ENERGY CODE TRAINING

Commercial Mechanical

Southface

INTRODUCTIONS

Mike Barcik
mikeb@southface.org

Matt Belcher
matt@verda-solutions.com

Heating, Ventilating, and Air Conditioning

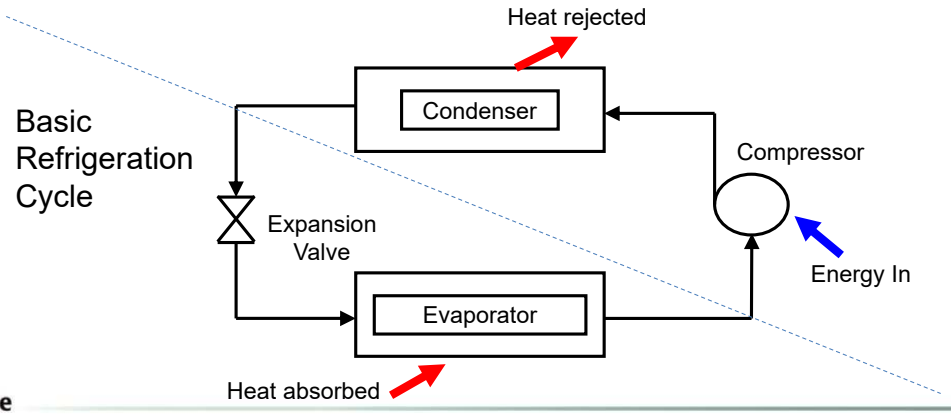
Photo: Jonathan Hillyer, 2009

HVAC 101- BASIC CONCEPTS

Heating, Ventilation and Air Conditioning

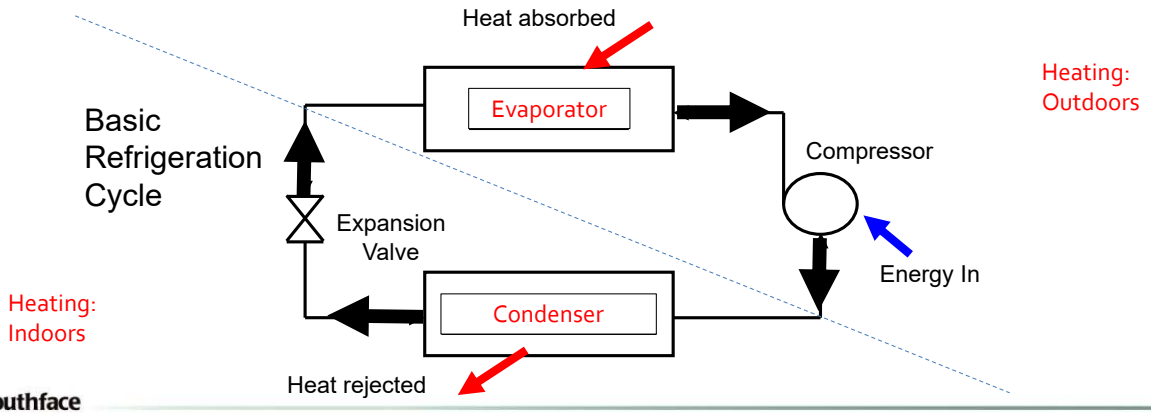
Provides *comfort* for people

Allows humans to *exist* under adverse conditions



HVAC 101- BASIC CONCEPTS

Heat pump in heating mode – compressor drives refrigerant in opposite direction (by means of a reversing valve)

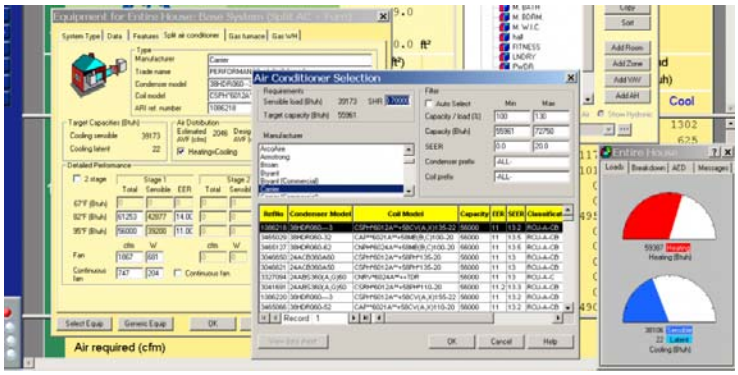


HVAC 101 – LOAD CALCULATIONS

Sizes heating and cooling equipment

Accuracy important!

- Design conditions
- Building shell load
- R / U value
- Solar heat gain
- Internal load
- Ventilation load
- Infiltration
- Occupancy schedules

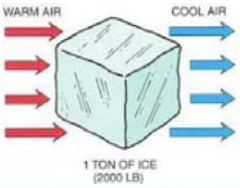


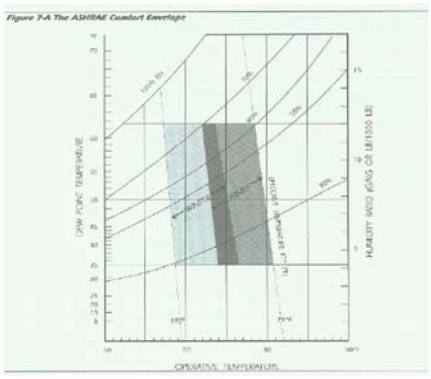
LOAD CALCULATIONS ARE MANDATORY

- Must calculate heating and cooling system design loads
- Must base calculations on generally accepted engineering standards and handbooks – ASHRAE / 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
  - ≤ 72°F for heating load
  - ≥ 75°F for cooling load





1 ton = 12,000 Btu/hr

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HVAC 101 - COMPONENTS

Basic HVAC Equipment

Fans / Blowers
Furnace / Heating unit
Filters
Compressor
Condensing units
Evaporator (cooling coil)
Control System
Air Distribution System

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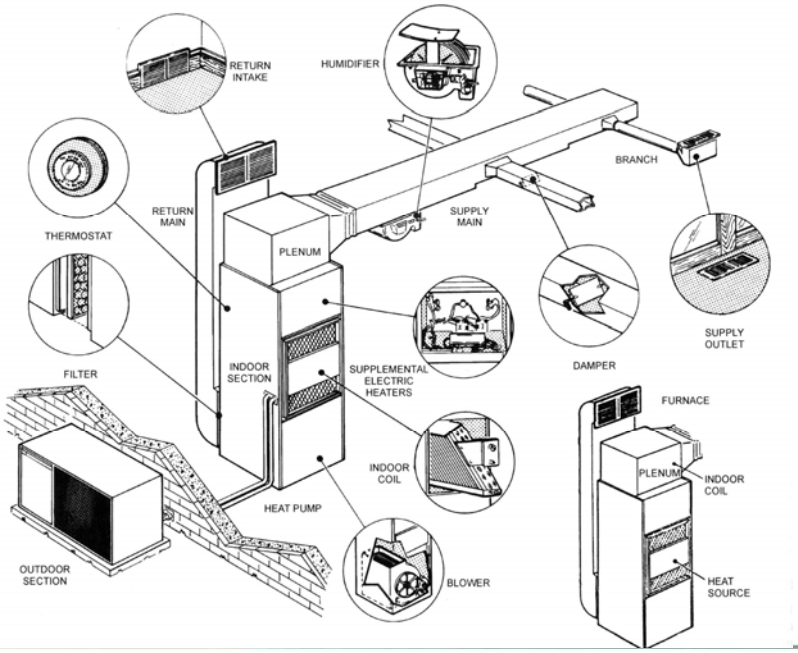
HVAC 101 – ANATOMY OF A SPLIT SYSTEM



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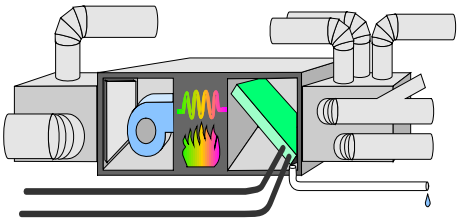
HVAC 101 – SYSTEM TYPES

Packaged versus Split Systems



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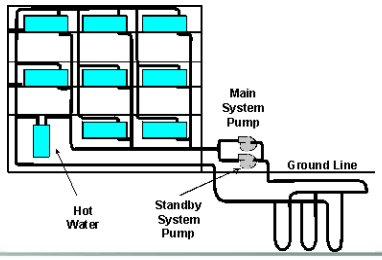
HVAC 101 – HEAT PUMPS

- Operate on basic refrigeration cycle
- Reversing the cycle provides heating
- Temperature limitations
- Extract/Reject heat
  - Air to air
  - Geothermal
  - Lake coupled
- Water source



HVAC 101 – USING WATER TO MOVE HEAT

Hydronic Systems

Pumps

Piping

Valves

Coils

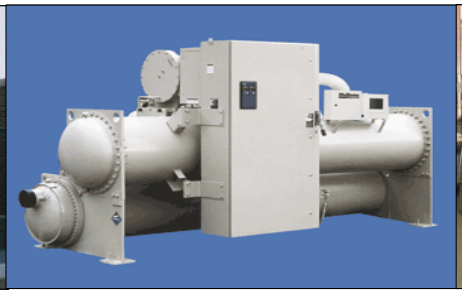
HVAC 101 – LARGE SYSTEMS

Major Equipment

Chillers

Boilers

Cooling Towers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Commercial HVAC Trivia

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

- True
- False

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HVAC 101 - CONTROLS

Control Devices

Thermostats

- Manual
- Programmable

DDC Systems

Automatic Valves and Dampers

Outdoor Sensors

Optimum Start

Variable Speed Drives

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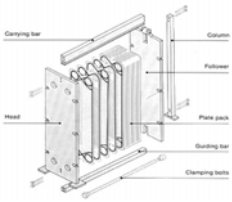
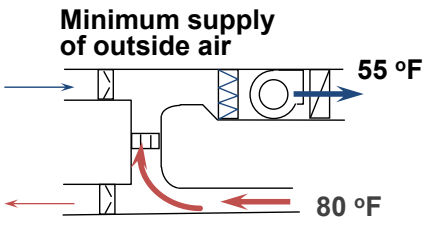
HVAC 101 - ECONOMIZERS

"**Free cooling**": Use cool outdoor air instead of mechanically cooled air

Air Side

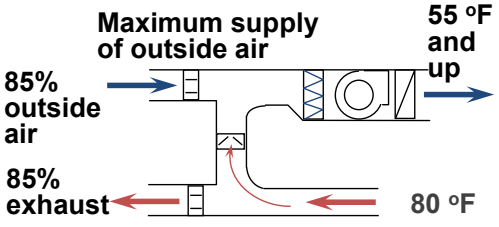


Water Side



Normal Operation

Outside air dampers provide minimum outside air



Economizer Operation

Outside air dampers are open to provide maximum outside air

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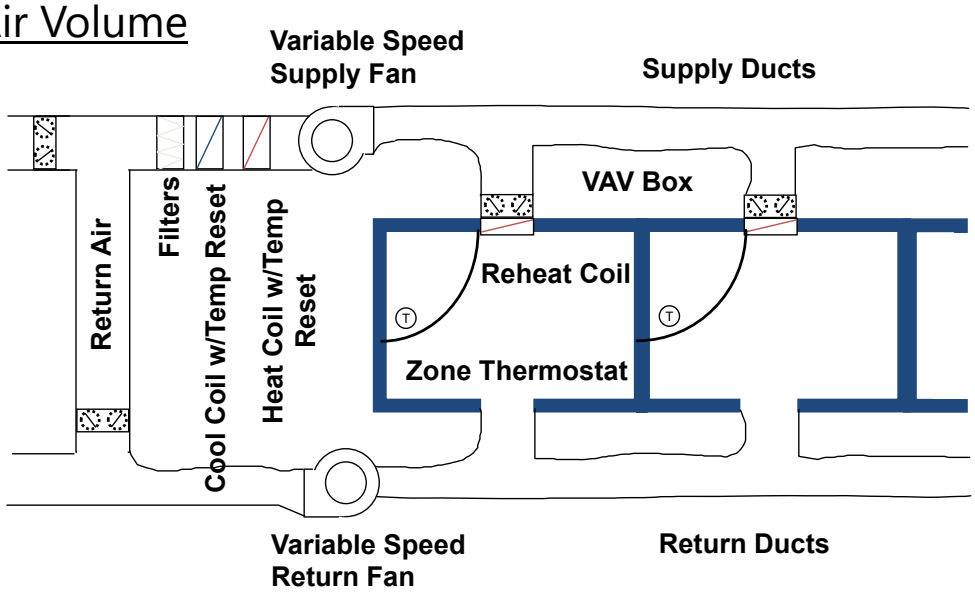
HVAC 101 - DISTRIBUTION

Variable Air Volume



HVAC 101 - DISTRIBUTION

Air Distribution

Ductwork
- Metal
- Flexible
- Ductboard

Grilles, Louvers, & Registers

Dampers
- Shut off
- Fire
- Smoke

Sealants

Supports

UFAD

HVAC 101 - RETURN PLENUMS

Ducted vs. non-ducted

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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

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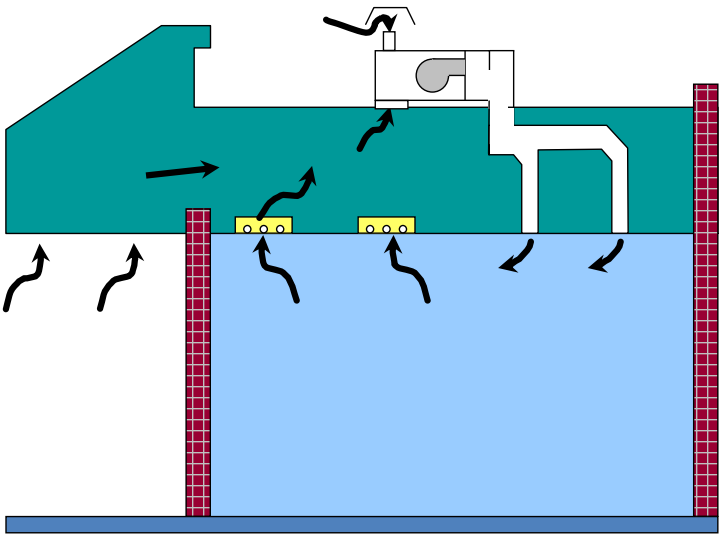
PROBLEMS OF NON-DUCTED RETURN AIR PLENUMS

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.)

WATER, WATER EVERYWHERE

Roof leak or something else?

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PLENUM INSULATION

C403.2.9 Duct and plenum insulation and sealing

Supply and return air ducts and plenums shall be insulated with a minimum of R-6 insulation where located in unconditioned spaces and where located outside the building with a minimum of R-8.

Where located within a building envelope assembly, the duct or plenum shall be separated from the building exterior or unconditioned or exempt spaces by a minimum of R-8 insulation.

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HEALTH CARE FACILITIES

- The 2018 or later Facility Guidelines Institute standards were adopted in many states.
- Those standards **require** ducted returns in many healthcare-related facilities to reduce the spread of infections.

CASE STUDY #1

CASE STUDY #2

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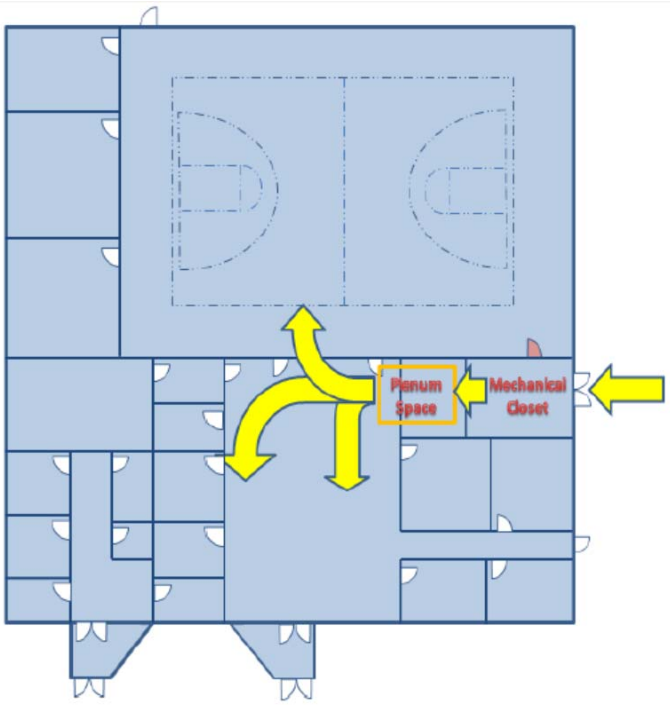
CASE STUDY #3

- Where is the air barrier?
- Where is the return plenum?



