DOCKETED	
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Project Title:	2022 Energy Code Pre-Rulemaking
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Document Title:	Presentation - October 7, 2020 Energy Code Pre-Rule Making Workshop
Description:	Staff Presentation on Indoor Lighting, Nonresidential Air Distribution, and By: Payam Bozorgchami - Nonresidential HVAC Controls on October 7, 2020 Energy Code on Pre-Rule Making Workshop
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Organization:	California Energy Commission
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Docketed Date:	10/7/2020

2022 Pre-Rulemaking for Building Energy Efficiency Standards

Payam Bozorgchami, P.E.

October 7, 2020

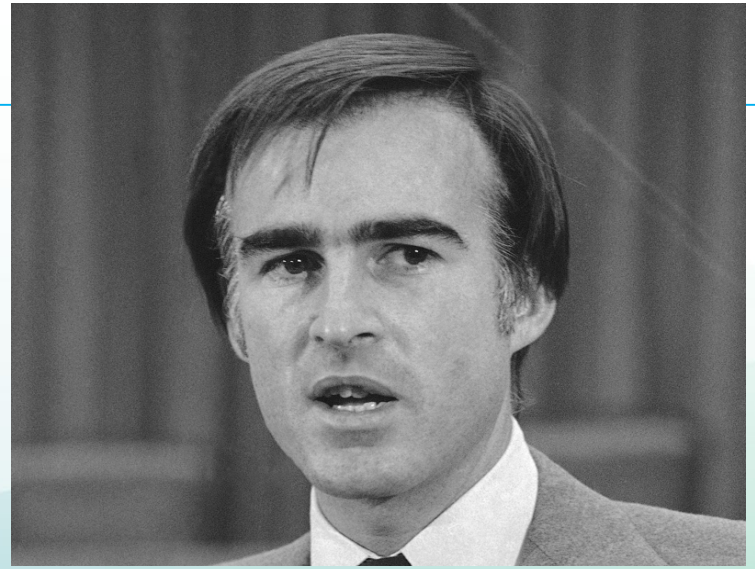
Start Time: 9:00 AM

What We Will Cover Today

- **Some Basic Background**
- **How Title 24, Part 6 is Developed**
- **Simon Lee, P.E.**
  - Indoor Lighting
    - Multi-zone Occupancy Sensing Controls for Large Offices.
    - Indoor Lighting Power Allowances
- **Ronald Balneg**
  - Nonresidential Air Distribution
    - Fan Power Budget
    - Fan Energy Index
    - Duct Leakage
  - Nonresidential HVAC Controls
    - Variable Air Volume Deadband Airflow
    - Dedicated Outdoor Air Systems
    - Exhaust Air Heat Recovery

Authority & Process

- **Public Resources Code (PRC 25402):** Reduction of wasteful, uneconomic, inefficient, or unnecessary consumption of energy
  - (a)(1) Prescribe, by regulation, lighting, insulation, climate control system, and other building design and construction standards that increase the efficiency in the use of energy and water…
  - Warren Alquist Act Signed into law in 1974 by Governor Ronald Reagan and launched by Governor Jerry Brown in 1975 which mandates updates Building Efficiency Standards and requires the building departments to enforce them through the permit process.



Goals of the California Energy Code

1. Increase building energy efficiency cost-effectively
2. Contribute to the state's GHG reduction goals
3. Enable pathways for all-electric buildings
4. Reduce residential building impacts on the electricity grid
5. Promote demand flexibility and self-utilization of PV generation
6. Provide tools for local government reach codes

Process Used to Updated Energy Codes

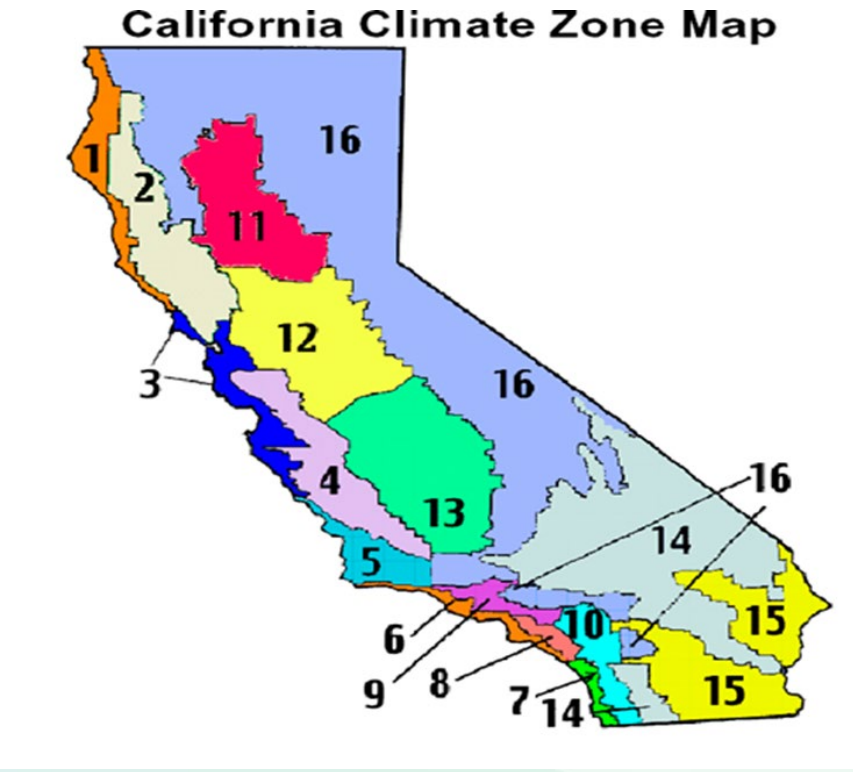
CEC staff, with input from utility partners and industry stakeholders, develop the triennial standards update

Opportunities for participation

- Utility-Sponsored Stakeholder Meetings
- CEC-Sponsored Workshops

Standards must be cost-effective

- Life-Cycle Costing Methodology
- Time Dependent Valuation (TDV)



