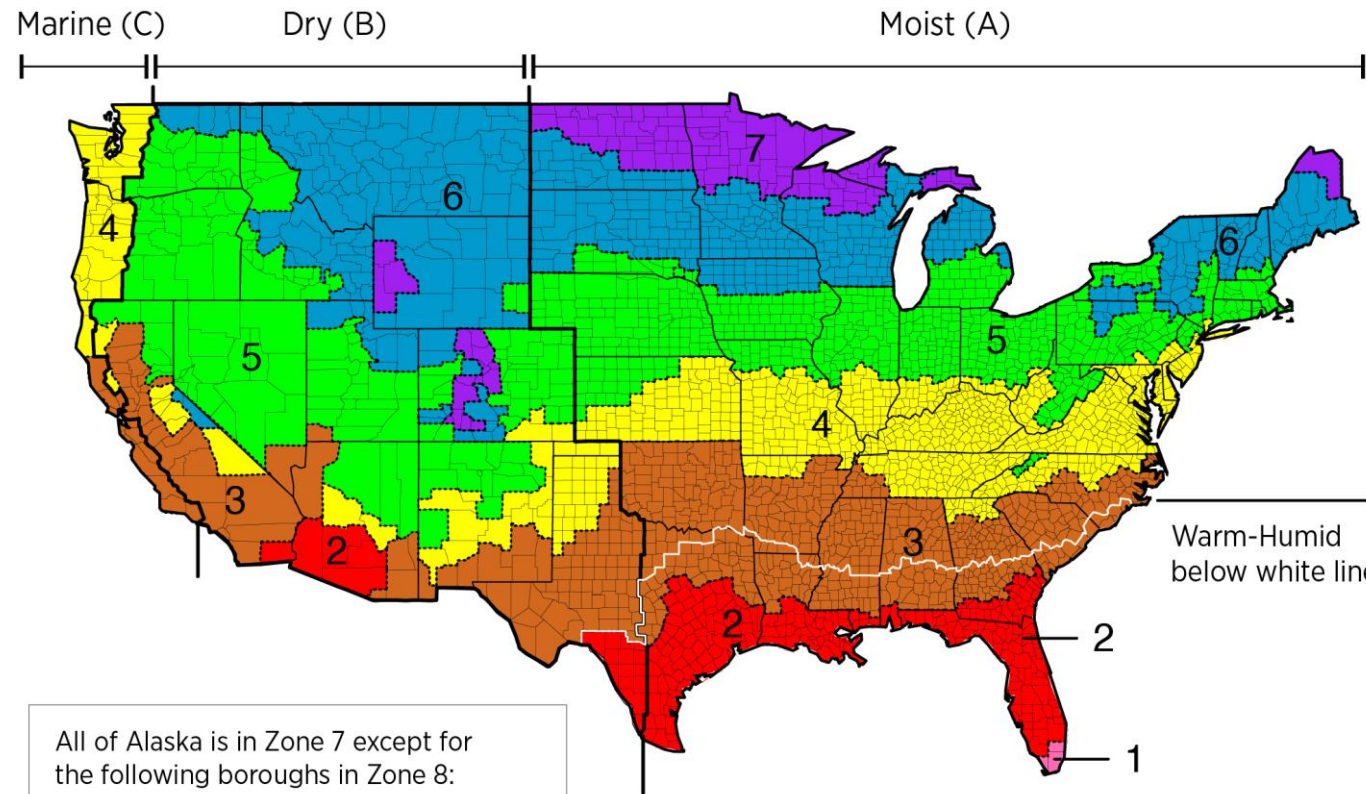
Stick-Built Curtain Wall



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

Warm-Humid below white line



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 in² 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/ft²

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

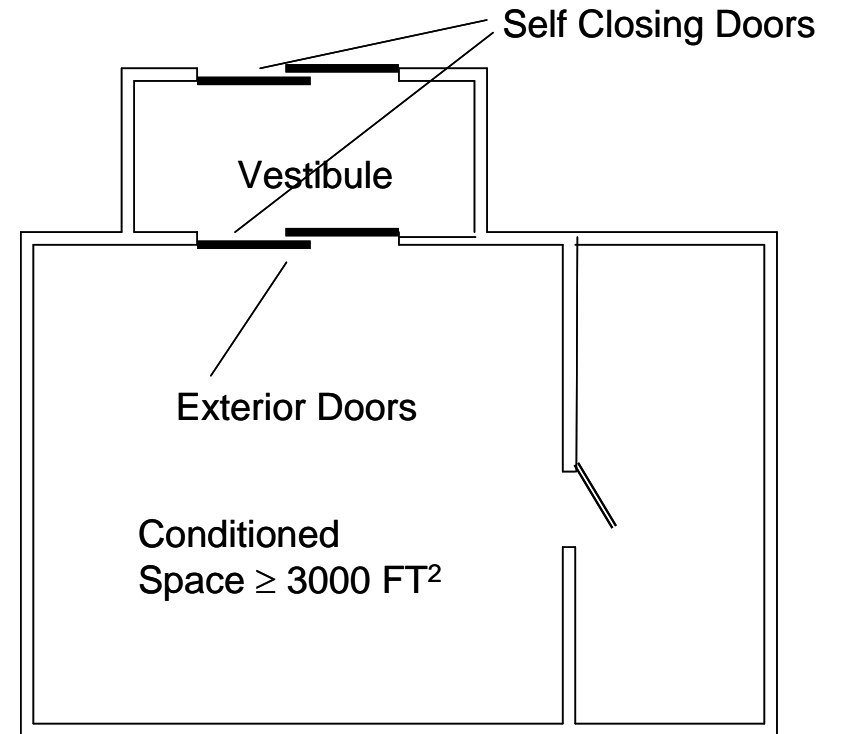


Image: U.S. Dept of Energy



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 ≤ 0.25 cfm/ft² (code minimum is ≤ 0.40 cfm/ft²)
 - 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 ≤ 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