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CASE STUDY #3

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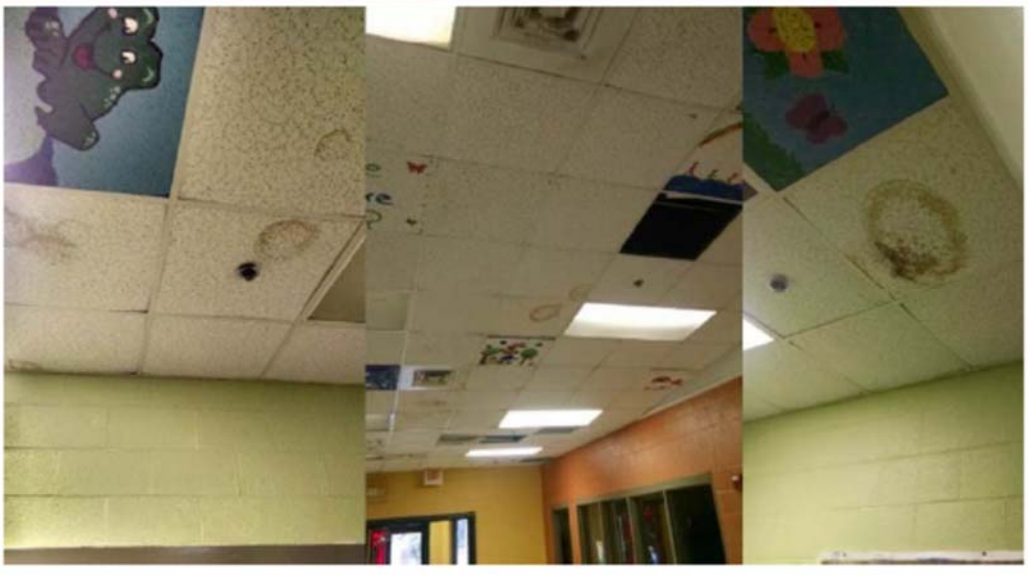
CASE STUDY #3



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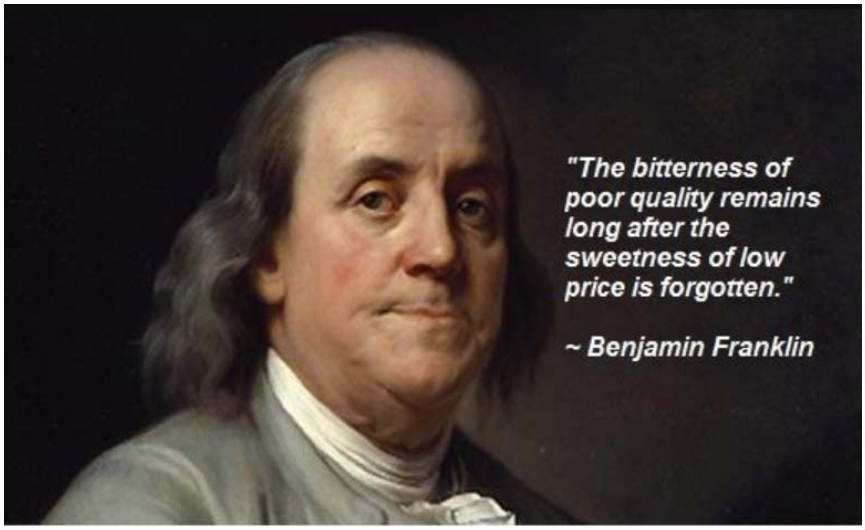
CONCLUSION – USE FULLY DUCTED RETURNS!



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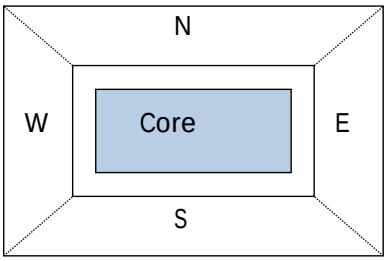
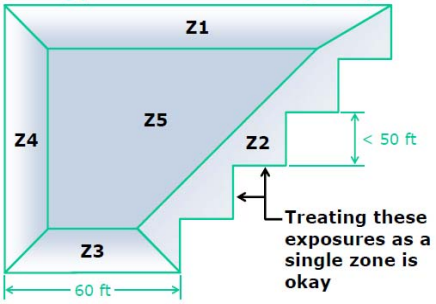
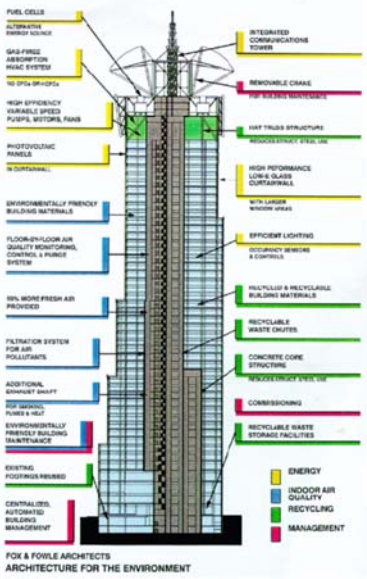
HVAC 101 - ZONES



building plan view: thermal zoning example

Core and each long exposure must be zoned separately





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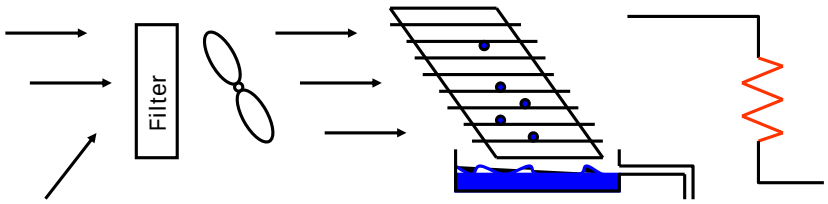
Mechanical Dehumidification

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



Additional Equipment

Energy Recovery Units

Desiccant Systems

HVAC 101 – "NEW" STUFF

New Technologies

Chilled beams

Radiant cooling

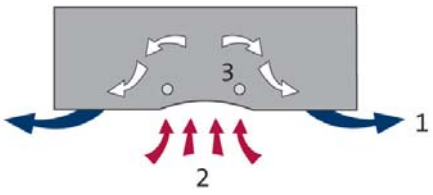


Illustration
1 Cooled air
2 Warm air
3 Cooling coil

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HVAC 101 – "NEW" STUFF

New Technologies

VRF (variable refrigerant flow)

Evaporative Mesh

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HVAC 101 – VENTILATION CONCEPTS

- Provide filtered, dehumidified outside air (OA) to space
- Consider designs that decouple and separately handle ventilation and space conditioning (DOAS)
- Utilize heat recovery to reduce ventilation energy cost
- Vary ventilation based on occupants and process loads - changes in occupancy can be measured by CO_2 sensors
- Effectively mix ventilation air into breathing zone of space
- Achieve positive pressure; exhaust from appropriate spaces
- Provide clean outside air, avoid:
  - loading docks
  - exhaust vents
  - plumbing stacks
  - waste collection
  - stagnant water

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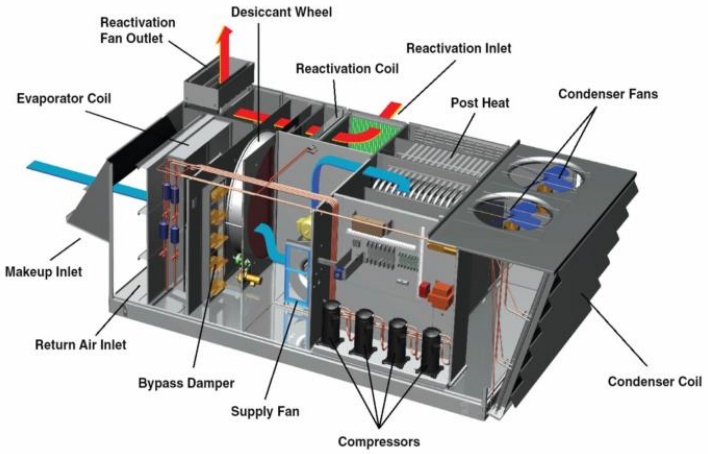
HVAC 101 - DOAS

- *Dedicated Outdoor Air Systems* **(DOAS)**
  - *Secondary air systems that regulate temperature, humidity, and gasses in buildings.*
- A **typical DOAS** configuration
  - *Shown to the right:*

Typical DX-DOAS (Air Cooled)



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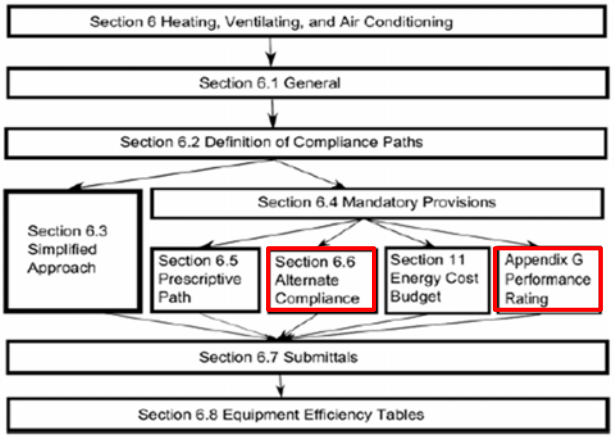
NEW COMPLIANCE PATHWAYS

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

ASHRAE 90.1-2019



2 New Compliance Pathways added in 2016

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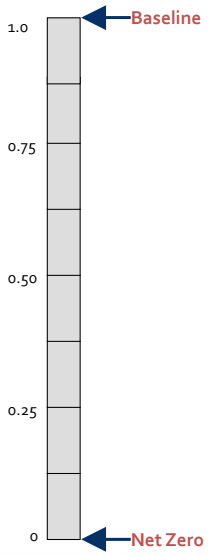
APPENDIX G – PERFORMANCE RATING

Requires a Performance Cost Index (PCI) specific to building type and climate zone

$$PCI = \frac{Proposed\ Building\ Performance}{Baseline\ Building\ Performance}$$

PCI of 1.0 = baseline building
PCI of 0.0 = zero net energy
For compliance, PCI < PCIt

PCIt specified in Standard, and varies by building type, climate zone, and proportion of regulated to unregulated load



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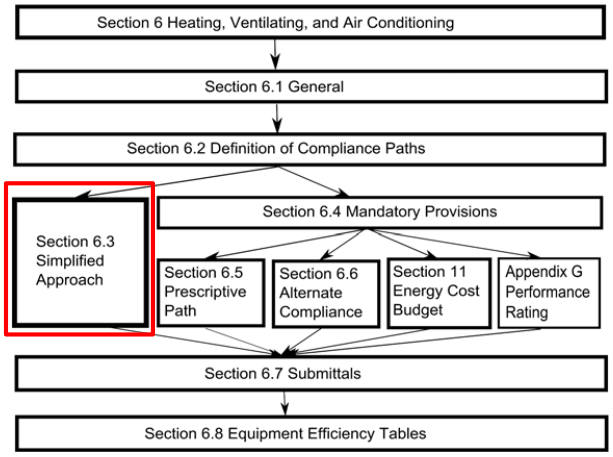
MECHANICAL COMPLIANCE

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.



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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.

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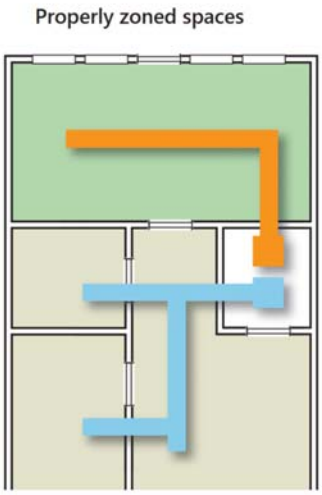
ZONES

A. The system must serve a single zone

An HVAC zone is a space or group spaces within a building with similar heating and cooling requirements that can be managed with a single control

- Multi-zone mechanical systems would not meet this requirement
- Separate mechanical systems serving individual zones would meet the requirement



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VARIABLE EQUIPMENT

B. Variable flow requirements

a. DX and chilled-water cooling units that control the capacity of the mechanical cooling directly based on space temperature shall have a minimum of two stages of fan control. The following rules apply:

- Low or minimum speed shall not exceed 66% of full speed.
- At low or minimum speed, the fan system shall draw no more than 40% of the fan power at full fan speed.
- Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.

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B. VARIABLE EQUIPMENT (CONT.)

b. All other units—including DX cooling units and chilled-water units that control the space temperature by modulating airflow—shall have modulating fan control. The following rules apply:

- Minimum speed shall not exceed 50% of full speed.
- At minimum speed, the fan system shall draw no more than 30% of the power at full fan speed.
- Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.

c. Units that include an air-side economizer to meet the requirements of Section 6.5.1 shall have a minimum of two speeds of fan control during economizer operation.

- Some exceptions are made when mechanical ventilation requirements necessitate larger volumes of outside air or for low-power fans.

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COOLING EQUIPMENT EFFICIENCY

C. Air-cooled or evaporatively cooled equipment meet minimum efficiencies

Efficiencies went up in ASHRAE 90.1 2019

6 Heating, Ventilating, and Air Conditioning

Table 6.8.1-1 Electrically Operated Unitary Air Conditioners and *Condensing Units*—Minimum *Efficiency* Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum *Efficiency*	Test Procedure[a]

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COOLING EQUIPMENT EFFICIENCY (CONT.)

Table 6.8.1-1 Electrically Operated Unitary Air Conditioners and *Condensing Units*—Minimum *Efficiency* Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum *Efficiency*	Test Procedure[a]
Air conditioners, air cooled	<65,000 Btu/h[b]	All	Split *system*, three phase and applications outside U.S. single phase[b]	13.0 *SEER* before 1/1/2023 13.4 *SEER2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
			Single-package, three phase and applications outside U.S. single phase[b]	14.0 *SEER* before 1/1/2023 13.4 *SEER2* after 1/1/2023	
Space constrained, air cooled	≤30,000 Btu/h[b]	All	Split *system*, three phase and applications outside U.S. single phase[b]	12.0 *SEER* before 1/1/2023 11.7 *SEER2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
			Single package, three phase and applications outside U.S. single phase[b]	12.0 *SEER* before 1/1/2023 11.7 *SEER2* after 1/1/2023	
Small duct, high velocity, air cooled	<65,000 Btu/h[b]	All	Split *system*, three phase and applications outside U.S. single phase[b]	12.0 *SEER* before 1/1/2023 12.0 *SEER2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
Air conditioners, air cooled	≥65,000 Btu/h and <135,000 Btu/h	*Electric resistance* (or none)	Split *system* and single package	11.2 *EER* 12.9 *IEER* before 1/1/2023 14.8 *IEER* after 1/1/2023	AHRI 340/360

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CODE QUIZ

The plans for a new retail building in St. Louis show a 5 ton (60,000 Btu/h) electrically operated 3-phase split system air conditioner has been specified. The efficiency rating for the equipment is listed as 13 SEER.

Does this spec meet the requirements of the energy code?

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ECONOMIZERS

D. The system shall have an air economizer meeting the requirements of Section 6.5.1
   - The HVAC system shall have an air economizer with either barometric or powered relief sized to prevent over-pressurization of the building.
   - Outdoor air dampers for economizer use shall be provided with blade and jamb seals.

Table 6.5.1-1 Minimum Fan-Cooling Unit Size for which an Economizer Is Required

Climate Zone	Cooling Capacity for which an Economizer Is Required
0A, 0B, 1A, 1B	No economizer requirement
2A, 2B, 3A, 4A, 5A, 6A, 3B, 3C, 4B, 4C, 5B, 5C, 6B, 7, 8	≥54,000 Btu/h

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ECONOMIZER EXCEPTIONS

- There are 12 exceptions, including for systems in certain types of computer rooms, healthcare facilities, and supermarkets.
- See Section 6.5.1 for details.
- The use of an economizers may be traded off with more efficient equipment:
- CZ4A = 42%

Table 6.5.1-2 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%
4B	49%
4C	64%
5A	49%
5B	59%
5C	74%
6A	56%
6B	65%
7	72%
8	77%

a. If a unit is rated with an *IPLV*, *IEER*, or *SEER*, then to eliminate the required 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.