2022 Standards Process

2022 STANDARDS UPDATE SCHEDULE	
DATE	**MILESTONES**
November 2018 - November 2019	Updated Weather Files
November 2018-December 2019	Metric Development
November 2018-July 2019	Measures Identified and approval
August 2019 to October 2020	Stakeholder meeting/workshop & final staff workshop
August 2020-October 2020	CASE Reports submitted to the CEC
February 2021	45-day Language Hearings
July 2021	Adoption of 2022 Standards at a Business Meeting
July 2021 to November 2021	Staff work on Software, Compliance Manuals, Electronic Documents Available to Industry
December of 2021	Approval of the Manuals
January 2022	Software, Compliance Manuals, Electronic Documents Available to Industry
January 1, 2023	Effective Date

Tentative Pre-Rulemaking Schedule

- **September 1**
  - Energy Savings and Process Improvements for Alterations and Additions
    - Roof deck insulation for low-slope roofs
    - Prescriptive attic insulation for alterations
    - Prescriptive duct sealing
    - Electric resistance water heating
    - Electric resistance space heating
    - 40-ft trigger for prescriptive duct requirements
    - Cool roof for steep-slope roofs
    - Cool roof for low-slope roof
- **September 9**
  - Nonresidential Grid Integration
  - Controlled Receptacle, CEA Proposal
- **September 10**
  - Verification Testing
- **September 22**
  - Outdoor lighting
  - Daylighting
- **September 23**
  - Computer Room Efficiencies
  - Pipe Sizing and Leak Testing for Compressed Air Systems
  - Refrigeration System Operation

Tentative Pre-Rulemaking Schedule (Cont.)

- **September 30**
  - Indoor Air Quality Roundtable discussion with the outside world
- **October 6 and November 19**
  - Solar Photo Voltaic and Electrification
  - Multifamily All Electric
- **October 7**
  - Nonresidential Indoor Lighting
  - Air Distribution
  - Nonresidential HVAC Controls
- **October 13**
  - Multifamily Domestic Hot Water
  - Multifamily Restructuring
- **October 20**
  - Nonresidential High Performance Envelope
- **October 27**
  - Control Environmental Horticulture
  - New Construction Steam Trap
- **October 29 Place holder (Commissioner roundtable discussion on September 30 on IAQ)**
  - Indoor Air Quality Roundtable discussion with the outside world

Key Web-Links

2022 Title 24 Utility-Sponsored Stakeholder
http://title24stakeholders.com/

Building Energy Efficiency Program
http://www.energy.ca.gov/title24/

Comments to be submitted to:
https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-03

NOTE: For this workshop comments To Be Submitted By October 21, 2020

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Comments For Todays Workshop

Due Date: October 21, 2020 By 5:00 PM

Comments to be submitted to:
https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-03

Questions ?

Thank You!

Indoor Lighting Proposal for 2022

Staff Pre-Rulemaking Workshop

Presenters: Simon Lee, Electrical Engineer

Date: October 7, 2022

Proposal Summary

Nonresidential Indoor Lighting

Two measures:

- Multi-zone Occupancy Sensing Controls for Large Offices
- Indoor Lighting Power Allowances

Multi-Zone Occupancy Sensing Controls for Large Offices

2022 Code Update Sections Affected

Title 24, Part 6:

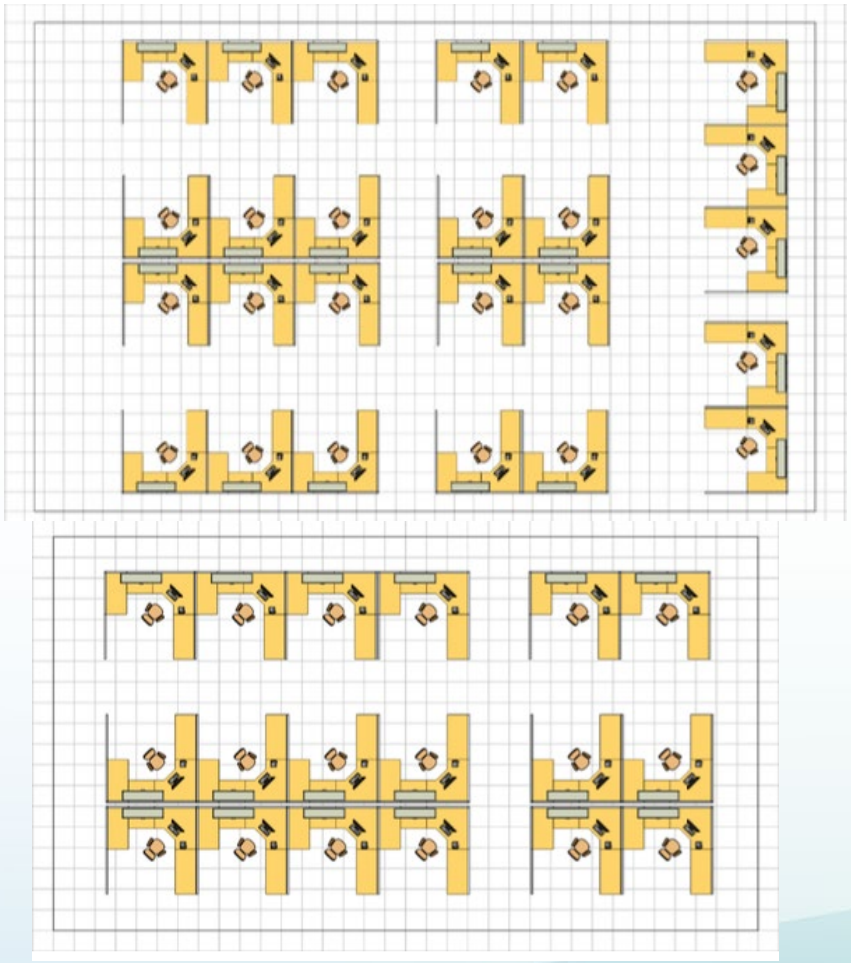
- Section 100.1
- Section 120.2(e)3
- Section 130.1(c)6D
- Section 130.1(f)
- Section 140.6
- Table 140.6-A
- Table 141.0-F