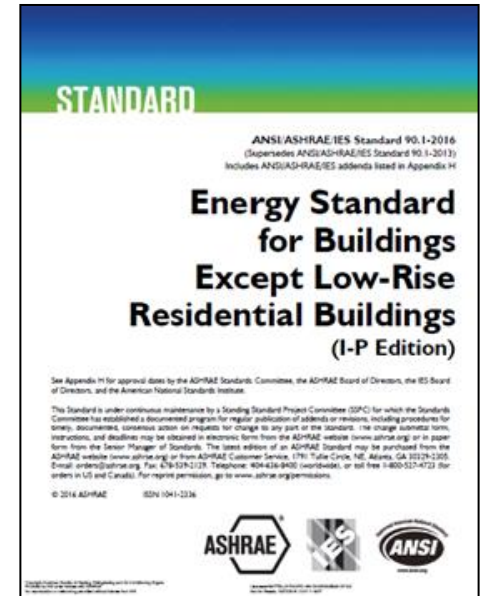


Image: ASHRAE.org



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)



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/ft²)
- Exterior Lighting Controls
 - Required Controls
 - Lamp Efficiency
- Exterior Lighting Power Allowances (watts/ft²)
- 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 ²)
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 ²)			
	2016	2013	2010	2007
Conference, multi-purpose and meeting rooms	1.07	1.23	1.23	1.23
Lounge/Breakroom in a healthcare facility	0.78	0.92	1.07	1.07
Healthcare – exam treatment room	1.68	1.66	1.66	1.66
Enclosed offices	0.93	1.11	1.11	1.11
Office open	0.81	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 ²)
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 ²)
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

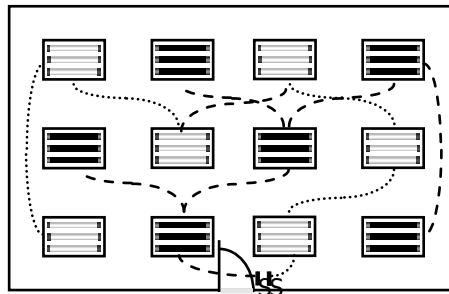
Light-reduction Control

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

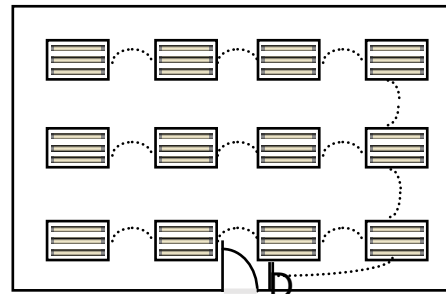
Light Reduction Controls must allow the occupant to reduce connected lighting load