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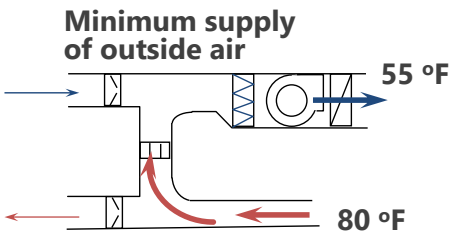
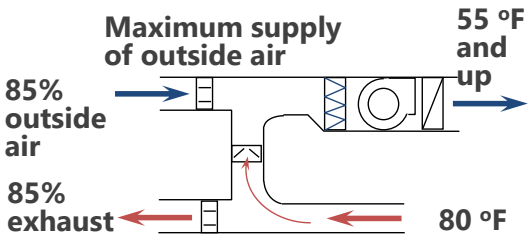
HVAC 101 - ECONOMIZERS

"Free" cooling: When available & appropriate, use cool outdoor air instead of mechanically cooled air

Normal Operation
Outside air dampers provide minimum outside air



Economizer Operation
Outside air dampers are open to provide maximum outside air



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HEATING EQUIPMENT EFFICIENCY

E. Heating must be provided by one of the following:

- Unitary packaged or split-system heat pump that meets applicable efficiency requirements
- Fuel-fired furnace that meets applicable efficiency requirements
- Electric resistance heater
- Baseboard system connected to a boiler that meets applicable efficiency requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air cooled (heating mode)	<65,000 Btu/h (cooling capacity)		Split *system*, three phase and applications outside U.S. single phase[b]	8.2 *HSPF* before 1/1/2023 7.5 *HSPF2* after 1/1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
			Single package, three phase and applications outside U.S. single phase[b]	8.0 *HSPF* before 1/1/2023 6.7 *HSPF2* after 1/1/2023	
Space constrained, air cooled (heating mode)	≤30,000 Btu/h (cooling capacity)		Split *system*, three phase and applications outside U.S. single phase[b]	7.4 *HSPF* before 1/1/2023 6.3 *HSPF2*after 1/ 1/2023	AHRI 210/240-2017 before 1/1/2023 AHRI 210/240-2023 after 1/1/2023
			Single package, three phase and applications outside U.S. single phase[b]	7.4 *HSPF* before 1/1/2023 6.3 *HSPF2* after 1/1/2023	

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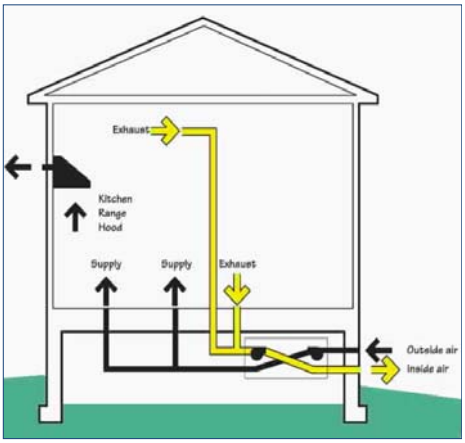
Table 6.8.1-6 Gas- and Oil-Fired *Boilers*—Minimum *Efficiency* Requirements

Equipment Type[a]	Subcategory or Rating Condition	Size Category (Input)	Minimum *Efficiency*	*Efficiency* as of 3/2/2020	Test Procedure
Boilers, hot water	Gas fired	<300,000 Btu/h[f,g]	82% *AFUE*	82% *AFUE*	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	80% E_t	80% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	82% E_c	82% E_c	
	Oil fired[e]	<300,000 Btu/h[g]	84% *AFUE*	84% *AFUE*	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	82% E_t	82% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	84% E_c	84% E_c	
Boilers, steam	Gas fired	<300,000 Btu/h[f]	80% *AFUE*	80% *AFUE*	10 CFR Part 430
	Gas fired—all, except natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	79% E_t	79% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	79% E_t	79% E_t	
	Gas fired—natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	77% E_t	79% E_t	
		>2,500,000 Btu/h[a]	77% E_t	79% E_t	
	Oil fired[e]	<300,000 Btu/h	82% *AFUE*	82% *AFUE*	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	81% E_t	81% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	81% E_t	81% E_t	

EXHAUST AIR ENERGY RECOVERY

F. The system shall meet the exhaust air energy recovery requirements of Section 6.5.6.1.
   - Each fan system shall have an energy recovery system when the system's supply airflow rate exceeds the value listed based on the climate zone and percentage of outdoor airflow rate at design conditions.
   - There are two tables based on hours (8,000 hours/year)
   - Energy recovery systems must have at least 50% energy recovery effectiveness.
   - Provisions must be made to bypass or control the energy recovery system to permit air economizer operation as required



EXAMPLE PROBLEM – ROOM TEMPERATURE

Find 75°F and 50% Relative Humidity.

Record the grains: _____

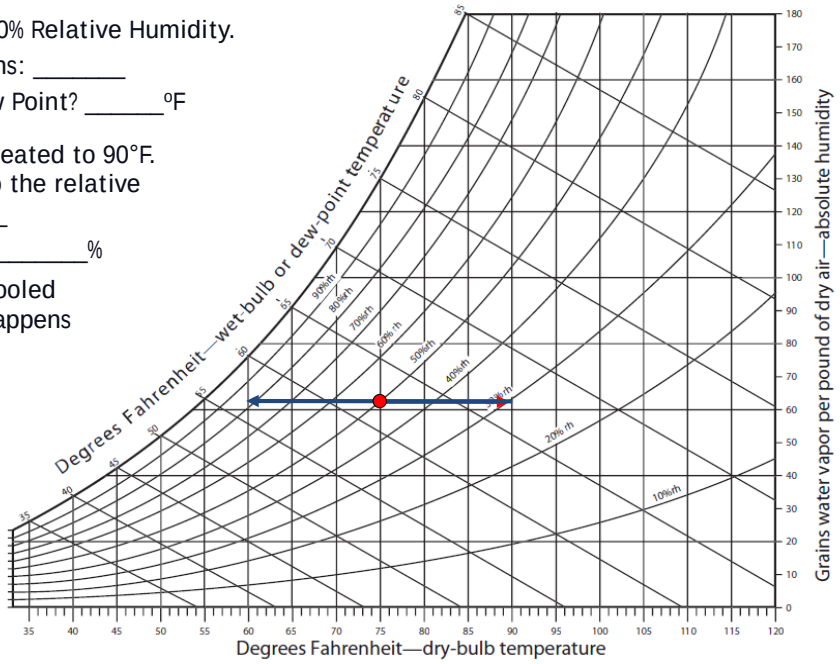
What is the Dew Point? _____ºF

This air is then heated to 90°F. What happens to the relative humidity? _____

What is the RH? _____%

This air is now cooled to 60°F. What happens to the relative humidity?

What is the relative humidity? _____%



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EXAMPLE PROBLEM – SUMMER

Find 80°F and 80% Relative Humidity.

Record the grains: _____

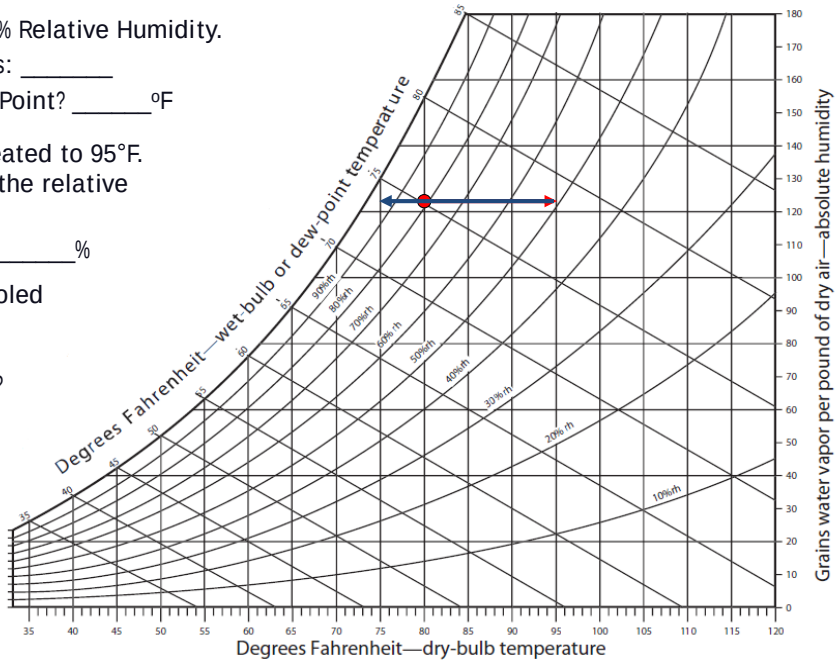
What is the Dew Point? _____ºF

This air is then heated to 95°F. What happens to the relative humidity? _____

What is the RH? _____%

This air is now cooled to 75°F. What happens to the relative humidity?

What is the relative humidity? _____%



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EXHAUST AIR ENERGY RECOVERY

Table 6.5.6.1-1 Exhaust Air *Energy* Recovery Requirements for *Ventilation Systems* Operating Less than 8000 Hours per Year

	% *Outdoor Air* at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
Climate Zone	**Design Supply Fan Airflow Rate, cfm**							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	NR	NR
0B, 1B, 2B,5C	NR	NR	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	≥28,000	≥26,500	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500
0A, 1A, 2A, 3A, 4A, 5A, 6A	≥26,000	≥16,000	≥5500	≥4500	≥3500	≥2000	≥1000	≥120
7,8	≥4500	≥4000	≥2500	≥1000	≥140	≥120	≥100	≥80

NR—Not required

Table 6.5.6.1-2 Exhaust Air *Energy* Recovery Requirements for *Ventilation Systems* Operating Greater than or Equal to 8000 Hours per Year

	% *Outdoor Air* at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and < 80%	≥80%
Climate Zone	**Design Supply Fan Airflow Rate, cfm**							
3C	NR	NR	NR	NR	NR	NR	NR	NR
0B, 1B, 2B, 3B, 4C, 5C	NR	≥19,500	≥9000	≥5000	≥4000	≥3000	≥1500	≥120
0A, 1A, 2A, 3A, 4B, 5B	≥2500	≥2000	≥1000	≥500	≥140	≥120	≥100	≥80
4A, 5A, 6A, 6B, 7, 8	≥200	≥130	≥100	≥80	≥70	≥60	≥50	≥40

NR—Not required

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EXHAUST HEAT RECOVERY EXCEPTIONS

- There are eight exceptions for exhaust air recovery systems, including laboratories, toxic fumes, commercial kitchens and others.
- There are distinctions made between heat recovery and cooling energy recovery based on climate zones

1. Laboratory systems meeting Section 6.5.7.3.
2. Systems serving spaces that are not cooled and that are heated to less than 60°F.
3. Where more than 60% of the outdoor air heating energy is provided from site-recovered energy or site-solar energy.
4. Heating energy recovery in Climate Zones 0, 1, and 2.
5. Cooling energy recovery in Climate Zones 3C, 4C, 5B, 5C, 6B, 7, and 8.
6. Where the sum of the airflow rates exhausted and relieved within 20 ft of each other is less than 75% of the design outdoor airflow rate, excluding exhaust air that is
   a) used for another energy recovery system,
   b) not allowed by ASHRAE Standard 170 for use in energy recovery systems with leakage potential, or
   c) of Class 4 as defined in ASHRAE Standard 62.1.
7. Systems requiring dehumidification that employ energy recovery in series with the cooling coil.
8. Systems expected to operate less than 20 hours per week at the outdoor air percentage covered by Table 6.5.6.1-1.

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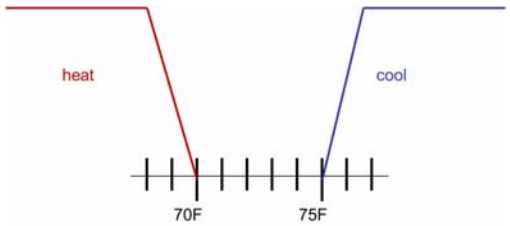
THERMOSTAT CONTROLS

G. The system must be equipped with a manual changeover or dual setpoint



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NEW LANGUAGE FOR 90.1-2016 & 19

- Throughout Section 6, when referring to controls requirements, the words “capable of” were replaced with “capable of and configured to”
- This language implies that controls will be set up at time of inspection.

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HEAT PUMPS

H. Heat pumps must have controls that prevent supplemental electric resistance operation when the heating load can be met by the heat pump alone.

The heat pump must be controlled by either:

- A digital or electronic thermostat designed for heat-pump use that energizes auxiliary heat only when the heat pump has insufficient capacity to maintain setpoint or to warm up the space at a sufficient rate
- A multistage space thermostat and an outdoor air thermostat wired to energize auxiliary heat only on the last stage of the space thermostat and when outdoor air temperature is less than 40°F

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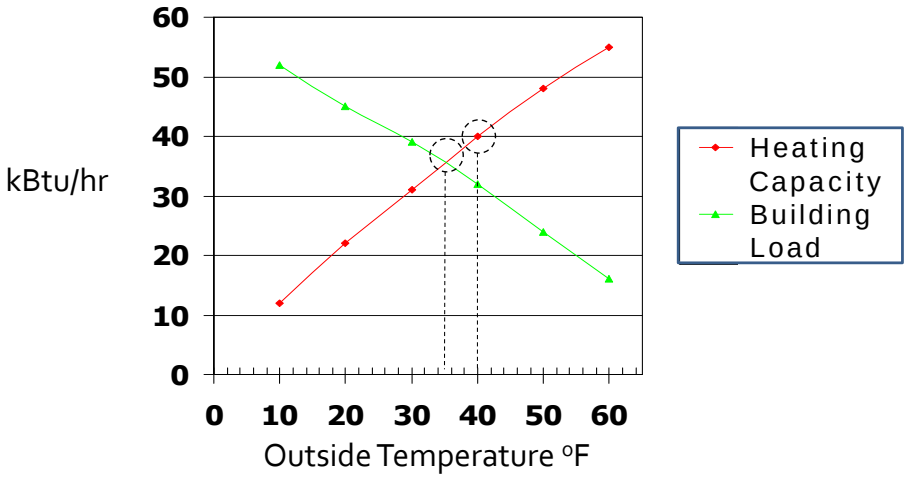
HEAT PUMP BALANCE POINT

The temperature at which the heat pump can deliver exactly the same amount of Btu's that the building is losing



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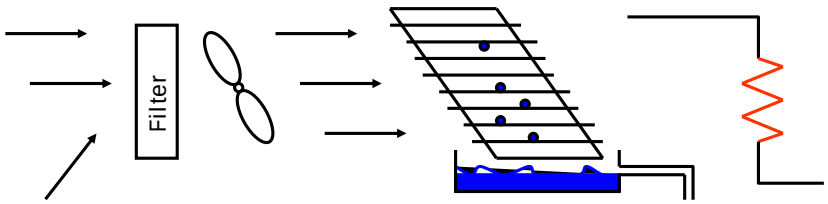
REHEAT CONTROLS

I. The system may not cool then reheat air to control humidity.

In general, reheat is banned (with a few exceptions such as site-solar energy) as more efficient means of dehumidification are available. If reheat is desired for humidity control, the Prescriptive Path must be used to demonstrate compliance.



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TIMECLOCK CONTROL

For spaces other than hotel / motel guest rooms

J. Systems with a cooling or heating capacity greater than 15,000 Btu/h and a supply fan motor power greater than 0.75hp must have a timeclock control that satisfies the following five requirements:

- Can start and stop the system under different schedules for seven different day types per week
- Is capable of retaining programming and time setting during a loss of power for a period of at least ten hours
- Includes an accessible manual override that allows **temporary** operation of the system for up to two hours
- Is capable of temperature setback down to 55°F during off-hours
- Is capable of temperature setup to 90°F during off-hours

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HOTEL/MOTEL GUEST ROOM AUTO CONTROLS

K. Hotels/motels with > 50 guest rooms to have automatic HVAC controls to apply the following requirements within 20 minutes of occupants leaving the room:

- **Guest Room HVAC Setpoint Control:**
  - Automatically raised by ≥ 4°F from the occupant set point (cooling).
  - Automatically lowered ≥ 4°F from the occupant set point (heating).
  - Specific conditions for unrented and unoccupied rooms.
- **Guest Room Ventilation Control:**
  - Ventilation and exhaust fans automatically be turned off, or isolation devices serving each guest room shall automatically shut off the supply of outdoor air to the guest room and shut off exhaust air from the guest room.
- Captive key cards are permitted to be used for compliance

HOTEL / MOTEL GUEST ROOMS (CONT.)