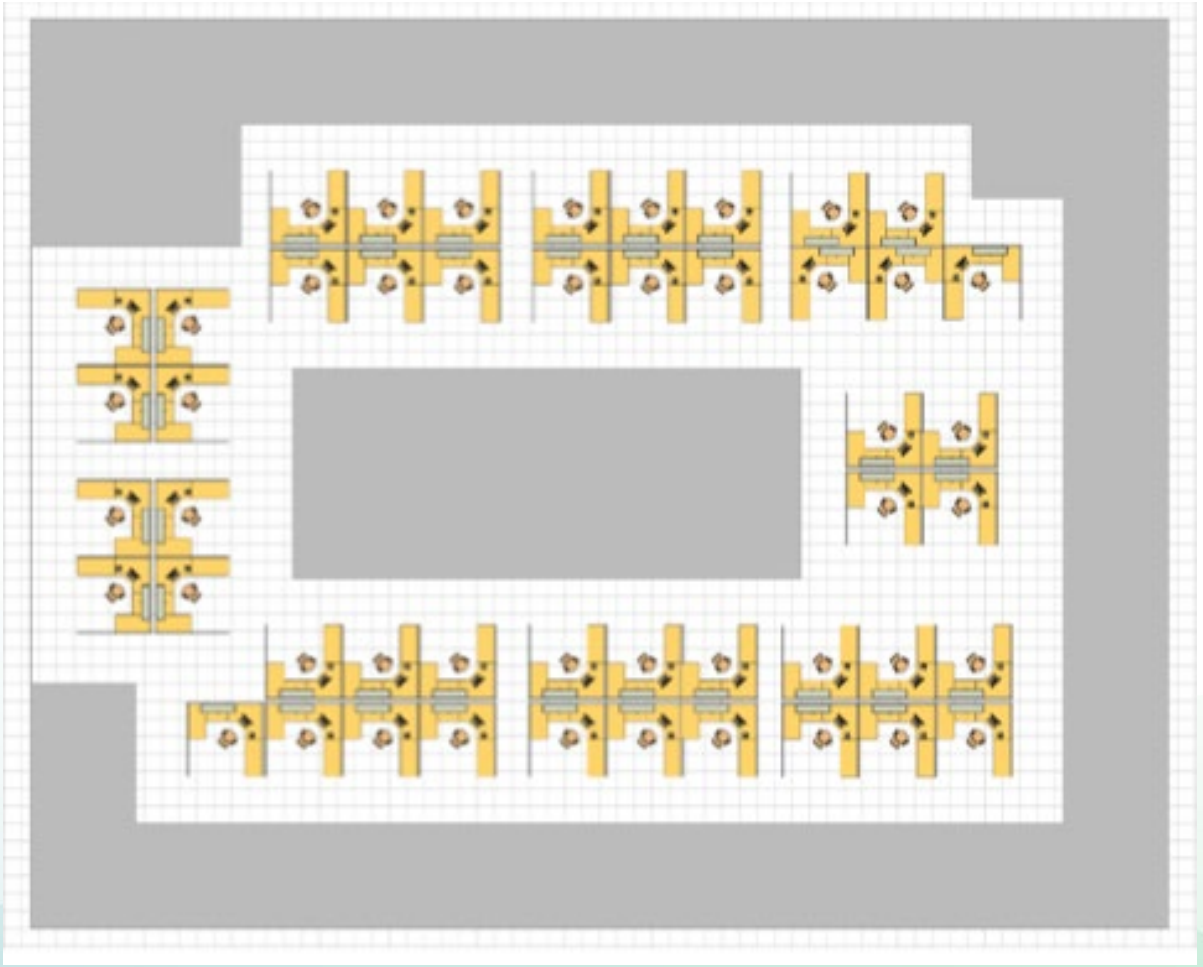
Reference Appendix

- NA 7.5.17
- NA 7.6.2.3

Multi-Zone Occupancy Sensing Controls for Large Offices

Large Offices, also known as Open Plan Offices:

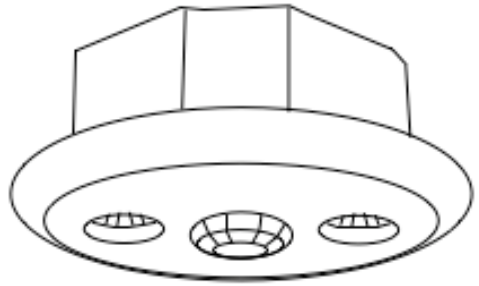




Occupancy Sensing Controls

Current Lighting Controls for Large Offices

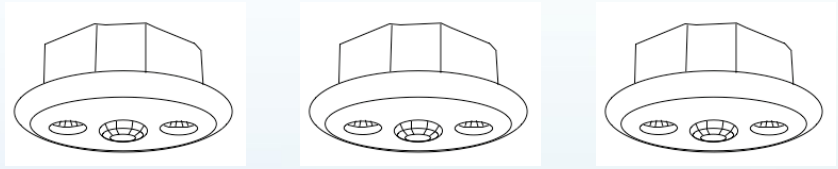
- Occupancy Sensing Controls is required for Offices 250 square feet or smaller. Section 130.1(c)5
- Not required for offices larger than 250 square feet.
- 2019 Code allows several occupancy sensing control types to meet this requirement. They include
  - occupant sensors,
  - partial-on occupant sensors (auto. activating between 50-70 percent of lighting power), and
  - vacancy sensors type to be used and installed.