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



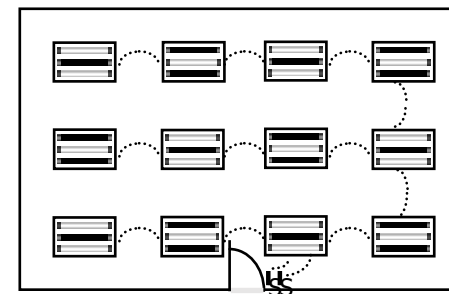
Alternating Luminaires

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

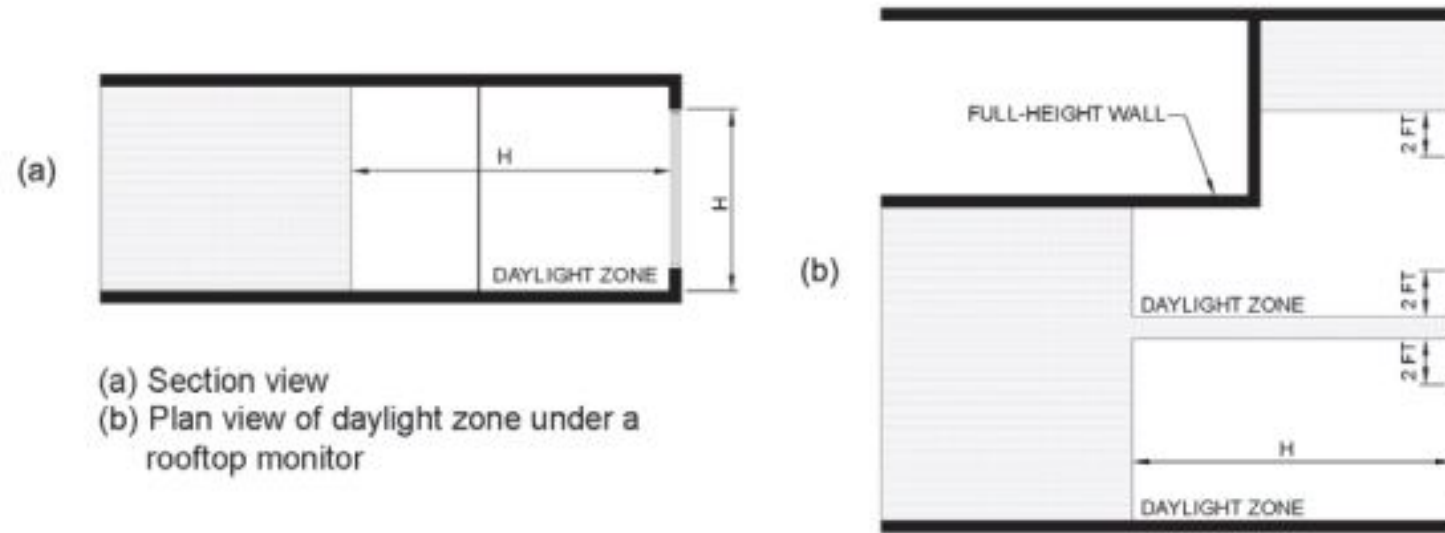


FIGURE C405.2.3.2 SIDELIT ZONE

Image: International Code Council

Toplit Daylight Zone

Section C405.2.3.3

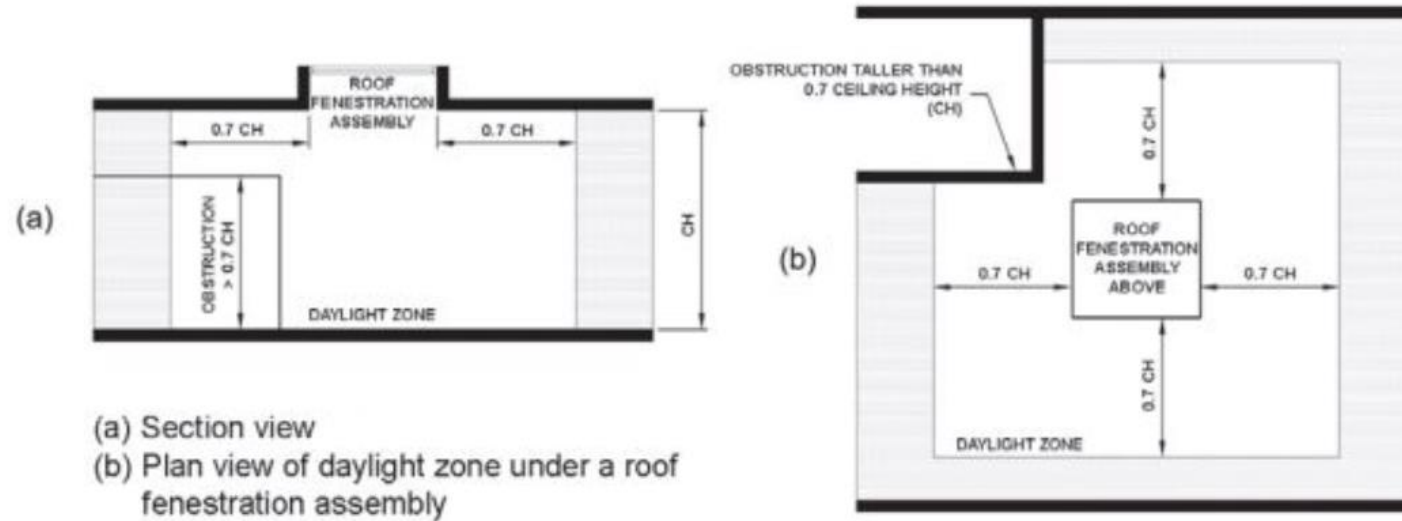