K. Systems serving hotel / motel guest rooms shall have controls that meet 6.4.3.3.5

6.4.3.3.5.2 Guest Room Ventilation Control

Within 20 minutes of all occupants leaving the guest room, *ventilation* and exhaust fans shall *automatically* be turned off, or *isolation devices* serving each guest room shall *automatically* shut off the supply of *outdoor air* to the guest room and shut off exhaust air from the guest room.

Exception to 6.4.3.3.5.2

Guest room *ventilation systems* shall be permitted to have an *automatic* daily preoccupancy purge cycle that provides daily *outdoor air ventilation* during unrented periods at the design *ventilation* rate for 60 minutes or at a rate and duration equivalent to one air change.

6.4.3.3.5.3 Automatic Control

Card key card controls shall be permitted to be used to indicate occupancy.

For spaces serving hotel / motel guest rooms

CODE QUIZ

A small dentist office in Cape Girardeau is planning to install a programmable thermostat for its single zone HVAC system. The model specified includes 7 day a week programming and is manual change over between heating and cooling.

Does this control device comply with the thermostatic control requirements of the code?

REFRIGERANT PIPE INSULATION

L. Refrigerant piping requires insulation that must be protected from the elements

- Insulation exposed to weather must be protected by aluminum, sheet metal, painted canvas, or plastic cover.
- Cellular foam insulation must be protected as above or painted with a coating that is water resistant and provides shielding from solar radiation.

PROTECTION OF HVAC **PIPE INSULATION**

Piping insulation exposed to weather shall be protected from damage, including that due to sunlight, moisture, equipment maintenance and wind.

When insulation isn't protected from UV, it deteriorates quickly. The thermal resistance of the insulation is reduced in some places to zero.

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DUCTWORK

M. Ductwork and plenums must be sealed and insulated

Duct insulation requirements as a function of the duct application (e.g., cooling-only supply duct); climate; and duct or plenum location (e.g., ventilated attic).

Climate Zone	Duct Location		
	Exterior [b]	*Unconditioned Space* and Buried Ducts	*Indirectly Conditioned Space* [c,d]
Supply and Return Ducts for Heating and Cooling			
0 to 4	R-8	R-6	R-1.9
5 to 8	R-12	R-6	R-1.9
Supply and Return Ducts for Heating Only			
0 to 1	None	None	None
2 to 4	R-6	R-6	R-1.9
5 to 8	R-12	R-6	R-1.9
Supply and Return Ducts for Cooling Only			
0 to 6	R-8	R-6	R-1.9
7 to 8	R-1.9	R-1.9	R-1.9

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DUCT BALANCING

N. Ducted systems must be air balanced to industry standards

Report must be included in construction documents

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DUCT BALANCING REPORT

TECHNICIAN			DATE
PROJECT		STATION	☐ MCMURDO ☐ PALMER ☐ SOUTH POLE
BLDG. NO.		BUILDING NAME	

	MAPCON NO. TAG NO.
EQUIPMENT LOCATION	
AREA SERVED	
EQUIPMENT MANUFACTURER	
MODEL	
SERIAL NUMBER	

MAPCON NO. TAG NO.

	SPECIFIED	ACTUAL
TOTAL CFM–FAN		
TOTAL CFM–OUTLET		
R/A CFM		
O/A CFM		
TOTAL STATIC		

SPECIFIED	ACTUAL

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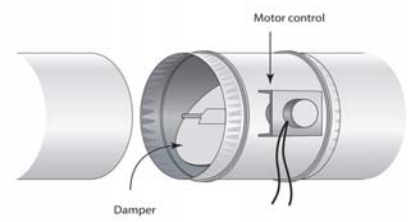
AUTOMATIC DAMPERS

O. Ventilation intake and exhaust systems must have motorized dampers

Motorized dampers should automatically shut when the systems or spaces served are not in use



Exceptions to 6.4.3.4.2

1. Nonmotorized (gravity back draft) dampers are acceptable for exhaust and relief in *buildings* less than three stories in height and for *outdoor air* intakes and exhaust and relief dampers in *buildings* of any height located in Climate Zones 0, 1, 2, and 3. Nonmotorized dampers for *outdoor air* intakes must be protected from direct exposure to wind.
2. Nonmotorized dampers are acceptable in *systems* with a design *outdoor air* intake or exhaust capacity of 300 cfm or less.
3. Dampers are not required in *ventilation* or exhaust *systems* serving *unconditioned spaces*.
4. Dampers are not required in exhaust *systems* serving Type 1 kitchen exhaust hoods.
5. Dampers are not required in systems intended to operate continuously.

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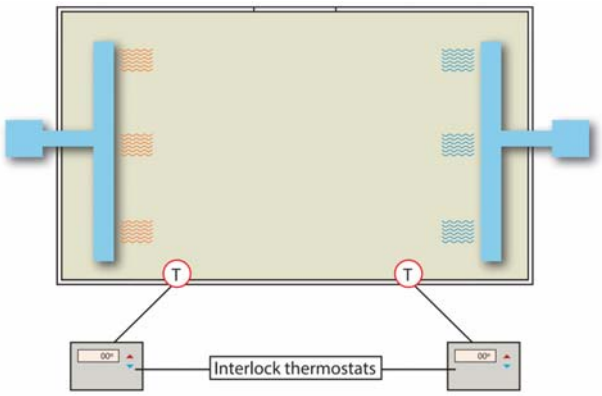
CODE QUIZ

A one story 4,000 ft^2 pizza restaurant is opening in Jefferson City. During plan review it is noticed that the plans do not call for a motorized damper on the (900 cfm) outside air intake. Instead a gravity damper has been specified.

Does this item comply with the energy code requirements for OA intakes?

INTERLOCKED THERMOSTATS

P. Thermostat systems in the same zone must have the ability to be interlocked to prevent simultaneous heating and cooling



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OPTIMUM START CONTROLS

Q. Systems with a design supply air capacity greater than 10,000 cfm shall have optimum start controls

These systems require a smart thermostat or control system to provide optimum start capability. Sometimes referred to as "adaptive learning," these controls are designed to automatically adjust the start time of an HVAC system each day with the intention of bringing the space to the desired occupied temperature levels immediately before scheduled occupancy.

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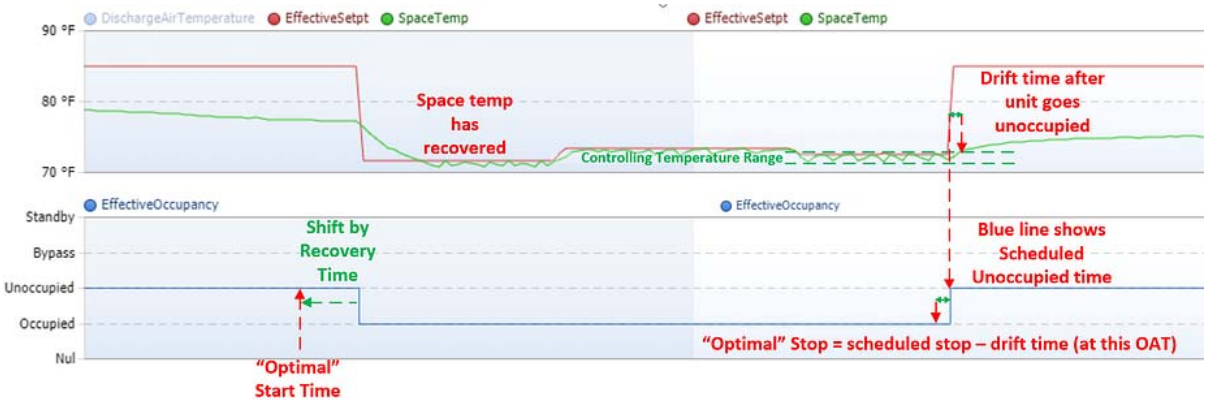
COOLING SEASON OPTIMUM START RECOVERY



DEMAND CONTROLLED VENTILATION

R. DCV must be provided for each zone with an area > 500 ft² and a design occupancy > 25 people/1000 ft² where the HVAC system has:

- air-side economizer
- automatic modulating control of outside air dampers
- design outdoor airflow > 3,000 cfm

Exceptions:

1. Systems with the exhaust air energy recovery complying with Section 6.5.6.1
2. Multiple-zone systems without DDC of individual zones communicating with a central control panel
3. Systems with a design outdoor airflow less than 750 cfm
4. Spaces where >75% of the space design outdoor airflow is required for makeup air that is exhausted from the space or transfer air that is required for makeup air that is exhausted from other space(s)
5. Spaces with one of the following occupancy categories as defined in ASHRAE Standard 62.1: correctional cells, daycare sickrooms, science labs, barbers, beauty and nail salons, and bowling alley seating.

VENTILATION DESIGN

Ventilation Design & Occupied-Standby Requirements

6.5.3.7 Ventilation Design

The required minimum *outdoor air* rate is the larger of the minimum *outdoor air* rate or the minimum exhaust air rate required by Standard 62.1, Standard 170, or applicable codes or accreditation standards. *Outdoor air ventilation systems* shall comply with one of the following:

a. Design minimum *system outdoor air* provided shall not exceed 135% of the required minimum *outdoor air* rate.

b. Dampers, *ductwork*, and *controls* shall be provided that allow the *system* to supply no more than the required minimum *outdoor air* rate with a single *set-point* adjustment.

c. The *system* includes exhaust air *energy* recovery complying with Section 6.5.6.1.

6.5.3.8 Occupied-Standby Controls

Zones serving only rooms that are required to have *automatic* partial OFF or *automatic* full OFF lighting controls per Section 9.4.1.1, where the ASHRAE Standard 62.1 occupancy category permits ventilation air to be reduced to zero when the space is in *occupied-standby mode*, and when using the Ventilation Rate Procedure, shall meet the following within five (5) minutes of all rooms in that zone entering *occupied-standby mode*.

a. Active heating set point shall be setback at least 1°F.

b. Active cooling set point shall be setup at least 1°F.

c. All airflow supplied to the zone shall be shut off whenever the space temperature is between the active heating and cooling set points.

Exception to 6.5.3.8

Multiple zone systems without *automatic* zone flow control dampers.

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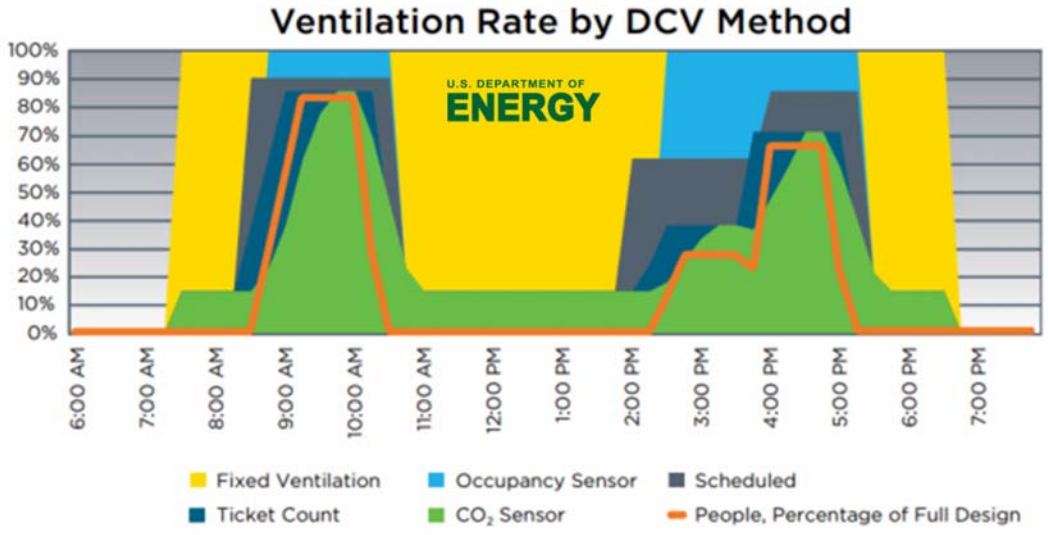
DEMAND CONTROLLED VENTILATION



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DCV REVIEW STEPS

Plan Check

1. Determine which spaces require DCV
2. For spaces that require it, verify that each system is equipped with DCV
3. Verify the sequence of operation for each system

Inspection

1. Verify installation of CO_2 sensor
2. Review commissioning information if required

Table 1. Demand control ventilation review steps

Step	Verification Procedure (for each space)	90.1-2016 Limit	2018 IECC Limit	
1	Review the list of high-density occupancies in Table 2 and note if any are present at the site.			
2	For the spaces identified in Step 1, do any have default occupant density above the limit stated?	>40 people/ 1,000 ft²	≥25 people/ 1,000 ft²	
3	For ASHRAE Standard 90.1 compliance, the requirement is related to design occupancy, not default occupancy. If design information is provided in the ventilation calculations or on the plans, use that density rather than the default from ASHRAE Standard 62.1-2010 or the 2012 IMC.	>40 people/ 1,000 ft² design		
4	Note any spaces from above that are larger than the area threshold.	>500 ft²	>500 ft²	
5	If the spaces that pass Steps 1-4 have DCV indicated, the check is complete; if not, check requirements and exceptions below.			
6	Does the system serving the space meet one of the three alternative requirements?	a. an air-side economizer b. automatic modulating control of the OSA damper c. design OSA > 3,000 cfm		
7	If a space **without** DCV has one of the requirements (Step 6) and meets Steps 1-4, then verify that one of the exceptions is met.			
7a	The system has an energy recovery system meeting:	6.5.6.1	C403.2.6	
7b	Multiple-zone systems without direct digital control of individual zones communicating with a central control panel.			
7c	Systems with a design outdoor airflow less than 1,200 cfm.			
7d	Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirement is less than 1,200 cfm.			
7e	Ventilation is provided for process loads only.	n/a		
8	If the space passes Steps 1-6 and none of the exceptions apply, DCV is required.			

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CODE QUIZ

An office building located in Joplin has a 1,000 ft² conference room. The space has a design occupancy of 40 people and the HVAC system serving the space includes an air-side economizer.

Is this space required to have Demand Controlled Ventilation?