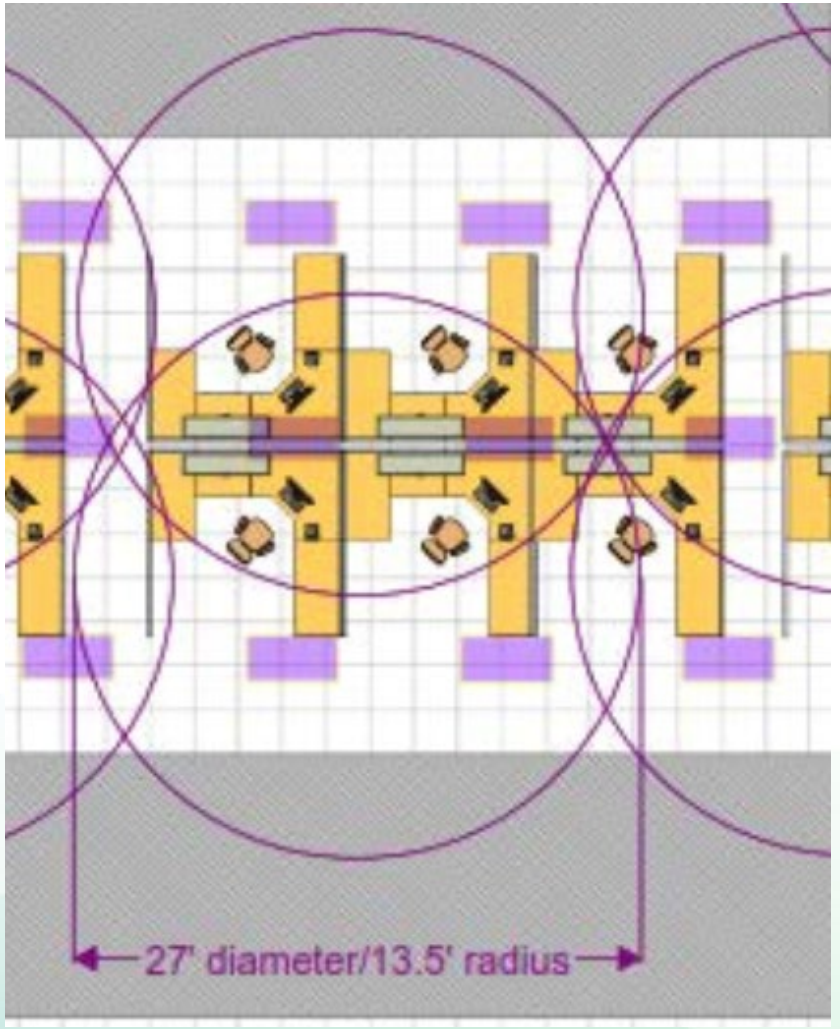


Proposed Multi-Zone Occupancy Sensing Controls for Large Offices

Proposed Multi-zone Occupancy Sensing Lighting Controls for Large Offices

- Multi-zone Occupancy sensing controls for large offices are mandatory;
- Time-switch controls are no longer permitted in 2022 (as multi-zone occupancy savings product greater energy savings than time-switch controls
- Minimum control zone of 600 SF; or a control zone cannot be greater than 600 SF.





Proposed Multi-Zone Occupancy Sensing Controls for Large Offices

	individual control zones	the entire office space (all zones)
Within 20 minutes of non-occupancy in a control zone (A)	The general lighting power in the control zone is reduced to no more than 20% of full power. note 1	Does not affect general lighting in control zones that have detection of occupancy.
Within 20 minutes of non-occupancy of the entire office space (B)	All lighting, including general lighting and all other lighting, is turned off in the space.	
Upon occupancy within a control zone (C)	The lighting in each control zone shall be allowed to automatically turn on to a level that required. note 2	

Proposed Multi-Zone Occupancy Sensing Controls for Large Offices

Table note 1. The general lighting power shall be reduced in a manner that the luminaires in the same control zone are dimmed together tot the same power level as a group.
Table note 2. A level that recognizes the control interactions specified in Section 130.1(f)8. Configure the controls so that the lighting power does not exceed the lessor of the allowed power by either control.
Note 3. For luminaires with an embedded occupancy sensor that are capable of reducing power independently from other luminaires, each luminaire can be considered its own control zone.
Note 4. Power adjustment factor (PAF) are available for control zones equal to or smaller than 250 SF.
Exception. Under shelf or furniture-mounted supplemental task lighting controlled by a local switch and either a time-switch or an occupancy sensor.

Proposed Language – Multi-Zone Occupancy Sensing Controls

Proposed Section 130.1(c)6D for Large Offices

D. Lighting in office spaces greater than 250 ft^2 shall be controlled by occupancy sensing controls that comply with all of the following:

i. The occupancy sensing controls shall be configured so that lighting shall be controlled separately in control zones not greater than 600 ft^2.

ii. Within 20 minutes of the control zone being unoccupied, the occupancy sensing controls shall uniformly reduce lighting power in the control zone to no more than 20 percent of full power.

iii. Within 20 minutes of the entire office space being unoccupied, the occupancy sensing controls shall automatically turn off general lighting in all control zones in the space.

iv. Lighting in each control zone shall be allowed to automatically turn on to full power upon occupancy within the control zone. When occupancy is detected in any control zone in the space, the lighting in other control zones that are unoccupied shall operate at no more than 20 percent of full power.

Exception: Under shelf or furniture-mounted supplemental task lighting controlled by a local switch and either a time clock or an occupancy sensor.

Note: For luminaires with an embedded occupancy sensor that are capable of reducing power independently from other luminaires, each luminaire can be considered its own control zone.

Proposal Language – Multi-Zone Occupancy Sensing Controls

Proposed Section 130.1(f) Control Interactions

8. For lighting controlled by automatic daylighting controls and by occupant sensing controls, the controls shall be configured so that power does not exceed the lesser of the allowed power by either control.

9. Space conditioning system zones serving only room(s) that are required to have occupant sensing controls in accordance with Section 130.1(c), and where the Table 120.1-A occupancy category permits ventilation air to be reduced to zero when the space is in occupied-standby mode, the space conditioning zone shall be controlled by Occupancy Sensing Zone Controls complying with Section 120.2(e)3.