FIGURE C405.2.3.3(1) TOPLIT ZONE

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

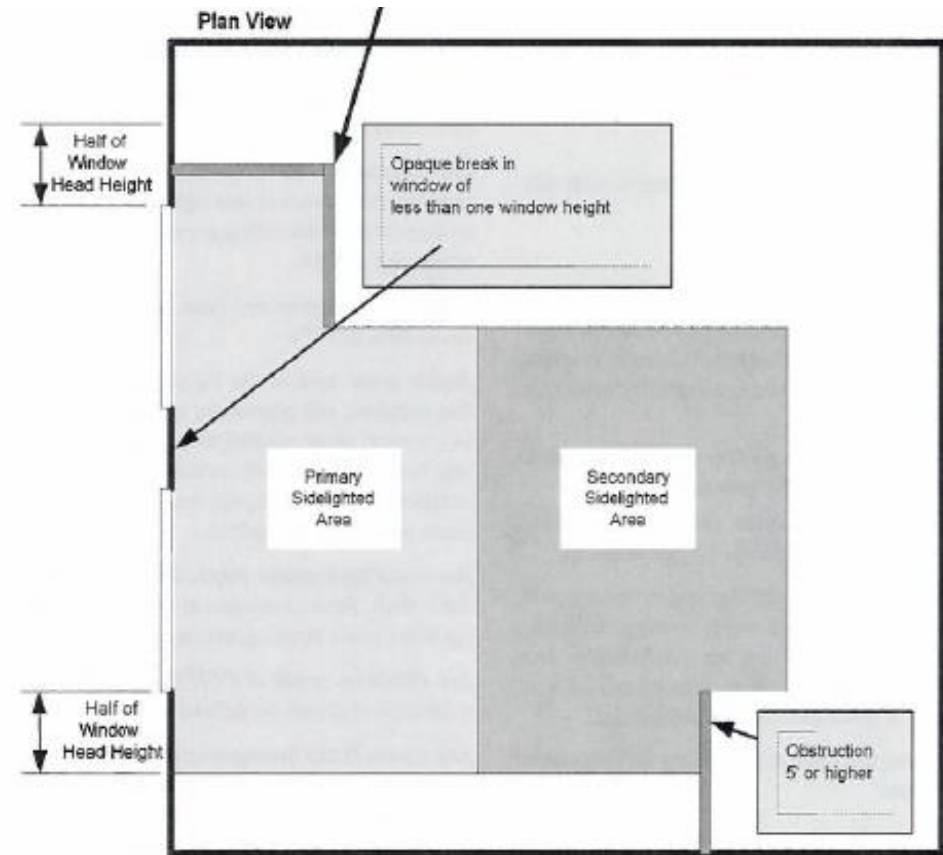



Image: US DOE



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

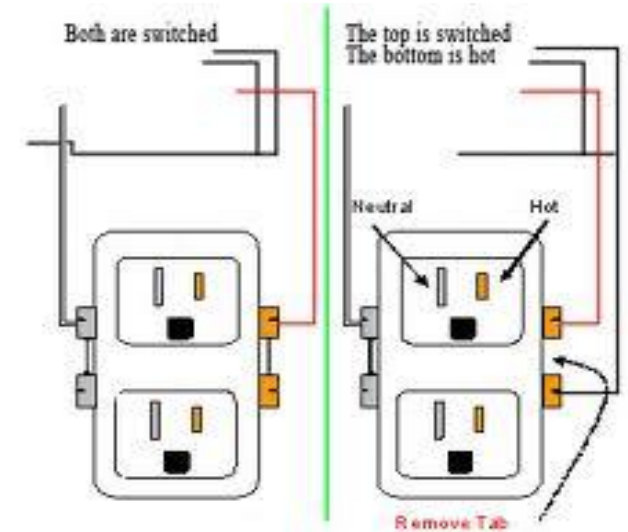
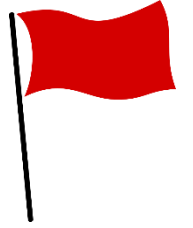


Image: US DOE



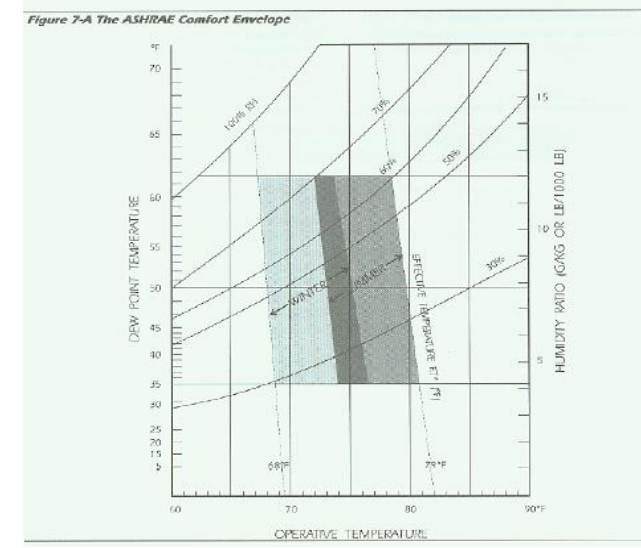
HVAC (Just a little bit)