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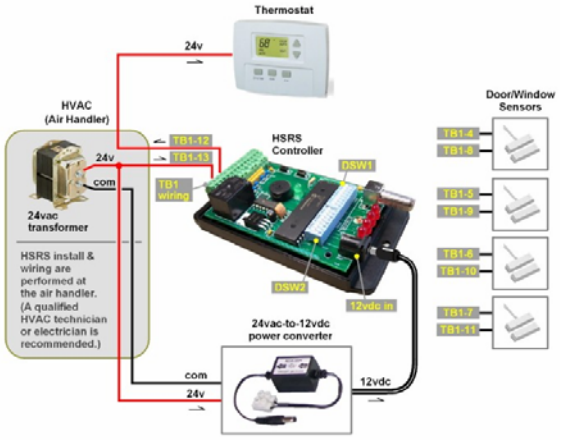
DOOR SWITCHES

S. Any conditioned space with a door that opens to the outdoors must be provided with the following controls that when the door is open:

- Disables mechanical heating or resets the heating setpoint to 55°F or lower within five minutes of the door being left open
- Disables mechanical cooling or resets the cooling setpoint to 90°F or greater within five minutes of the door being left open



HVAC Smart Relay System - Kadtronix

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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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CONCLUSION

ENERGY CODE TRAINING

Commercial Lighting

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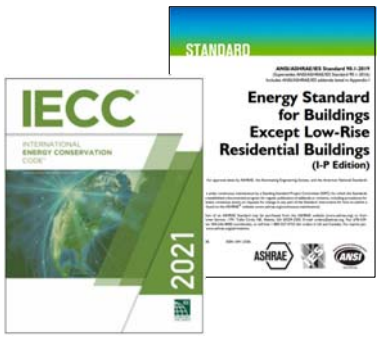
INTRODUCTIONS

Mike Barcik

mikeb@southface.org
www.southface.org



Matt Belcher
MO Energy Code Support
Matt@moenergycodesupport.org

Mike Barcik – Technical Principal
mikeb@southface.org

Matt Belcher – Code Consultant
Matt@verda-solutions.com

INTRODUCTIONS

Mike Barcik
mikeb@southface.org

Matt Belcher
matt@verda-solutions.com

EFFECTIVE COMMERCIAL LIGHTING

Lighting 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

Lighting Trivia 2

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

- True
- False

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 Small College had recently (5 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
- 2014 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 electronic ballasts and LED tubes
D. Swap fluorescent tubes with LED tubes

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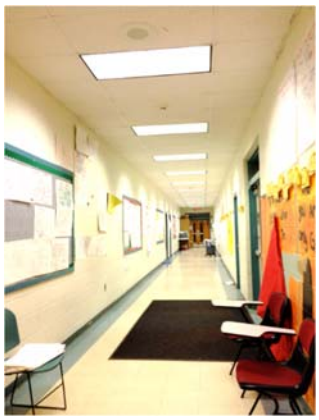
Lighting Trivia 4

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

- True
- False



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Lighting 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

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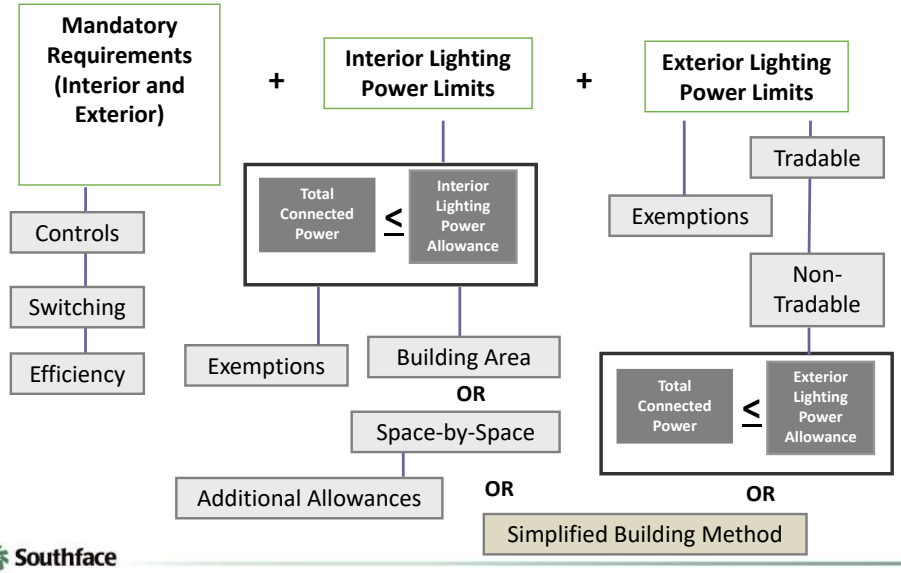
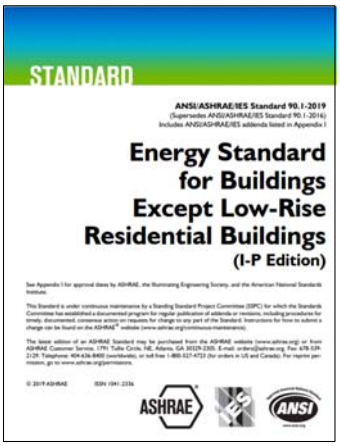
COMPLIANCE OPTIONS





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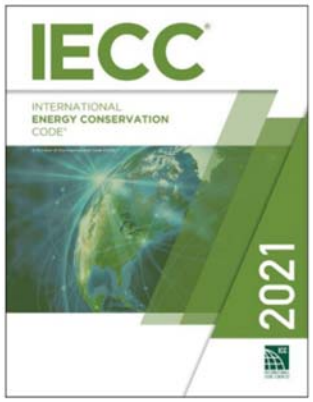
COMPLIANCE OPTIONS

Prescriptive path must comply with these:

- C402 Envelope
- C403 Mechanical
- C404 SWH
- **C405 Lighting**

Plus one optional path from C406

- C406.3 Reduced Lighting Power
- C406.4 Enhanced Digital Controls



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406.3 REDUCED LIGHTING POWER (OPTIONAL)

- The total connected interior lighting power calculated in accordance with Section C405.3.1 shall be less than **90 percent** of the total lighting power allowance calculated in accordance with Section C405.3.2.

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406.4 ENHANCED DIGITAL CONTROLS (OPTIONAL)

Interior lighting in the building shall have the following enhanced lighting controls that shall be located, scheduled and operated in accordance with Section C405.2.2.

1. Luminaires shall be configured for continuous dimming
2. Luminaires shall be addressed individually & where individual addressability is not available for the luminaire class type, a controlled group of not more than four luminaries shall be allowed
3. Not more than eight luminaires shall be controlled together in a daylight zone

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406.4 ENHANCED DIGITAL CONTROLS (OPTIONAL)

4. Fixtures shall be controlled through a digital control system that includes the following function:
    1. Control reconfiguration based on digital addressability
    2. Load shedding
    3. Occupancy sensors shall be capable of being reconfigured through the digital control system
5. Construction documents shall include submittal of a Sequence of Operations, including a specification outlining each of the functions in Item 4
6. Functional testing of lighting controls shall comply with Section C408

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NEW BUILDINGS AND…

Retrofits:

- Where luminaires are added, replaced, or removed
- That include replacement of lamp plus ballast in luminaires

Requires BOTH interior and exterior alterations to comply with Lighting Power Density (LPD) limits and basic after hours automatic shutoff requirements

Photo Courtesy of Verde Energy Efficiency Experts

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EXCEPTIONS

- Spaces where alterations involve less than 20% of connected lighting load and the LPD for the space is not increased
- Alterations that only involve replacement of lamps plus ballasts/drivers or only involve one-for-one luminaire replacement to only comply with LPD requirement and Section 9.4.1.1(h) and 9.4.1.1(i)
- Routine maintenance or repair

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EXCEPTIONS

- Historic buildings
  - State or National listing
  - Eligible to be listed
- A report demonstrating that compliance with that provision would threaten, degrade or destroy the historic form, fabric or function of the building must be submitted by a code official and one of the following:
  - A registered design professional
  - A representative of the State Historic Preservation Office
  - The historic preservation authority having jurisdiction

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EXCEPTIONS (CONT.)

- Alterations where less than **20%** of the luminaires in a space are replaced and installed interior power lighting is not increased
- Lighting within dwelling units
  - Where ≥ 75% of permanently installed fixtures (except low-voltage) are fitted for and include high-efficacy lamps
- Walk-in coolers, walk-in freezers, refrigerated warehouse coolers, and refrigerated warehouse freezers comply with C403.2.15 or C403.2.16

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HIGH-EFFICACY LAMPS

- Neither ASHRAE nor the IECC require LEDs
- Future codes, your local jurisdiction, and your customers might have more stringent requirements
- Compact fluorescent lamps, T8 or smaller diameter linear fluorescent lamps, or other lamps with an efficacy based on lamp wattage may be made to comply
- Avoid halogen & incandescents

Lighting	Efficacy
bulbs	65 lumens/watt
luminaire	45 lumens/watt

However…

- 90.1-2019 does include partial or complete LED efficacy in many space type models in recognition of:
  - Proven LED efficacy and energy savings capability
  - Continued reduced cost of LEDs
  - Product maturity and reasonable applicability

However…

- IECC does require minimum 90% of all bulbs in dwelling units be efficient

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CALCULATING LPDS

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BUILDING AREA METHOD

- Determine gross lighted area for each building type area using:
  - Exterior faces of exterior walls
  - Centerline of interior walls
- Calculate the area power allowance by multiplying the gross lighted area by the applicable building type allowance from Table 9.5.1
- Sum all the allowances (if more than one building type area)

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BUILDING AREA METHOD

Advantages
- Fewer calculations
- One and done, so fast

Disadvantages
- Limited building area type selection - use reasonably equivalent type
- Insensitive to specific space functions and room configurations
- Generally more restrictive that space-by-space method

Table 9.5.1 ***Lighting Power Density*** **Allowances Using the** ***Building*** **Area Method**

Building Area Type[a]	*LPD*, W/ft²
Automotive facility	0.75
Convention center	0.64
Courthouse	0.79
Dining: Bar lounge/leisure	0.80
Dining: Cafeteria/fast food	0.76
Dining: Family	0.71
Dormitory	0.53
Exercise center	0.72
Fire station	0.56
Gymnasium	0.76
Health-care clinic	0.81
Hospital	0.96
Hotel/motel	0.56
Library	0.83
Manufacturing facility	0.82
Motion picture theater	0.44
Multifamily	0.45
Museum	0.55
Office	0.64
Parking garage	0.18
Penitentiary	0.69
Performing arts theater	0.84
Police station	0.66
Post office	0.65
Religious facility	0.67
Retail	0.84
School/university	0.72
Sports arena	0.76
Town hall	0.69
Transportation	0.50
Warehouse	0.45
Workshop	0.91

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SIMPLIFIED BUILDING METHOD

9.3 Simplified Building Method Compliance Path

The Simplified Building Method contains the requirements for interior lighting in Section 9.3.1 and exterior lighting in Section 9.3.2 and shall be allowed to be used where at least 80% of the floor area supports either office *buildings*, retail *buildings*, or *school* buildings. The Simplified Building Method shall be used for new *buildings* or tenants improvements of less than 25,000 ft^2. Interior and exterior wattage allowances shall be calculated and complied with separately.

Applicable to

- Offices
- Retail
- Schools

Limitations

- Limited to new buildings or tenant spaces < 25,000 s.f.

Table 9.3.1-1 Simplified Building Method for Office *Buildings*

Interior *Space* Type	Interior Lighting Power Allowance	*Controls* [a]
All *spaces* in office *buildings* other than parking garages, stairwells, and corridors	0.70 W/ft^2	All lighting shall be *automatically* controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied. (**Exception:** Lighting load not exceeding 0.02 W/ft^2 multiplied by the gross lighted area of the *building* shall be permitted to operate at all times.) Each *space* shall have a *manual control* device that allows the occupant to reduce lighting power by a minimum of 50% and to turn the lighting off.
Office *spaces* less than or equal to 250 ft^2, classrooms, conference rooms, meeting rooms, training rooms, storage rooms, and break rooms	0.70 W/ft^2	These *spaces* shall also be controlled by *manual-ON occupant sensors*.
Office *spaces* greater than 250 ft^2 and restrooms	0.70 W/ft^2	These *spaces* shall also be controlled by *occupant sensors*.
Stairwells and corridors in office *buildings* and parking garages	0.70 W/ft^2	These *spaces* shall also be controlled by *occupant sensors* that reduce the lighting power by a minimum of 50% when no activity is detected for not longer than 20 minutes and be controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied.
Parking garages	0.13 W/ft^2	All lighting shall be *automatically* controlled to turn off during garage nonoperating hours. Lighting shall also be controlled by *occupant sensors*. *Controls* shall reduce the power by a minimum of 50% when no activity is detected for not longer than 20 minutes. No device shall control more than 3600 ft^2.

a. All lights in the space shall be controlled.

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SIMPLIFIED BUILDING METHOD

Advantages

- Streamlined details for offices, retail and schools (under 25,000 s.f.)

Table 9.3.1-2 Simplified Building Method for Retail *Buildings*

Interior *Space* Type	Interior Lighting Power Allowance	*Controls* [a]
All *spaces* in retail *buildings* other than parking garages, stairwells, and corridors	1.00 W/ft^2	All lighting shall be *automatically* controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied. (**Exception:** Lighting load not exceeding 0.02 W/ft^2 multiplied by the gross lighted area of the *building* shall be permitted to operate at all times.) Each *space* shall have a *manual control* device that allows the occupant to reduce lighting power by a minimum of 50% and to turn the lighting off.
Sales area	1.00 W/ft^2	These *spaces* shall also be controlled • to reduce the *general lighting* power by a minimum of 75% during nonbusiness hours, • to turn off all lighting other than *general lighting* during nonbusiness hours, and • by *continuous daylight dimming* controls [b] in *spaces* with *toplighting*.
Stock rooms, dressing/fitting rooms, locker rooms, and restrooms	1.00 W/ft^2	These *spaces* shall also be controlled by; auto-ON or *manual-ON occupant sensors*, and *continuous daylight dimming* controls [b] in *spaces* with *toplighting*.
Office *spaces*, conference rooms, meeting rooms, training rooms, storage rooms, break rooms, and utility *spaces*	1.00 W/ft^2	These *spaces* shall also be controlled by; *manual-ON occupant sensors*, and *continuous daylight dimming* controls [b] in *spaces* with *toplighting*.
Stairwells and corridors in retail *buildings* and parking garages	1.00 W/ft^2	These *spaces* shall also be controlled by *occupant sensors* that reduce the lighting power by a minimum of 50% when no activity is detected for not longer than 20 minutes and be controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied.
Parking garages	0.13 W/ft^2	All lighting shall be *automatically* controlled to turn off during garage nonoperating hours. Lighting shall also be controlled by *occupant sensors*. *Controls* shall reduce the power by a minimum of 50% when no activity is detected for not longer than 20 minutes. No device shall control more than 3600 ft^2.

a. All lights in the space shall be controlled.
b. When the combined input power of the general lights completely or partially within the *daylight areas* is 150 W or greater.

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SIMPLIFIED BUILDING METHOD

Advantages

- Streamlined details for offices, retail and schools (under 25,000 s.f.)

Table 9.3.1-3 Simplified Building Method for School *Buildings*

Interior *Space* Type	Interior Lighting Power Allowance	*Controls* [a]
All *spaces* in school *buildings* other than parking garages, stairwells, and corridors	0.70 W/ft^2	All lighting shall be *automatically* controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied. (**Exception:** Lighting load not exceeding 0.02 W/ft^2 multiplied by the gross lighted area of the *building* shall be permitted to operate at all times.) Each *space* shall have a *manual control* device that allows the occupant to reduce lighting power by a minimum of 50% and to turn the lighting off.
Classrooms, offices *spaces*, conference rooms, meeting rooms, library, storage rooms, and break rooms	0.70 W/ft^2	These *spaces* shall also be controlled by *manual-ON occupant sensors*.
Gymnasiums and cafeterias	0.70 W/ft^2	These *spaces* shall also be controlled by *occupant sensors*.
Restrooms	0.70 W/ft^2	These *spaces* shall also be controlled by *occupant sensors*.
Stairwells and corridors in school *buildings* and parking garages	0.70 W/ft^2	These *spaces* shall also be controlled by *occupant sensors* that reduce the lighting power by a minimum of 50% when no activity is detected for not longer than 20 minutes and be controlled to turn off when the *building* is either unoccupied or scheduled to be unoccupied.
Parking garages	0.13 W/ft^2	All lighting shall be *automatically* controlled to turn off during garage nonoperating hours. Lighting shall also be controlled by *occupant sensors*. *Controls* shall reduce the power by a minimum of 50% when no activity is detected for not longer than 20 minutes. No device shall control more than 3600 ft^2.

a. All lights in the space shall be controlled.

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SIMPLIFIED BUILDING METHOD

Building Exteriors

- Streamlined details for offices, retail and schools (under 25,000 s.f.)

Table 9.3.2 Simplified Building Method for *Building* Exteriors

Exterior Area Type	*Exterior Lighting Power Allowance* [a,b]	*Controls* [c]
Base allowance	200 W	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Façade lighting and special feature areas, walkways, plazas	0.10 W/ft^2	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Landscape	0.04 W/ft^2	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Entry doors	14 W/linear foot	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Stairs and ramps	0.7 W/ft^2	No additional *controls* required.
Parking lots and drives	0.05 W/ft^2	*Luminaires* mounted 25 ft or less above grade shall be controlled to reduce the power by at least 50% when no activity is detected for not longer than 15 minutes.
All other areas not listed	0.20 W/ft^2	*Luminaires* shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.

a. To calculate the exterior allowance, multiply the *space* or area square footage by the allowed W/ft^2 and sum the exterior allowances and the base allowance. Façade lighting shall be calculated separately by multiplying the façade area by the allowed W/ft^2. Façade allowance shall not be traded with other exterior areas or between separate *façade areas*.
b. For *buildings* in Lighting Zone 2, as defined in Table 9.4.2-1, decrease exterior allowances by 20%. For *buildings* in Lighting Zone 4, as defined in Table 9.4.2-1, increase exterior allowances by 25%.
c. All exterior lighting shall be automatically controlled by either a photocell or an astronomical time switch to shut off the lighting when daylight is available.