Proposal Language – Multi-Zone Occupancy Sensing Controls

Proposed Section 120.2(e) Shutoff and Reset Controls for Space-Conditioning Systems

3. Occupancy Sensing Zone Controls. Space conditioning systems~~-~~ zones serving only space(s) ~~room(s)~~ that are required to have occupant sensing controls in accordance with Section 130.1(c), and where the~~-~~Table 120.1-A occupancy category permits ventilation air to be reduced to zero when the space is in occupied-standby mode, shall meet the following:

A. Occupancy Sensing Zone Controls shall comply with the Occupant Sensor Ventilation Control Device requirements of Section 120.1(d)5 and allow preoccupancy ventilation requirements of Section 120.1(d)2; and

B. Occupancy sensors shall comply with Section 110.9(b)4 and be capable of changing HVAC operation mode or indicating a space is unoccupied no more than 20 minutes after a space has been vacated; and

C. ~~A.~~ ~~The~~ When the zone is scheduled to be occupied, and occupancy sensing controls in all room(s) served by the zone indicate the rooms are unoccupied, the zone shall be placed in occupied standby mode ~~all room(s) served by the zone are unoccupied for more than 5 minutes~~; and

Proposal Language – Multi-Zone Occupancy Sensing Controls (continue)

Proposed Section 120.2(e) Shutoff and Reset Controls for Space-Conditioning Systems

D. ~~B.~~ ~~During~~ Within 5 minutes of entering occupied standby mode:

i. Automatically setup the operating cooling temperature set point by 2°F or more and setback the operating heating temperature set point by 2°F or more; or

ii. For multiple zone systems with Direct Digital Controls (DDC) to the zone level, setup the operating cooling temperature setpoint by 0.5°F or more and setback the operating heating temperature setpoint by 0.5°F or more.

E. ~~C.~~ ~~During~~ Within 5 minutes of entering occupied-standby mode all airflow to the zone shall be shut off whenever the space temperature is between the active heating and cooling setpoints.

Exception to 120.2(e)3: Zones which are only ventilated by a natural ventilation system in accordance with Section 120.1(c)2.

Proposal Language – Multi-Zone Occupancy Sensing Controls

Proposed revised definitions in Section 100.1. Staff are seeking inputs for proposed changes below.

MECHANICAL COOLING is lowering the temperature within a space using refrigerant compressors or absorbers, desiccant dehumidifiers, or other systems that require energy to directly condition the space. Systems that are solely energy recovery ventilation (ERV) or heat recovery ventilation (HRV) are not considered mechanical cooling. In nonresidential, highrise residential, and hotel/motel buildings, cooling of a space by direct or indirect evaporation of water alone is not considered mechanical cooling.

MECHANICAL HEATING is raising the temperature within a space using electric resistance heaters, fossil fuel burners, heat pumps, or other systems that require energy to directly condition the space. Systems that only use solar energy or heat recovery as the heat source are not mechanical heating systems.

OCCUPIED STANDBY MODE is when a zone is scheduled to be occupied and an occupant sensor indicates zero population within the zone.

SPACE-CONDITIONING SYSTEM is a system that provides mechanical heating, or mechanical cooling within or associated with conditioned spaces in a building, and may incorporate use of components such as chillers/compressors, fluid distribution systems (e.g., air ducts, water piping, refrigerant piping), pumps, air handlers, cooling and heating coils, air or water cooled condensers, economizers, terminal units, and associated controls.

PAF for Occupancy Sensing Controls in Office Spaces

Table 140.6-A Lighting Power Adjustment Factors (PAF)		
Type of Control	Type of Area	FACTOR
Occupancy Sensing Controls in ~~Large Open Plan~~ Office Spaces Greater than 250 SF	One sensor controlling an area that is no larger than 125 SF	0.30 ~~0.40~~
	One sensor controlling an area from 126 SF to 250 SF	0.20 ~~0.30~~

Proposed Lighting System Alterations

Table 141.0-F Control Requirements for Indoor Lighting System Alterations			
Control Specifications		**Projects complying with Section 141.0(b)2li**	**Projects complying with Sections 141.0(b)2lii and 141.0(b)2liii**
Automatic Shut Off Controls	130.1(c)6	Required	Required except for 131.0(c)6D

Acceptance Testing for Multi-Zone Occupancy Sensing Controls

- Add a new test method for multi-zone controls in NA 7.6.2.3.2, Multi-Zone Occupant Sensing Controls
- Clarify delay timing in NA7.5.17, Occupied Standby

Acceptance Testing - NA7.5.17.2 Occupied Standby

Clarify delay timing in NA7.5.17.2 Functional Testing:

Step 7: Confirm that within 5 minutes of occupancy sensing controls indicating all spaces are unoccupied ~~being vacated~~ the setpoint is setup or setback and the zone is within the occupied standby deadband. (Note: occupancy sensing controls are allowed to have a time delay of up to 20 minutes before indicating the space is unoccupied and Occupancy Sensing Zone Controls allow an additional 5 minute time delay after occupancy sensing controls have indicated all rooms served by the zone are unoccupied before resetting zone temperature setpoints and shutting off zone ventilation air).

Step 8: Confirm that no ventilation is being supplied to the space with the occupancy sensor.

Step 9: Put the zone in pre-occupancy ventilation mode (i.e. adjust the occupancy schedule to one hour prior to normal scheduled occupancy).

Acceptance Testing - NA7.5.17.2 (continue)

Clarify delay timing in NA7.5.17.2 Functional Testing:

Step 10: Physically vacate all spaces served by the zone.

Step 11: Confirm that within 5 minutes of occupancy sensing controls indicating that all spaces served by the zone are unoccupied, the zone is supplied with pre-occupancy ventilation rate of Section 120.1(d)2: either the minimum rate of outdoor air required by Section 120.1(c) or three complete air changes is supplied to the zone during the one hour period immediately before the zone is scheduled to be occupied. (See note for Step 7 concerning maximum occupancy sensing control time delay).