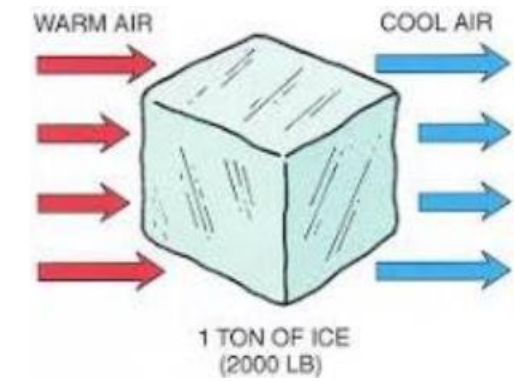


Load Calculations are Mandatory

- 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

Impacts of Non-Ducted Return Air Plenums

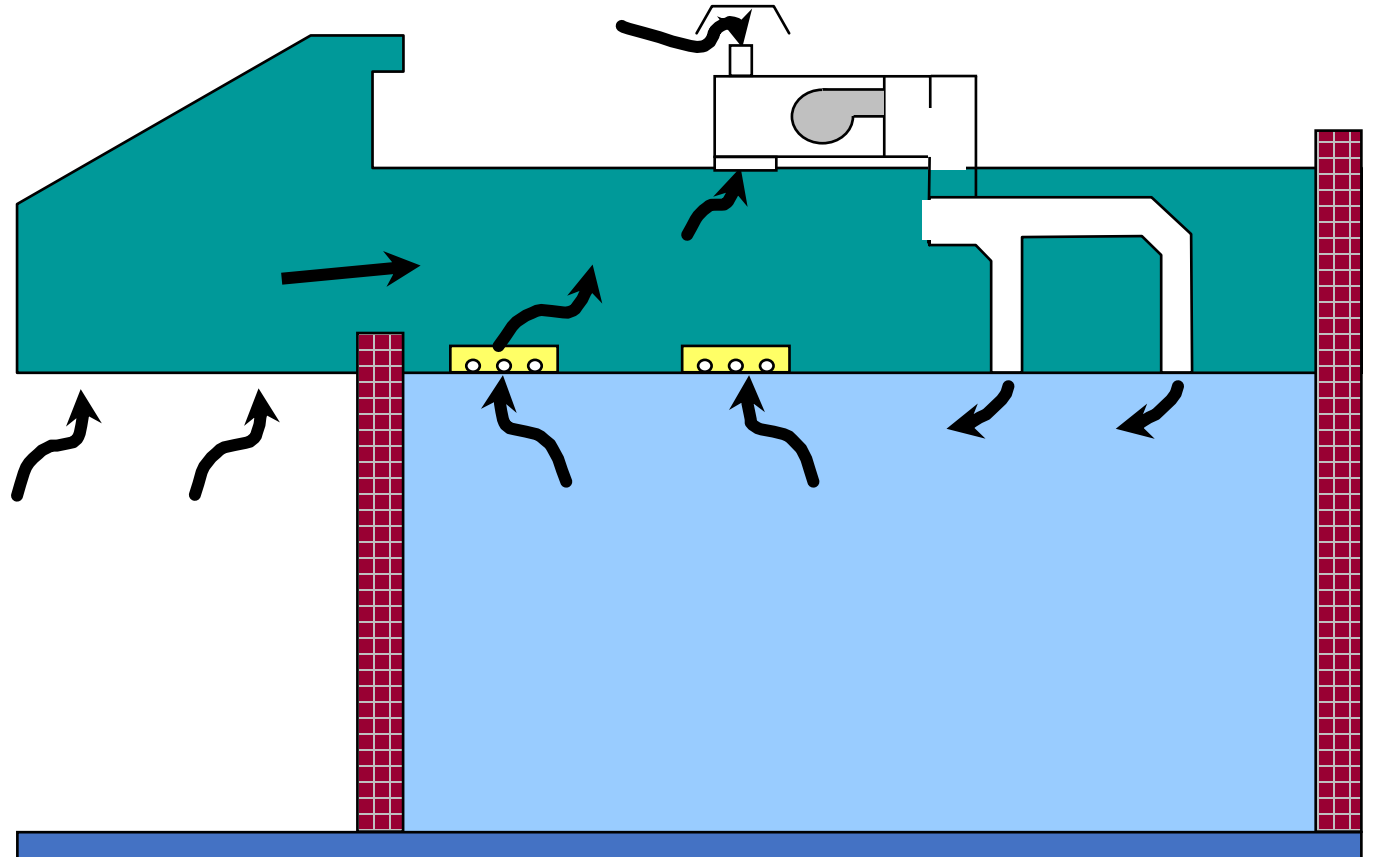
- Reduced HVAC system costs of about 10% to 20% of the total HVAC system cost.
- Reduced efforts for coordination of overhead utilities.
- Assumed reduced fan energy costs due to lower pressure drop of the plenum return system.



Photo by Yuji Sakai

Problems of Non-Ducted Return Air Plenums

- What could possibly go wrong here?



Problems of Non-Ducted Return Air Plenums

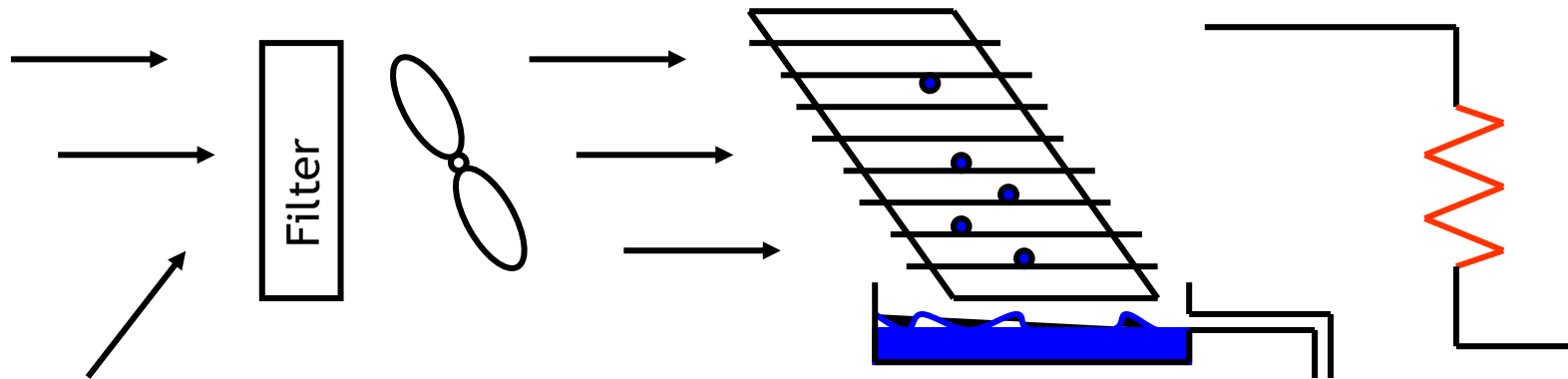
- Cavities above suspended ceilings are used as equipment tunnels and chases causing major air leakage
- These areas are highly (de)pressurized, which exacerbates the air leakage
- They are often adjacent to unconditioned spaces (storage, plant, warehouse, etc.)