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SPACE-BY-SPACE METHOD

- Determine the gross lighted area of each space type, include balconies and mezzanines
- Use centerline of walls between spaces
- Calculate the space power allowance by multiplying the space type area by the applicable allowance from Table 9.6.1
- **Sum all the allowances**

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SPACE-BY-SPACE METHOD

Advantages

- More flexible than building area method
- More accurately accounts for actual room lighting power needs
- Provides additional allowances for:
  - Difficult room configurations
  - Decorative and retail needs
  - Use of advanced controls not already required in the standard

Disadvantages

- More calculations needed (individual spaces)

Common Space Types	LPD (w/ft²)
Locker room	0.52
Lounge/breakroom	
In a healthcare facility	0.42
Otherwise	0.59
Office	
Enclosed (≤ 250 s.f.)	0.74
Open plan	0.61

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SPACE-BY-SPACE METHOD

- If a physical space has multiple functions such that more than one space type from Table 9.6.1 applies
- Break the space into smaller subspaces
- Use the centerline of interior walls and dividing line between subspaces to determine subspace areas
- Calculate the allowance separately for each subspace
- Exception - Subspaces with areas less than 20% of the original space and less than 1,000 ft^2 do not need to be broken out separately

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SECTION 9.6: INTERIOR LIGHTING BUDGET

9.6.2 - Space-by-Space Method

Additional Interior Lighting Power

Decorative / highlighting luminaires

- 0.75 W/ft^2 in space where used

Retail Sales Area

Additional Allowance = 1000 watts
+ (Retail Area 1 x .45 W/ft2)
+ (Retail Area 2 x .45 W/ft^2)
+ (Retail Area 3 x 1.05 W/ft^2)
+ (Retail Area 4 x 1.88 W/ft^2)

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)

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]

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SECTION 9: INTERIOR LIGHTING BUDGET

9.6.4 – Space-by-Space

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

Common *Space* Types[1]	*RCR* Threshold
Electrical/Mechanical Room[7]	6
Emergency Vehicle Garage	4
Food Preparation Area	6
Guest Room	6
Laboratory	
In or as a classroom	6
All other laboratories	6
Laundry/Washing Area	4
Loading Dock, Interior	6
Lobby	
Facility for the visually impaired (and not used primarily by the staff)[3]	4
Elevator	6
Hotel	4
Motion picture theater	4
Performing arts theater	6
All other lobbies	4
Locker Room	6

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ROOM CAVITY RATIO ADJUSTMENT

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

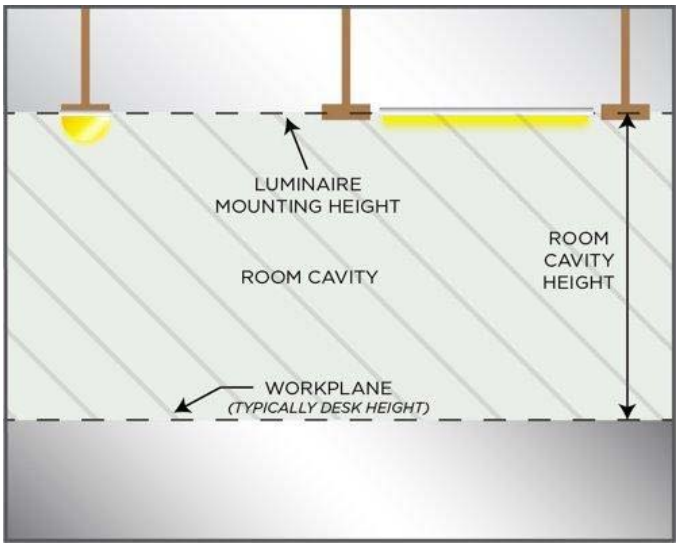
*Room cavity height **=** luminaire mounting height **-** workplane

Example: 30'x40' open office with 16.5' fixture height:

RCR = 2.5 x 14 x (140/1200) = **4.1**

Common *Space* Types[1]	*LPD*, W/ft²	*RCR*
Office		
Enclosed and ≤250 ft²	0.74	8
Enclosed and >250 ft²	0.66	8
Open plan	0.61	4
Parking Area, Interior	0.15	4
Pharmacy Area	1.66	6

This space is allowed 20% more wattage!



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SPACE-BY-SPACE METHOD

School Example	LPD (w/ft²)
Audience Seating Area - Gym	0.23
Classroom	0.71
Computer Room	0.94
Lab - Classroom	1.11
Cafeteria	0.40
Restroom	0.63
Locker Room	0.52

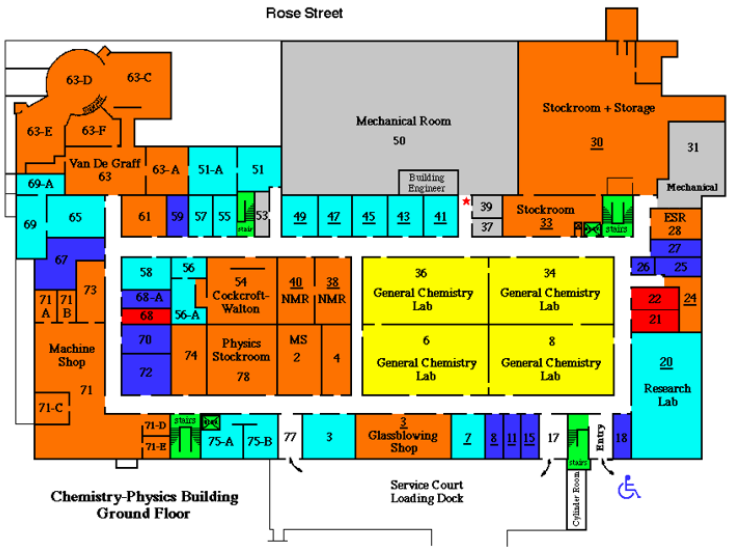

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Table 9.6.1 *Lighting Power Density* Allowances Using the Space-by-Space Method and Minimum *Control* Requirements Using Either Method

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.								
			Local *Control* (See Section [a])	Restricted to *Manual* ON (See Section [b])	Restricted to Partial *Automatic* ON (See Section [c])	Bilevel Lighting *Control* (See Section [d])	*Automatic* Daylight Responsive *Controls* for Sidelighting (See Section [e]*)	*Automatic* Daylight Responsive *Controls* for Toplighting (See Section [f]*)	*Automatic* Partial OFF (See Section [g] [Full Off complies])	*Automatic* Full OFF (See Section [h])	Scheduled Shutoff (See Section [i])
Common *Space* Types[1]	*LPD* Allowances, W/ft²	*RCR* Threshold	a	b	c	d	e	f	g	h	i
Atrium											
<20 ft in height	0.39	NA	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
≥20 ft and ≤40 ft in height	0.48	NA	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
>40 ft in height	0.60	11	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Audience Seating Area											
Auditorium	0.61	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Gymnasium	0.23	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Motion picture theater	0.27	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Penitentiary	0.67	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Performing arts theater	1.16	8	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Religious facility	0.72	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Sports arena	0.33	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
All other audience seating areas	0.23	4	REQ	ADD1	ADD1		REQ	REQ		ADD2	ADD2
Banking Activity Area	0.61	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Breakroom (See Lounge/Breakroom)											
Classroom/Lecture Hall/Training Room											
Penitentiary	0.89	4	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
All other classrooms/lecture halls/training	0.71	4	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	

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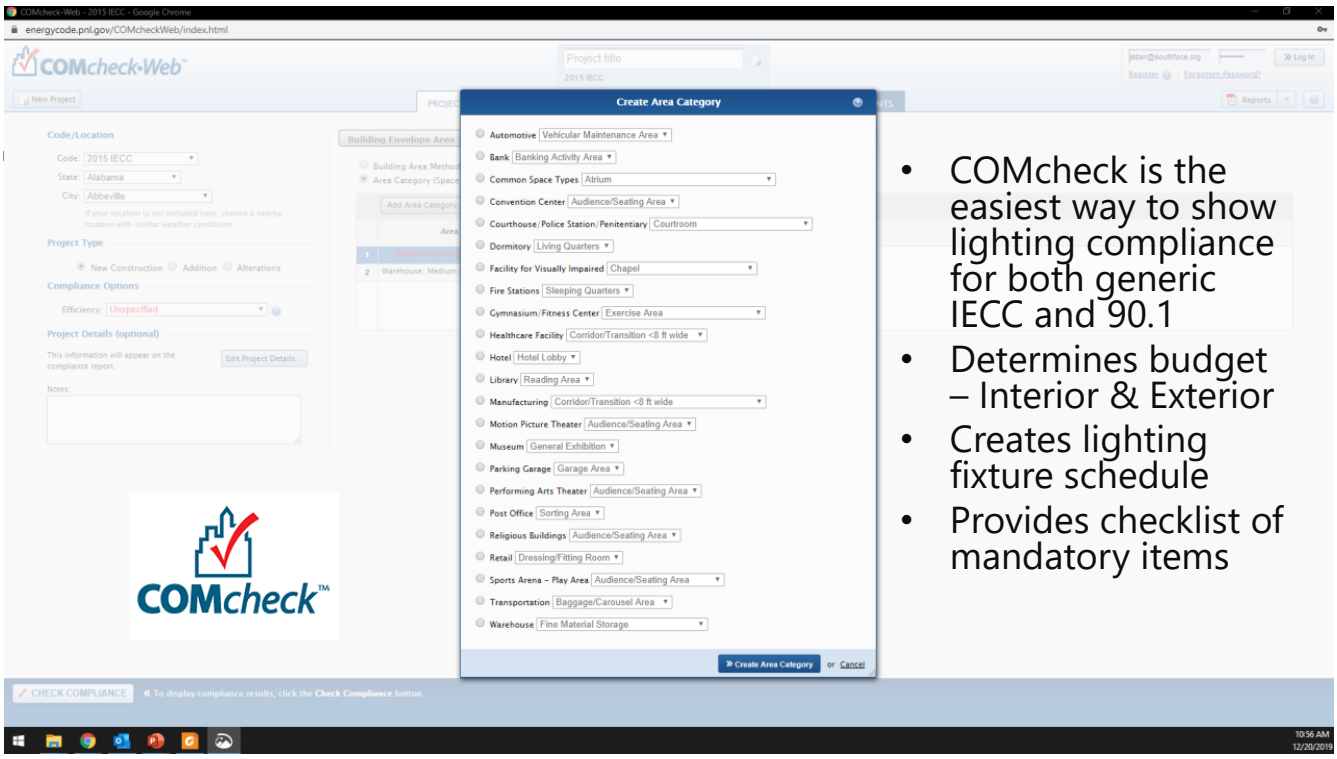


- COMcheck is the easiest way to show lighting compliance for both generic IECC and 90.1
- Determines budget – Interior & Exterior
- Creates lighting fixture schedule
- Provides checklist of mandatory items

INTERIOR LIGHTING POWER CALCULATION EXEMPTIONS

- Theatrical, stage, film, and video production
- Medical and dental procedures
- Exhibit displays for museums, monuments, and galleries
- Integral to equipment or instrumentation installed by manufacturer
- Integral to both open and glass-enclosed refrigerator and freezer cases
- Retail display windows, provided the display is enclosed by ceiling-height partitions
- Food warming and food preparation equipment
- Interior spaces specifically designated as registered interior historic landmarks
- Integral part of advertising or directional signage
- Exit signs
- Sale or lighting educational demonstration systems
- Lighting for television broadcasting in sporting activity areas
- Casino gaming areas
- Furniture-mounted supplemental task lighting controlled by automatic shutoff and complying with 9.4.1.4(d)
- For use in areas specifically designed for life support of nonhuman life forms
- Mirror lighting in dressing rooms and accent lighting in religious pulpit and choir areas
- Parking garage transition lighting
- Antimicrobial lighting for disinfecting a space

NEW ENERGY CODE LIGHTING QUIZ - OFFICE

What is the Lighting Power Density Allowance for a 2500 ft^2 enclosed office under the Building Area Method of 90.1-2019?

Building Area Method

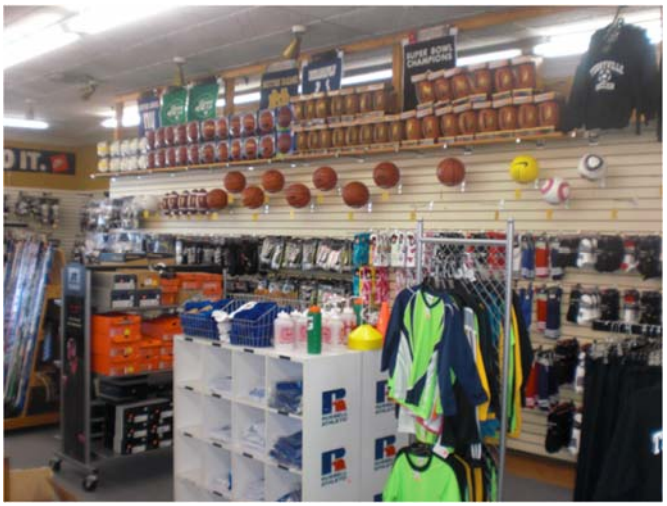
Building Area Type[a]	*LPD*, W/ft^2
Automotive facility	0.75
Convention center	0.64
Courthouse	0.79
Dining: Bar lounge/leisure	0.80
Dining: Cafeteria/fast food	0.76
Dining: Family	0.71
Dormitory	0.53
Exercise center	0.72
Fire station	0.56
Gymnasium	0.76
Health-care clinic	0.81
Hospital	0.96
Hotel/motel	0.56
Library	0.83
Manufacturing facility	0.82
Motion picture theater	0.44
Multifamily	0.45
Museum	0.55
Office	0.64

What is the LPD Allowance using the Space by Space Method of 90.1-2019?

Common *Space* Types[1]	*LPD*, W/ft^2
Office	
Enclosed and ≤250 ft^2	0.74
Enclosed and >250 ft^2	0.66
Open plan	0.61
Parking Area, Interior	0.15
Pharmacy Area	1.66
Restroom	
Facility for the visually impaired (and not used primarily by the staff)[3]	1.26
All other restrooms	0.63
Sales Area[4]	1.05

ENERGY CODE LIGHTING QUIZ - RETAIL

What is the Additional Interior Lighting Power Allowance provided for a retail sporting goods store using the Space-by-Space Method in 90.1-2016?