Step 12: Occupy a space served by the zone during the one hour immediately prior to scheduled occupancy. Confirm that that the zone is supplied with pre-occupancy ventilation rate of Section 120.1(d)2.

Acceptance Testing - NA7.6.2.3.2 Multi-zone Lighting Controls

A new section in NA 7.6.2.3.2 – Acceptance Test for Multi-Zone Occupant Sensing Controls (Lighting Controls)

New tests for multi-zone occupancy sensors:

- Occupied Test;
- Unoccupied Control Zone Test;
- Control Zone Size Test;
- Unoccupied Office Test

Acceptance Testing - NA7.6.2.3.2 (continue)

Occupied Test – a part of NA 7.6.2.3.2 (new)

(a) Simulate an occupied condition in the control zone controlled by the occupancy sensor. Verify and document the following:

1. Immediately upon occupancy of the control zone, the occupancy sensor turns on controlled lighting.
2. Measure the illuminance at a location in the control zone where the light output is due to the controlled lighting.
3. Signal sensitivity is adequate to achieve desired control.
4. Status indicator or annunciator operates properly.

Acceptance Testing - NA7.6.2.3.2 (continue)

Unoccupied Control Zone Test – a part of NA 7.6.2.3.2 (new)

Simulate an unoccupied condition in the control zone controlled by the occupancy sensor. Confirm that at least one control zone within the office greater than 250 ft2 is occupied. Verify and document the following:

1. The occupancy sensor uniformly reduces light output of the controlled lighting within a maximum of 20 minutes from the start of the unoccupied condition in the control zone.
2. Measure the illuminance at the same location as in Step(a)1.Verify that the light output during unoccupancy is no more than 20% of the full light output measured in Step (a)1.
3. The occupancy sensing control does not trigger a false on from movement outside of the control zone or from HVAC operation. a. Note: The field of view of occupancy sensors in the adjacent control zones in offices greater than 250 ft2 may overlap, but the field of view must not include an adjacent enclosed spaces that is not part of the large office, like conference rooms, private offices, etc.
4. Signal sensitivity is adequate to achieve desired control.

Acceptance Testing - NA7.6.2.3.2 (continue)

Control Zone Size Test – a part of NA 7.6.2.3.2 (new) – 1st Method

Simulate an unoccupied condition in the control zone controlled by the occupancy sensor while standing in an adjacent control zone. Determine the "edge" of the control zone controlled by the occupancy sensor by moving toward the occupancy sensor until the lights controlled by the occupancy sensor turn on as in Step (a)1, therefore simulating an occupied condition. Verify and document the following:

1. Measure the distance (in feet) from the "edge" of the control zone to the spot that is directly below the occupancy sensor. This is the radius of the control zone.
2. Determine the area of the control zone by using the formula: Area= π*radius^2.
   a. Note: π is the mathematical constant representing the ratio of a circle's circumference to its diameter and is roughly equal to 3.1416. The formula assumes the field of view of the occupancy sensor is a circle, which is the most common coverage pattern of occupancy sensors. If the coverage pattern for an occupancy sensor under test is non-circular and is supported by available documentation, the test technician shall adjust the formula accordingly.
3. The area of the control zone must be less than or equal to 600 ft^2.

Acceptance Testing - NA7.6.2.3.2 (continue)

Control Zone Size Test – a part of NA 7.6.2.3.2 (new) – 2nd Method

Simulate an unoccupied condition for the entire office space. Verify and document the following:

- Walk thru the space and count the number of zones of lighting turned on automatically as walking thru the space.
- Record the number of zones counted and also find out the size of the office in square footage from the construction plans or other information source.
- Divide the size of the office by the number of zones and this computed value (in square feet) is the assessed control zone size.
- If the value is less than or equal to 600 SF, it passes the test. Otherwise, it fails the test.

Acceptance Testing - NA7.6.2.3.2 (continue)

Unoccupied Office Test – a part of NA 7.6.2.3.2

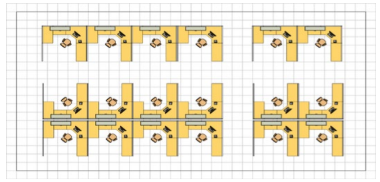
Simulate an unoccupied condition in the control zone controlled by the occupancy sensor and in all other control zones within the enclosed space (room). Verify and document the following:

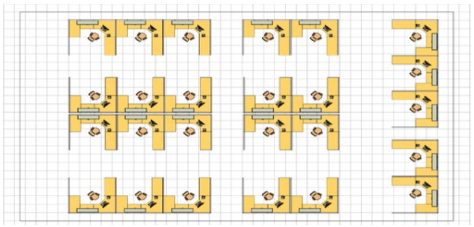
1. All lighting in the enclosed space turns off within a maximum of 20 minutes from the start of the unoccupied condition.

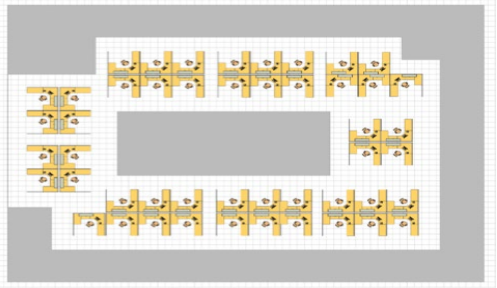
   a. **Note:** While the focus of the acceptance test is general lighting, when all the control zones are unoccupied, all lighting must be turned off within a maximum of 20 minutes. Therefore, this specific test segment must verify all lighting is turned off within a maximum of 20 minutes of the start of the unoccupied condition.