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




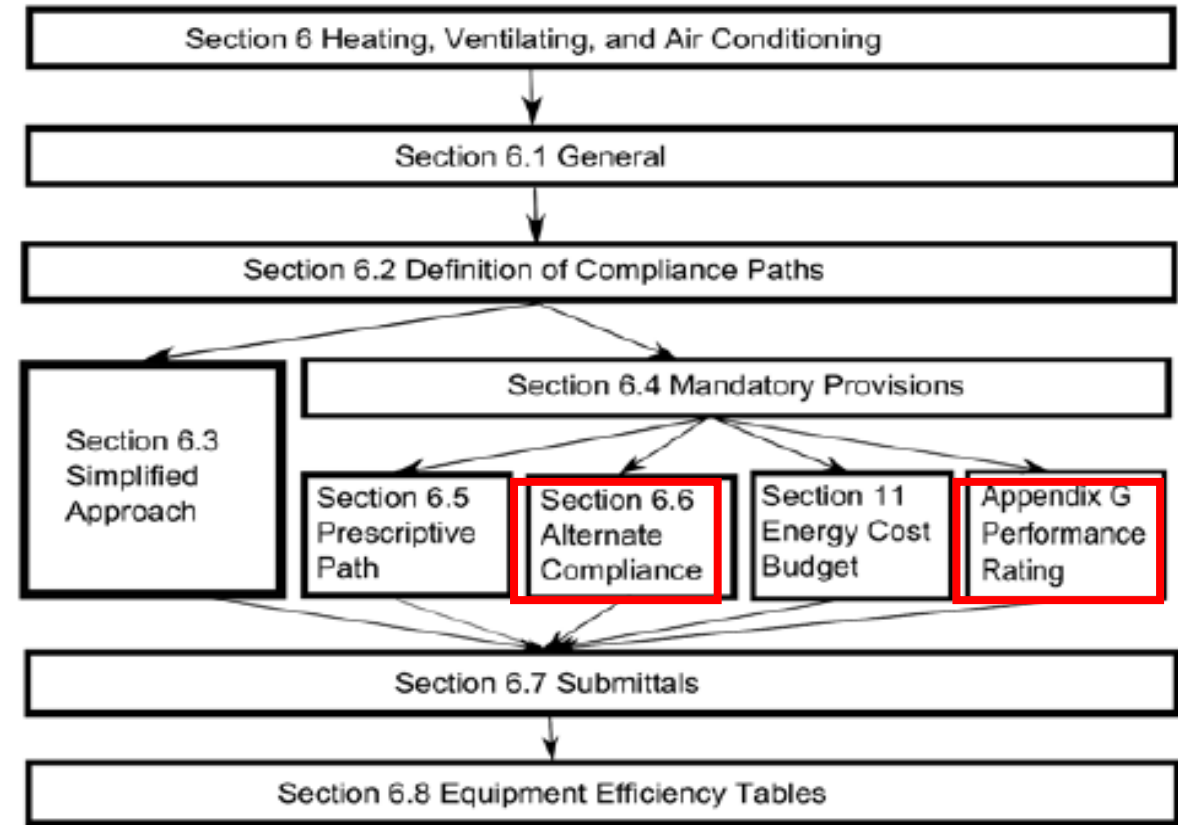
New Compliance Pathways



ASHRAE 90.1-2019

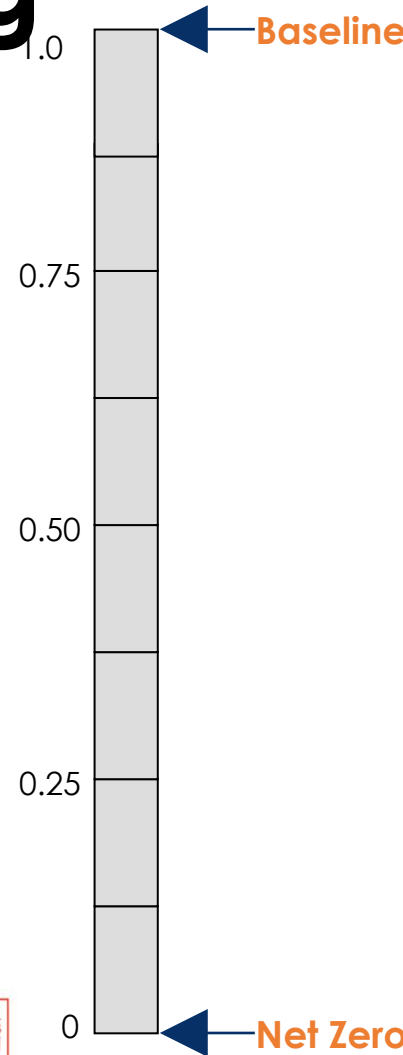
- 6.6 Alternative Compliance Path (for Computer Rooms)
- Appendix G is a new alternative compliance pathway