TOTAL CONNECTED LIGHTING POWER

TCLP = [LVL + BLL + LED + TRK + OTHER]

LVL = labeled wattage of luminaires connected directly to building power

BLL = wattage of the ballast or transformer

LED = wattage of LEDs with either integral or remote drivers

TRK = wattage of lighting tracks, cable conductors, rail conductors, and plug-in busways specified wattage of the luminaires

- not less than **8 W per linear foot** *or*
- the wattage limit of other permanent current-limiting devices on the system *or*
- wattage limit of the transformer

OTHER = the wattage of all other luminaires and lighting sources not covered previously

SECTION 9.1.4: CONNECTED LIGHTING POWER 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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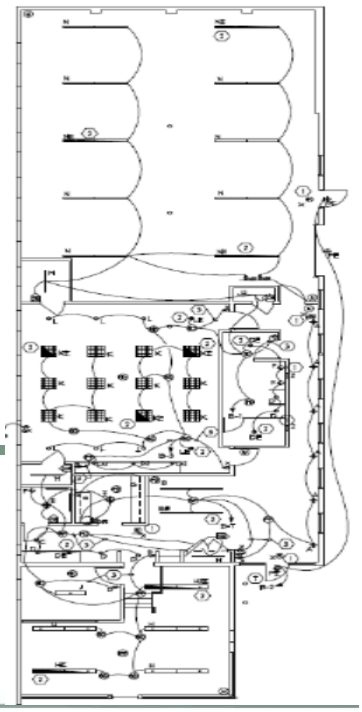
SWEET NEW –
USING COMCHECK FOR LIGHTING



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END PART 1

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EAZEE BUILDING –INTERIOR LIGHTING

COMCHECK HW PROBLEM

Small 10’ Strip Retail Building

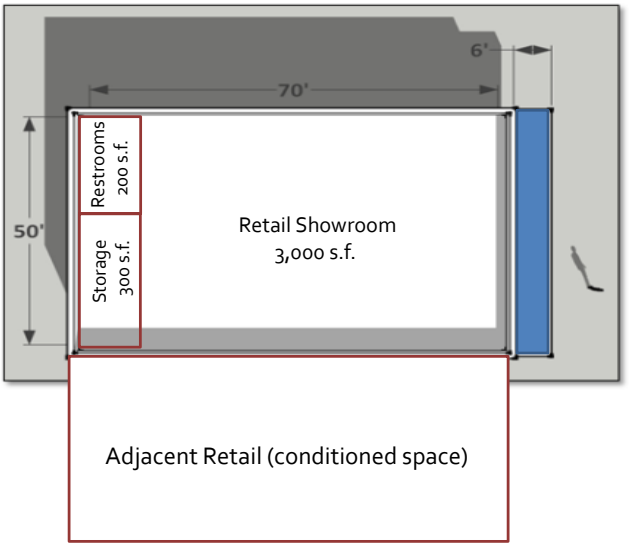
East Wall: R-19 2x6, 16” o.c. all metal curtain-wall glazing is on the Front

Enter the following fixtures into COMcheck to check for lighting compliance [Quantity]:

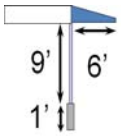
A – 48” T-8 Fluorescent-(3)32W bulbs, elec ballast) – 90W [12]

B – 96” Linear LED – 8000 Lumens – 80W [30]

C – Wall sconces – 11 W LED [32]



Using COMCheck, enter lighting fixtures and create a budget using both the Building Area and also the Space-by-Space methods. Does the building pass 90.1-2019?



LIGHTING CONTROLS EXTERIOR LIGHTING

INTERIOR LIGHTING CONTROLS

Minimum Control Requirements (a-i) from Table 9.6.1

Table 9.6.1 *Lighting Power Density* Allowances Using the Space-by-Space Method and Minimum *Control* Requirements Using Either Method *(Continued)*

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.								
			Local Control (See Section [a])	Restricted to *Manual* ON (See Section [b])	Restricted to Partial *Automatic* ON (See Section [c])	Bilevel *Lighting Control* (See Section [d])	*Automatic* Daylight Responsive *Controls* for Sidelighting (See Section [e][a])	*Automatic* Daylight Responsive *Controls* for *Toplighting* (See Section [f][a])	*Automatic* Partial OFF (See Section [g] [Full Off complies])	*Automatic* Full OFF (See Section [h])	Scheduled Shutoff (See Section [i])
Common Space Types[1]	*LPD*, W/ft²	*RCR* Threshold	a	b	c	d	e	f	g	h	i
Conference/Meeting/Multipurpose Room	0.97	6	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Confinement Cells	0.70	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Copy/Print Room	0.31	6	REQ	ADD1	ADD1	REQ	REQ	REQ		REQ	
Corridor[2]											
Facility for the visually impaired (and not used primarily by the staff)[3]	0.71	width <8 ft	REQ				REQ	REQ	REQ	ADD2	ADD2
Hospital	0.71	width <8 ft	REQ				REQ	REQ	ADD2	ADD2	ADD2
All other corridors	0.41	width <8 ft	REQ				REQ	REQ	REQ	ADD2	ADD2
Courtroom	1.20	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Computer Room	0.94	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Dining Area											
Penitentiary	0.42	6	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Facility for the visually impaired (and not used primarily by staff)[3]	1.27	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Bar/lounge or leisure dining	0.86	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
Cafeteria or fast food dining	0.40	4	REQ	ADD1 OR	ADD1	REQ	REQ	REQ		ADD1 OR	ADD2
Family dining	0.60	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2
All other dining areas	0.43	4	REQ	ADD1	ADD1	REQ	REQ	REQ		ADD2	ADD2

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A. 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 to occupants
- Located where the controlled lights are visible
- Must identify the area served by the lights and indicate their use

Exceptions:

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

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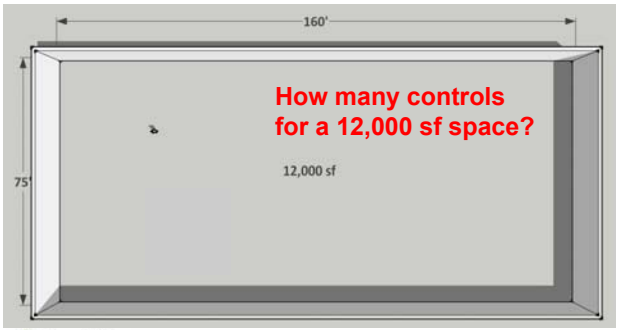
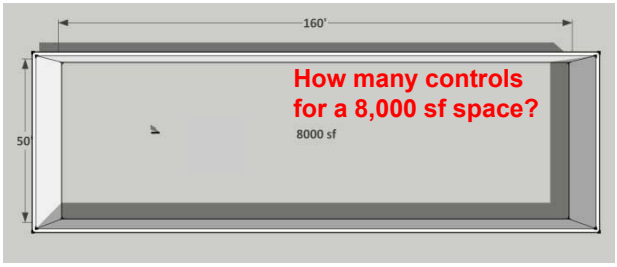
ASHRAE 90.1 SECTION 9.4.1.2 SPACE CONTROL

"Small" Spaces (<10,000 s.f.):
1 control / 2,500 s.f.





"Large" Spaces (>10,000 s.f.):
1 control / 10,000 s.f.

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B. RESTRICTED TO MANUAL ON

Occupancy

- Turn lights ON automatically upon detecting the presence of people
- Occupancy sensors are better for areas with no daylight like bathrooms or where safety is a concern

Vacancy

- Must be turned on manually
- Vacancy sensors save more energy
- No "false positives"

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EXEMPTIONS

Full auto-on controls allowed in

- Public corridors
- Stairways
- Restrooms
- Primary building entrance areas and lobbies
- Areas where manual-on operation would endanger safety or security of room or occupants

C. RESTRICTED TO PARTIAL AUTOMATIC ON

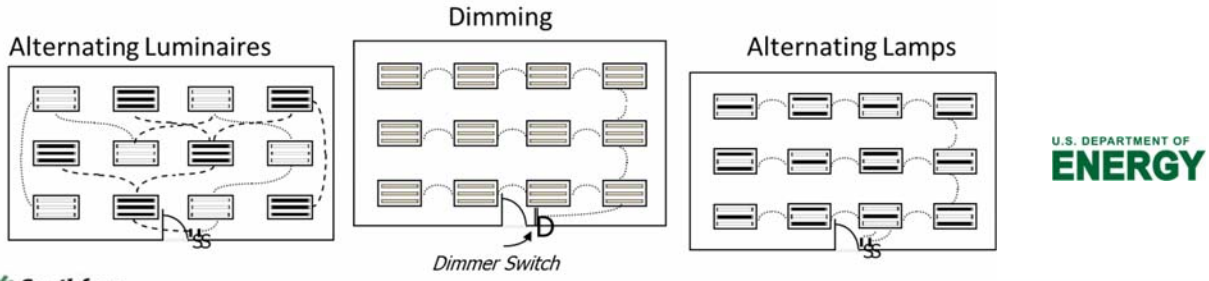
Maximum of 50% of the lighting power for general lighting is allowed to be automatically turned on and none of the remaining shall be auto ON

Exception

- Lighting in open-plan offices allowed to turn on automatically to > 50% if control zone is ≤ 600 ft^2

D. BILEVEL LIGHTING CONTROLS

- Light Reduction Controls must allow the occupant to reduce connected lighting load
  - To have at least one control step between 30% and 70% (inclusive) of full lighting power in addition to all off
  - In a reasonably uniform illumination pattern
- Light-reduction control are not required in daylight zones with daylight responsive controls complying with C405.2.3



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D. BILEVEL LIGHTING CONTROLS (CONT.)

- 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

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E./F. AUTO DAYLIGHT CONTROLS

- Photocontrols required for general lighting in any space top-lit by >150 W
- Photocontrols shall have:
  - Continuous dimming or
  - At least one control point between 50% and 70% of design light power
  - Second control point between 20% and 40% of design light power or
  - Lowest dimming level technology allows
  - Third control point that turns off all controlled lighting
  - Calibration doesn't require physical presence of a person at sensor while calibration is processing
- Calibration adjustment located ≤ 11ft above finished floor
- Exceptions for toplighting with tall adjacent shading, skylight VT <0.4, spaces in CZ 8 <200 W

DAYLIGHTING

- Daylighting maximizes sunlight through proper window placement, window types and room dimensions
- Keeps lights off
  - Save lighting energy
  - Save energy on cooling
- Couple with daylight sensor

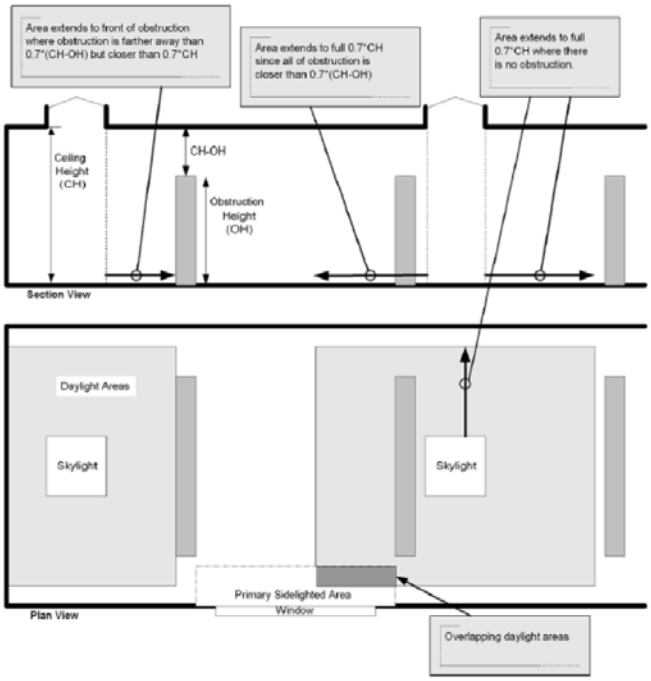
DAYLIGHTED AREA - SKYLIGHTS

Daylight 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).



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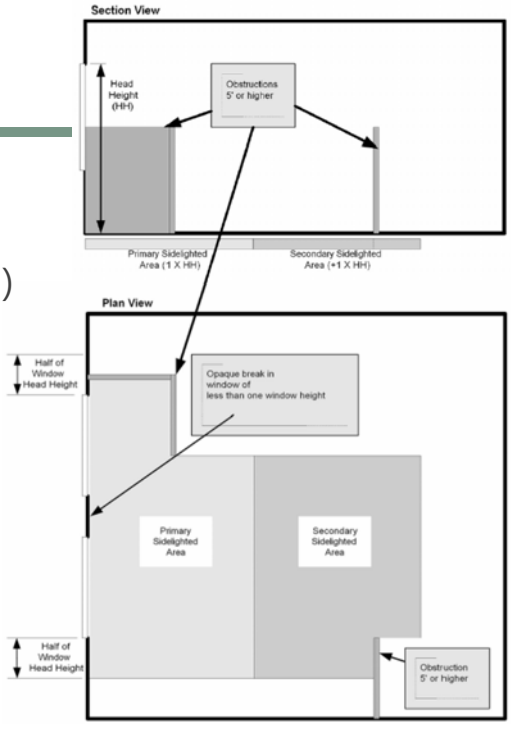
DAYLIGHT ZONES - WINDOWS

- Primary and Secondary
  - Based on Head Height (HH) (distance from floor to top of glazing)

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.



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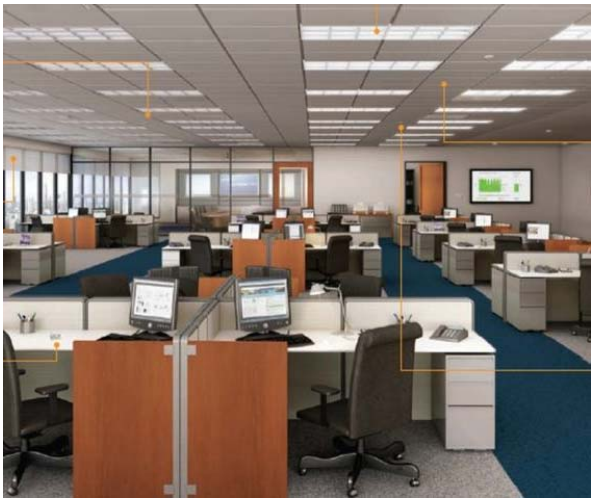
DAYLIGHT ZONE CONTROL

- Lights in daylight zones shall be controlled independently from general area lighting
- Exceptions
  - Daylight spaces enclosed by walls with only 1 or 2 fixtures.



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MAXIMUM SKYLIGHT AREA

IECC

Can increase skylight area from 3 percent to **5 percent** with the use of daylight responsive lighting controls

ASHRAE

Can increase skylight area from 3 percent to **6 percent** with the use of daylight responsive lighting controls

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G. AUTO PARTIAL OFF

- Automatically turn lights off within 20 minutes after occupants have left space
- Either manual-on or controlled to automatically turn on lighting to not more than 50% power
- Incorporate a manual control to allow occupants to turn off lights

Exceptions

- Space has LPD < 0.80 W/ft^2
- Space is lighted by High Intensity Discharge technology
- General lighting power in space is automatically reduced by ≥ 30% within 20 minutes of all occupants leaving the space
- Lighting load ≤ 0.02 W/ft^2 multiplied by gross lighted area of the building

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

I. SCHEDULED SHUTOFF

Must include an override switching device with the following:

- Minimum 7-day clock
- Capable of being set for 7 different day types/week
- Incorporate holiday "shutoff" feature to turn all controlled lighting loads for ≥ 24 hours and resume to normally scheduled operations
- Program backup capabilities to prevent loss of program and time setting for ≤ 10 hours if power is interrupted

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OVERRIDE CONTROLS

Override switch should include:

- Manual control
- Control lighting to remain on for <2 hours
- Control lighting for an area <5,000 ft^2

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CONTROL OF SPECIAL APPLICATIONS

Special applications separately controlled from general lighting

- Display or accent lighting
- Case lighting
- Nonvisual lighting
- Demonstration lighting

Photo Courtesy of Sweet Grass Pastures

SPECIAL APPLICATIONS

9.4.1.3 Special Applications

Lighting controls noted in this section are the only required controls for this equipment and these applications. Lighting exempt from interior lighting power shall be controlled in accordance with Table 9.2.3.1. Lighting using additional interior lighting power applications shall be controlled in accordance with Section 9.6.2.

a. Lighting used for the following applications shall be equipped with a local control independent of the control of the *general lighting* in accordance with Section 9.4.1.1(a). In addition, such lighting shall be controlled in accordance with Section 9.4.1.1(h) or Section 9.4.1.1(i).
   1. Display or accent lighting
   2. Lighting in display cases

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 to 9.4.1.3(b)(1)

Enclosed spaces where the lighting and switched receptacles are controlled by card key *controls* 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 to 9.4.1.3(b)(2)

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

c. 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. a local control independent of the control of the *general lighting* in accordance with Section 9.4.1.1(a).

   In addition, such lighting shall be controlled in accordance with Section 9.4.1.1(h) or Section 9.4.1.1(i).

DWELLING UNITS

- Dwelling units (apartment, condo, living space, etc.) must be built so that at least 75 percent of the permanently installed lighting fixtures utilize lamps with an efficacy of at least 55 lm/W, or have a total luminaire (fixture) efficacy of at least 45 lm/W.

  Exception: Lighting that is controlled with dimmers or automatic control devices.
- Applies to 4 story above grade multi-family (3 story and below not in scope of 90.1)
- Other common spaces in the building must follow standard 90.1 Requirements.

IECC 2021
- 100% efficient bulbs

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C405: LIGHTING SYSTEMS
Major Items of Note

- Dwelling units *may* comply by having 90% of permanently installed fixtures be high efficacy — C405.1.1
- 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/breakrooms.
5. Enclosed offices.
6. Open plan office areas.
7. Restrooms.
8. Storage rooms.
9. Locker rooms.
10. Corridors.
11. Warehouse storage areas.
12. Other spaces 300 square feet (28 m^2) or less that are enclosed by floor-to-ceiling height partitions.