Energy Savings Calculations

Large Office Model A, B, C:







Office Floor Plan Model	Model Office A	Model Office B	Model Office C
Square footage	2,584 SF	4,000 SF	7,540 SF
Number of occupants	18	25	48
Average area per workstation/cubicle	140 SF	154 SF	154 SF
Number of luminaires	28	40	78
General lighting layout	95 SF/luminaire	100 SF/luminaire	97 SF/luminaire
Total lighting load	1,120 W	1,600 W	3,120 W
Lighting power density	0.43 W/SF	0.40 W/SF	0.41 W/SF

Energy Savings Calculations

Large Office Model A, B, C – First-Year Energy Impacts Per Square Foot

Model Office Floor Plan	Climate Zone	Electricity Savings (kWh/ft²)	Peak Electricity Demand Reductions (W/ft²)	Natural Gas Savings (therms/ft²)	TDV Energy Savings (TDV kBtu/ft²)
Model Office A (2,584 ft²)	All	0.938	0.160	0.00021	30.049
Model Office B (4,000 ft²)	All	0.999	0.165	0.00021	31.621
Model Office C (7,540 ft²)	All	1.137	0.177	0.00021	35.589
Average	All	1.025	0.167	0.00021	32.420

Incremental Measure First Cost

Cost Component	Minimum	Maximum	Average	Value Used in Estimate	Source
Cable Connector ($/item)	N/A	N/A	N/A	$5.34	Manufacturers
Commissioning and ATT Labor ($/hour)	$91.35	$176.76	$118.41	$118.41	RSMeans
Design Labor ($/hour)	N/A	N/A	N/A	$120.58	Designer
HVAC Occupied Standby Integration	N/A	N/A	N/A	$0.13	2019 Final CASE Report based on ASHRAE 90.1
Installation and Startup Labor ($/hour)	$79.18	$153.21	$102.63	$102.63	RSMeans
Junction Box	$2.24	$4.45	$3.35	$3.35	Manufacturers
Occupancy Sensors ($/item)	$55.63	$83.67	$70.17	$55.63	Multiple Stakeholders
Power Cable ($/1′)	N/A	N/A	N/A	$0.73	RSMeans
Room Controllers ($/item)	$69.82	$121.60	$98.64	$104.50	Multiple Stakeholders
Time-switch ($/item)	$243.24	$1,360.00	$595.17	$244.54	Multiple Stakeholders
2-Wire 0-10V Cable ($/25′)	N/A	N/A	N/A	$25.31	RSMeans

Measure Cost-Effectiveness

Estimated 15-Year Cost-Effectiveness Summary Per Square Foot

Model Office Layout	Benefits TDV Energy Cost Savings + Other PV Savings (2023 PV$)	Costs Total Incremental PV Costs (2023 PV$)	Benefit-to-Cost (B/C) Ratio
Model Office A (2,584 ft^2)	$2.67	$2.12	1.26
Model Office B (4,000 ft^2)	$2.81	$2.38	1.18
Model Office C (7,540 ft^2)	$3.17	$2.36	1.35
		Average B/C Ratio	1.26

Benefits for Implementation

Statewide Energy and Energy Cost Impacts

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (PV$ million in 2023)
New Construction	24.46	3.98	0.01	$69.05
Additions and Alterations	37.98	6.18	0.01	$107.23
TOTAL	62.44	10.17	0.02	$176.28

Greenhouse Gas (GHG) Emissions Reduction

First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings (GWh/yr)	Reduced GHG Emissions from Electricity Savings (Metric Tons CO2e)	Natural Gas Savings (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings (Metric Tons CO2e)	Total Reduced CO_2e Emissions (Metric Tons CO2e)
Multi-Zone Occupancy Sensing Controls	62.44	15,007	0.02	96	15,103

Preliminary Findings

Technical Feasibility

Occupancy Sensors	Preliminary Findings for Multi-Zone Occupancy Sensing Controls for Large Offices
Occupancy sensors connectable to room controllers or networked lighting control systems; Occupancy sensors of Luminaire Level Lighting Controls (LLLC) type	Commonly available in marketplace for office lighting controls application

Cost Effectiveness

- cost effective in all climate zones and for all building types.

Questions

Indoor Lighting Power Allowances

2022 Code Update Sections Affected and Highlights

Title 24, Part 6:

- Section 100.1
- Section 130.0(c)
- Section 140.6(a)
- Section 140.6(c)
- Table 140.6-B,C,D,G

Highlights of changes to Indoor Lighting Power Provisions:

- Complete Building Method Lighting Power Densities
- Area Category Method Lighting Power Densities
- Tailored Method Lighting Power Densities
- Lighting, Luminaires and Wattage

Complete Building Method Lighting Power Allowances

Table 140.6-B **Type of Building**	**Allowed Lighting Power Densities(W/ft²)**
Assembly Building	0.65 ~~0.55~~
Bank or Financial Institution Building	0.65
Grocery Store Building	0.90 ~~0.95~~
Gymnasium Building	0.60 ~~0.65~~
Motion Picture Theater Building	0.60 ~~0.70~~
Museum Building	0.65
Office Building	0.60 ~~0.65~~
Performing Arts Theater Building	0.75 ~~0.80~~
Restaurant Building	0.65 ~~0.70~~
School Building	0.60 ~~0.65~~

Highlights of the updates to Table 140.6-B:

- A new museum complete building lighting power densities (LPD) allowance.
- Building types not listed here have the same LPD of the 2019 Code. No proposed changes to their LPD values.

Lighting Power Allowances for Area Category Method

Indoor Lighting Power Densities (LPD) - Area Category Method

Essential changes to Indoor Lighting Power Densities (LPD) for Area Category Method :

- The area lighting power densities have been revisited and re-anaylzed with lumen method and revised lumen method inputs.
- Some of the general and additional lighting power allowance in the Area Category Method has been revised up; others down. Still others stay the same.
- Proposed LPDs for all area types were assumed to be met with LED luminaires.
- Function Area highlights:
  - “Open plan office” is merged with the rest of Office Area: > 250 ft“
  - Parking garage Dedicated Ramps” are proposed to be merged with parking zone.
- Changes to clarify qualified lighting systems in Table 140.6-C.