 2 New Compliance Pathways added in 2016



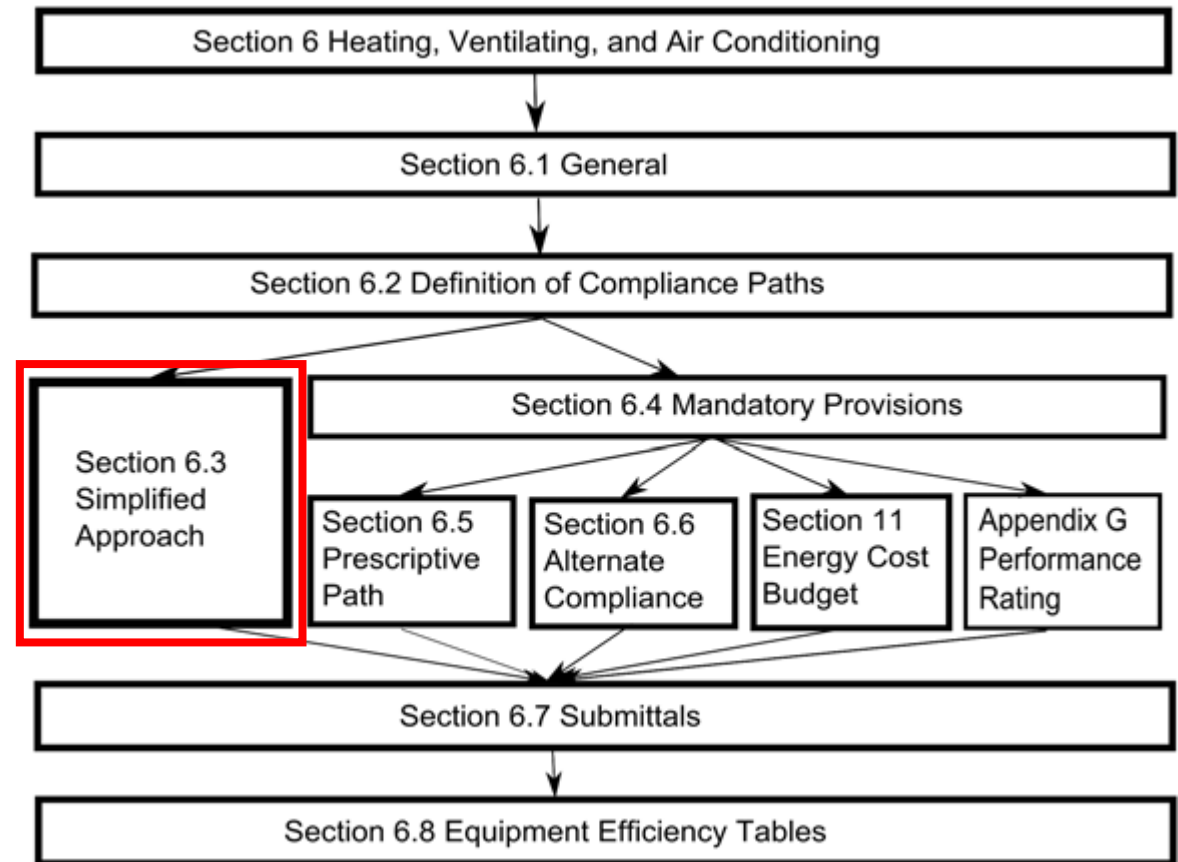
Appendix G – Performance Rating

- 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



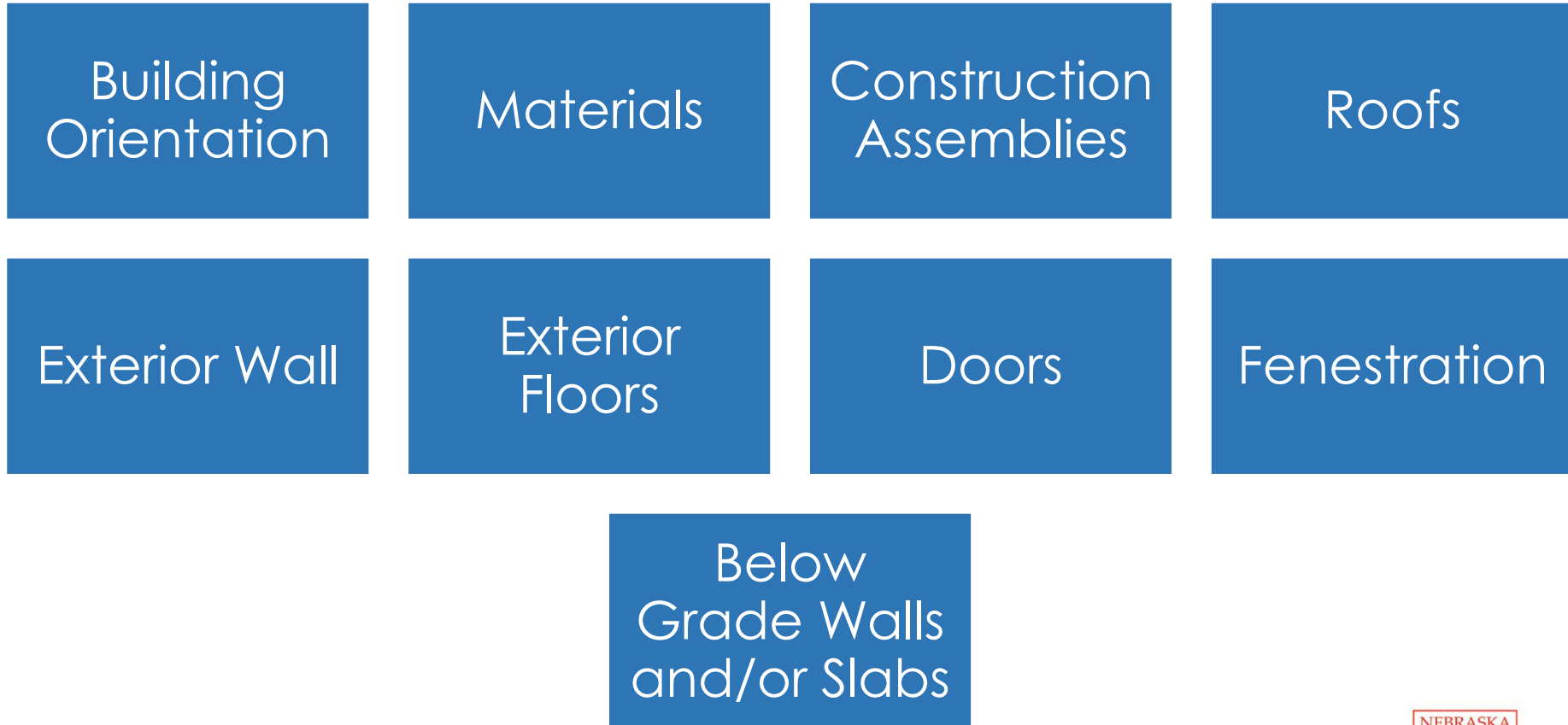


Functional Testing of Lighting Controls

Section C408.3.1

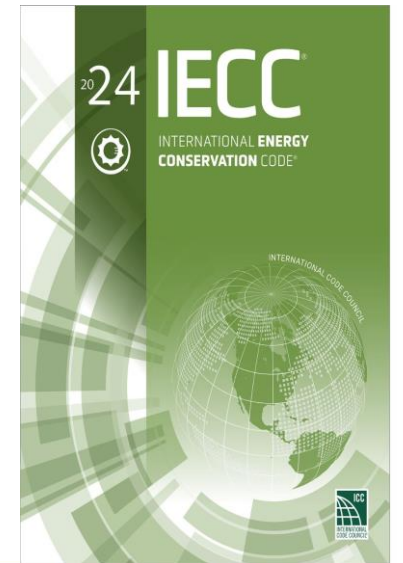
- Prior to passing final inspection, registered design professional to provide evidence that lighting control systems:
 - have been tested to ensure that control hardware and software are calibrated, adjusted, programmed and in proper working order per construction documents and manufacturer's installation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

Commissioning: Building Envelope Data Points



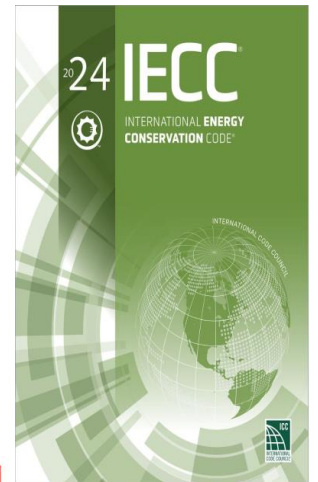
2024 National Energy Standard

- In Process since November '21 Final Approval 3/24!
- Use '21 Energy Code as Basis and Improvements from there.
- Many more stakeholders than IECC Development
- Glide slope to Net Zero by 2030
- Expanded Appendices
- Carbon Impact/Credits



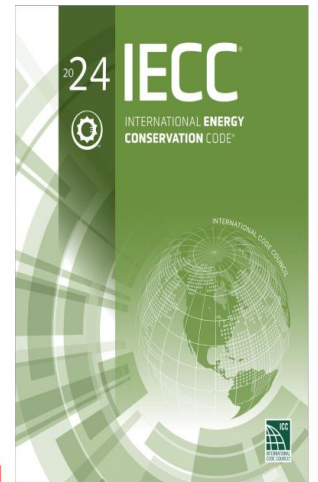
2024 National Energy Standard (Cont.)

- **More focus on Electrification**
- **Tables for Envelope and Fenestrations (402/403) updated**
- **More reliance of high performance**
- **More focus on testing/verification**
- **More intent to move appendices items forward in 2027 & 2030 versions**



2024 National Energy Standard (Cont.)

- **More focus on Electrification**
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2024 IECC The final result is a code that:

- **Added a wide range of reasonable options for compliance with R408**
- **Fixed the ERI path**
- **Recognizes federal preemption challenges with both electrification and higher levels of stringency**

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

Key Takeaways

- **2024 Energy Standard has new requirements for:**
 - Electrification
 - EV Charging
 - Solar
 - Grid Interaction
 - Carbon
- **Using & Understanding Guides and formulas is *critical***
 - Good Design!!!
 - Proper envelope construction is key
 - Right-sizing HVAC is required
 - Documenting construction and certification

Resources

- DOE 2018 IECC Presentation: 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
- DOE 90.1-2016 Presentation: 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
- 2018 IECC: 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?





Thank you!

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