Exception: Luminaires that are required to have specific application controls in accordance with Section C405.2.5.

C405.2

Auto shut-off within **20 minutes**
Limits to all on %
Manual override
Warehouse aisles
Open plan offices

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C405: LIGHTING SYSTEMS

Major Items of Note (cont.)

Time-switch controls required: C405.2.2
- 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: C405.2.2
- daylit zones,
- patient care,
- safety or security,
- continuous operation lighting,
- shop and laboratory classrooms

Light-reduction controls required C405.2.3

Exception for daylit zones (with compliant daylight responsive controls):
- 50% power reduction
- dimming or alternate lamp switching

Manual Controls: C405.2.6
- Readily accessible,
- Located in space with fixture or status indicator required,

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C405: LIGHTING SYSTEMS

Major Items of Note (cont.)

C405.2.3

Daylight responsive controls required:
- Electric general lighting > 150 Watts in daylit zones
- Sidelight daylit zones separate from Toplight zones

Exceptions for:
- Sleeping units,
- Patient care,
- Exempted lighting
- First floor in Group A2 and M occupancies

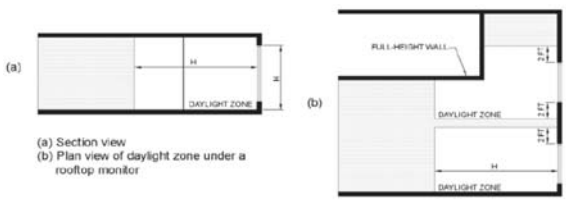

FIGURE C405.2.3.2
SIDELIT ZONE

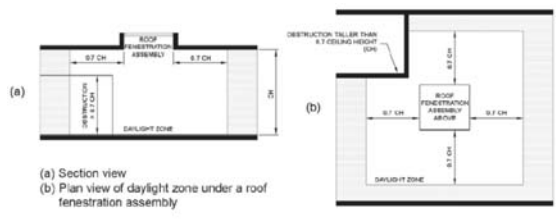

FIGURE C405.2.3.3(1)
TOPLIT ZONE

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C405: LIGHTING SYSTEMS

Major Items of Note (cont.)

Specific application controls required: C405.2.5

- Display & Accent Lighting
- Case lighting
- Supplemental task lighting
- Lighting sales demonstration
- Hotel/motel sleeping unit master control for luminaires and switched receptacles
  - Exceptions for captive key system
    - Exceptions for direct patient care
- Non-visual lighting (food warming and plant growth) – time switch control (separate from room controls)

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C405: LIGHTING SYSTEMS

Major Items of Note (cont.)

Exterior Lighting controls C405.2.7

- 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)
- Exterior time-switch control

Connected lighting may not exceed budget C405.3

- List of exempt lighting

Lighting power budget C405.3.2.1&2
(Building Area vs. Space-by-Space)

Additional lighting power for retail & decorative lighting C405.3.2.2.1

- No RCR or Additional Control wattage allowance

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LIGHTING CONTROL DESIGN

- Keep sensors simple and verify that they are set up properly
- Foster good human behavior to save energy
- An *educated* occupant is the best sensor

LIGHTING CONTROL DESIGN

- Occupants must have ready access
- Recommission equipment if necessary, even (especially) on new buildings

FUNCTIONAL TESTING

ASHRAE 90.1

- Functional testing (calibrated/adjusted/programmed) of lighting control devices and systems required within 90 days of occupancy
- Must be performed by individuals **not** involved in design, manufacture, or installation

IECC

Prior to passing final inspection, a *registered design professional* shall 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

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EXTERIOR LIGHTING

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EXTERIOR LIGHTING POWER ALLOWANCES

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 nontradable surfaces.)					
	No allowance	350 W	400 W	500 W	900 W
Tradable Surfaces (*LPD* allowances 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	0.03 W/ft^2	0.04 W/ft^2	0.06 W/ft^2	0.08 W/ft^2
***Building* Grounds**					
Walkways/ramps less than 10 ft wide	No allowance	0.5 W/linear foot	0.5 W/linear foot	0.6 W/linear foot	0.7 W/linear foot
Walkways/ramps 10 ft wide or greater Plaza areas Special feature areas	No allowance	0.10 W/ft^2	0.10 W/ft^2	0.11 W/ft^2	0.14 W/ft^2
Dining areas	No allowance	0.65 W/ft^2	0.65 W/ft^2	0.75 W/ft^2	0.95 W/ft^2
Stairways	No allowance	0.6 W/ft^2	0.7 W/ft^2	0.7 W/ft^2	0.7 W/ft^2
Pedestrian tunnels	No allowance	0.12 W/ft^2	0.12 W/ft^2	0.14 W/ft^2	0.21 W/ft^2
Landscaping	No allowance	0.03 W/ft^2	0.04 W/ft^2	0.04 W/ft^2	0.04 W/ft^2
***Building Entrances*, Exits, and Loading Docks**					
Pedestrian and vehicular entrances and exits	No allowance	14 W/lin ft of opening	14 W/lin ft of opening	21 W/lin ft of opening	21 W/lin ft of opening
Entry canopies	No allowance	0.20 W/ft^2	0.20 W/ft^2	0.20 W/ft^2	0.20 W/ft^2
Loading docks	No allowance	0.35 W/ft^2	0.35 W/ft^2	0.35 W/ft^2	0.35 W/ft^2
Sales Canopies					
Free standing and attached	No allowance	0.4 W/ft^2	0.4 W/ft^2	0.6 W/ft^2	0.7 W/ft^2
Outdoor Sales					
Open areas (including vehicle sales lots)	No allowance	0.2 W/ft^2	0.2 W/ft^2	0.20 W/ft^2	0.20 W/ft^2
Street frontage for vehicle sales lots in addition to "open area" allowance	No allowance	No allowance	7 W/linear foot	7 W/linear foot	21 W/linear foot

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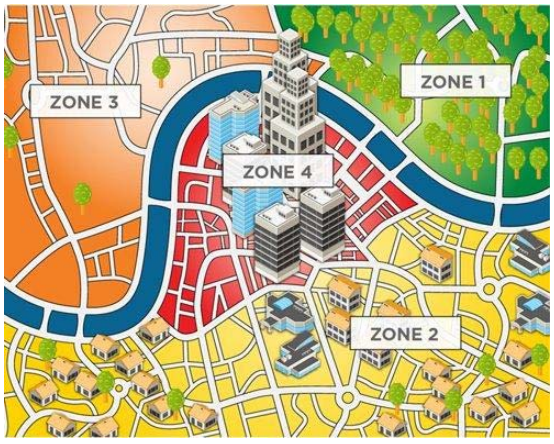
EXTERIOR LIGHTING ZONES

Lighting Zone	Description
0	Undeveloped areas within parks or undeveloped areas
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 not classified as lighting zone 1, 2 or 4
4	High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority



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NONTRADABLE SURFACES

- Building grounds, building entrances, exits/loading docks, canopies/overhangs, and outdoor sales areas may be traded
- Building facades, parking entrances, roadways, etc. are not tradeable

Nontradable Surfaces
(*LPD* allowances 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 (The allowance for each illuminated facade *orientation* shall be calculated by multiplying the allowable value by the entire façade area or facade length for that *orientation*.)	No allowance	No allowance	0.1 W/ft² of *façade area* or 2.5 W/linear foot of façade length	0.15 W/ft² of *façade area* or 3.75 W/ linear foot of façade length	0.2 W/ft² of *façade area* or 5.0 W/linear foot of façade length
Automated teller machines and night depositories	No allowance	135 W per location plus 45 W per additional ATM per location	135 W per location plus 45 W per additional ATM per location	135 W per location plus 45 W per additional ATM per location	135 W per location plus 45 W per additional ATM per location

	Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
Uncovered entrances and gatehouse inspection stations at guarded facilities	No allowance	0.5 W/ft²	0.5 W/ft²	0.5 W/ft²	0.5 W/ft²
Uncovered loading areas for law enforcement, fire, ambulance, and other emergency *service* vehicles	No allowance	0.35 W/ft²	0.35 W/ft²	0.35 W/ft²	0.35 W/ft²
Drive-through windows/ *doors*	No allowance	200 W per drive-through	200 W per drive-through	200 W per drive-through	200 W per drive-through
Parking near 24-hour retail entrances	No allowance	400 W per main entry	400 W per main entry	400 W per main entry	400 W per main entry
Roadway/parking entry, trail head, and toilet facility, or other locations approved by the *authority having jurisdiction*.	A single *luminaire* of 25 W or less	No additional allowance	No additional allowance	No additional allowance	No additional allowance
For areas that are not listed in this table or are not comparable to areas listed in this table, use the comparable interior *space* type from Table 9.6.1 as modified by factors in this row.	No allowance	65% of the *interior lighting power allowance* value	65% of the *interior lighting power allowance* value	80% of the *interior lighting power allowance* value	100% of the *interior lighting power allowance* value

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90.1-2019 ENERGY CODE LIGHTING QUIZ

What is the exterior lighting Base Site Allowance for a building being developed in a mixed-use residential area?

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EXTERIOR LIGHTING CONTROLS

- Automatic off control when daylight is available
- Curfew hours for façade and landscape lighting
(midnight – 6am or close to open)
- Other exterior lighting (**including advertising**) must automatically reduce power by a minimum of 30% either:
  - Midnight – 6am (or 1 hour after business close until open)
  - Motion sensor control (any period of inactivity greater than 15 min)

EXTERIOR CONTROLS EXCEPTIONS

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

PARKING GARAGE CONTROLS

Automatic lighting shutoff

- Must reduce lighting power at least 30% when no activity is detected for 20 minutes within a lighting zone ≤ 3,600 ft^2
- Automatically reduce power at least 50% in response to daylight for luminaires within 20 ft of any perimeter wall that has
  - a net opening to wall ratio of greater than 40% and
  - no exterior obstructions within 20 ft

Exception

Daylight transition zones and ramps without parking are exempt from 30% reduction and daylight control

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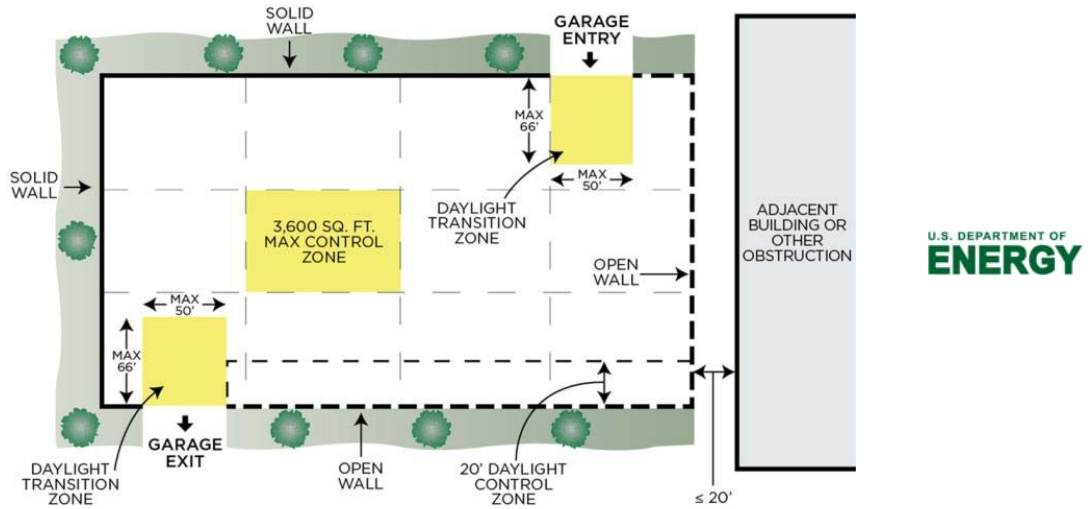
PARKING GARAGE CONTROLS



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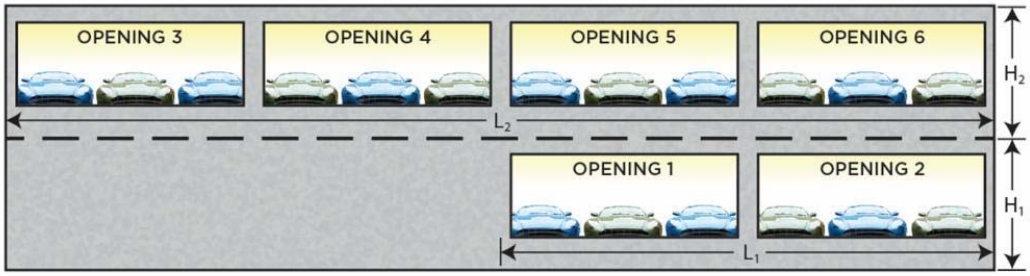
PARKING GARAGE CONTROLS

PARKING GARAGE SIDE VIEW (ELEVATION)



Daylighting control required if the total area of all openings in a wall section (i.e. openings 1-2) are greater than or equal to 40% of the total wall area (HxL).

Example: $\frac{\text{Opening 1 + Opening 2}}{H_1 \times L_1}$ *Example:* $\frac{\text{Opening 3 + Opening 4 + Opening 5 + Opening 6}}{H_2 \times L_2}$

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POWER

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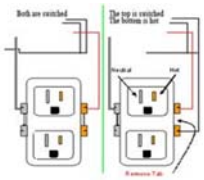
AUTOMATIC RECEPTACLE CONTROL

- At least 50% of all 125V 15 and 20 amp receptacles and at least 25% of branch circuit feeders for modular furniture
  - Private offices, conference rooms, printing/copy rooms, break rooms, classrooms, and individual workstations
- Controlled by:
  - Scheduled control (zones of 1 floor or 5,000 SF, whichever is less)
  - Occupancy sensor
  - Automated control system
- Must be permanently marked to differentiate controlled and non-controlled and distributed uniformly



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ELECTRICAL ENERGY MONITORING

- Each of the following must be monitored separately:
  - Total electrical energy
  - HVAC systems
  - Interior lighting
  - Exterior lighting
  - Receptacle circuits
- Individual tenant spaces separately monitored and made available to each tenant
- Recorded every 15 minutes for at least 36 months

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EAZEE BUILDING –EXTERIOR LIGHTING

COMCHECK HW PROBLEM

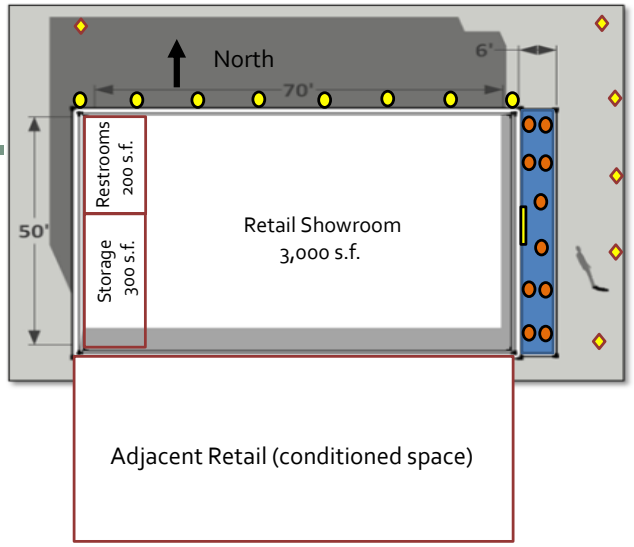
Small 10’ Strip Retail Building

North Wall: A - 8 exterior sconces – 28W LED downlights

East Wall: B - 1 LED strip doorway light – 8’ 20W LED

C -10 Canopy Can lights – 13 W CFL’s

D- 6 Parking overhead fixtures – 88W LED’s



Enter the above exterior fixtures into COMcheck as well as the following to check for lighting compliance:

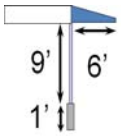
– North side driveway, 70’x15’

– East Entry Canopy, 50’x6’

– Main Entry Doorway, 6’

– Front Parking Area, 65’x100’

Using COMCheck, enter exterior lighting fixtures and create an exterior lighting budget assuming typical neighborhood business district. Does the design pass or fail 90.1-2019 for exterior lighting and by what percentage?



CONCLUSION