Proposal – Indoor Lighting Definitions

Section 100.1 – definitions under considerations

There are proposed changes to a few lighting definitions in both the indoor and outdoor CASE reports. Staff are seeking stakeholder's inputs for the following proposed changes.

Accent Lighting is directional lighting to emphasize a particular object or surface feature, or to draw attention to a part of the field of view. It can be recessed, surface mounted, or mounted to a pendant, stem or track, and can be display lighting. It shall not provide general lighting.

Display Lighting … Types of display lighting include:

Floor: supplementary lighting required to highlight features, such as … sculpture or free standing of artwork, …

Wall: supplementary lighting required to highlight features, such as wall-mounted artwork …

Decorative (Lighting/Luminaire) is lighting or luminaires installed only for aesthetic purposes and that does not serve as display lighting, general lighting. *Decorative luminaires are chandeliers, sconces, lanterns, neon and cold cathode, light emitting diodes, theatrical projectors, moving lights, and light color panels, not providing general lighting or task lighting.*

Ornamental (Lighting/Luminaire) is lighting or luminaires installed outdoor which are rated 50 watts or less. Ornamental luminaires are post-top luminaires, lanterns, pendant luminaires, chandeliers, and marquee lighting, not providing general lighting or task lighting.

Proposal – Indoor Lighting Section

Section 130.0 (c) Luminaire Classification and Power

Proposed Language:

2. For luminaires with line voltage lamp holders not served by drivers, ballasts or transformers, the wattage shall be determined as the maximum rated wattage as labeled in accordance with Section 130.0(c)1.

Existing Code (2019):

2. For luminaires with line voltage lamp holders not containing permanently installed ballasts or transformers, the wattage of such luminaires shall be determined as follows:

A. The maximum rated wattage of the luminaire; and

B. For recessed luminaires with line-voltage medium screw base sockets, wattage shall not be less than 50 watts per socket, or the rated wattage of the installed JA8 compliant lamps.

Proposed Qualifying Tunable White and Dim-to-warm Luminaires

Changes to clarify and update the qualifying luminaires as tunable white and dim-to-warm luminaires; Section 140.6(a)4B

Qualifying luminaires shall have

- an aperture length longer than 18 inches, and a luminaire aperture no wider than 4 inches; or
- a luminaire aperture length of 18 inches or less shall be have a luminaire aperture no wider than 8 inches.

Section 140.6(a)4B	
Luminaire aperture length longer than 18 inches	and aperture width of 4 inches or less
OR Luminaire aperture length of 18 inches or shorter	and aperture width of 8 inches or less

Proposed a new Definition: Luminaire Aperture is the opening in the luminaire through which usable light exits.

For qualifying small aperture tunable-white and dim-to-warm LED luminaires, the adjusted indoor lighting power of these luminaires shall be calculated by multiplying their maximum rated wattage by ~~0.75~~ 0.80.

Indoor Lighting Power measure Model and Methodology

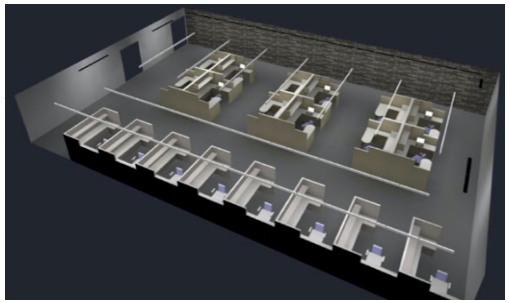
Lumen Model Inputs:

- Mapping out general, task, supplemental and wall washing lighting light level to the appropriate IES Recommended Practices and Handbook chapter/section. (Appendix J)
  - The light levels are the recommended light levels for the task. The mapping does not include ornamental and architectural lighting.
  - Assigned fraction for Task and supplemental lighting - a fraction which indicates the room illuminated to the illuminance value.
  - Assigned fraction for wall wash lighting – the fraction of the wall areas illuminated to the illuminance value
- Luminaire lumen output ranges of standard lumens, high lumens and low lumens. (Appendix I)
- Prototypical primary function area data: dimensions, room cavity ratio, and the ceiling, wall and floor reflectances (average). Appendix J)

Large Office Analysis with radiosity method using AGI32 software tool:

- Include scenarios where one wall is of low reflectance

Indoor Lighting Power measure Model and Methodology



Large Office Analysis:

AGI Model Open Office Summary (Table 132 of CASE Report)

Model	General Lighting Luminaires	Design Type	Wall Reflectance	General Lighting LPD	Display/ Decorative LPD	Portable/ Undercabinet Task LPD	Total LPD
Model A	Direct/Indirect Pendants	Task/ Ambient	All Medium	0.183	0.156	0.117	0.456
Model B	Recessed Basket Troffers	Task/ Ambient	All Medium	0.202	0.156	0.117	0.475
Model A1	Direct/Indirect Pendants	Task/ Ambient	One wall low	0.183	0.242	0.117	0.542
Model A2	Direct/Indirect Pendants	Monolithic	One wall low	0.484	0.253	0.000	0.737
Model B1	Recessed Basket Troffers	Task/ Ambient	One wall low	0.238	0.253	0.117	0.608
Model B2	Recessed Basket Troffers	Monolithic	One wall low	0.422	0.253	0.000	0.675

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional Allowance for Qualified Lighting Systems (W/ft²)**
Audience Seating Area	0.50 ~~0.60~~	Display/Decorative 0.25 ~~Ornamental 0.30~~
Auditorium Area	0.70	Display/Decorative 0.45 ~~Ornamental 0.30~~ ~~Accent, display and feature: 0.20~~
Barber, Beauty Salon, Spa Area	0.65 ~~0.80~~	Display/Decorative 0.25 ~~Ornamental 0.30~~ Detailed Task Work: 0.20
Civic Meeting Place Area	0.90 ~~1.00~~	Display/Decorative 0.25 ~~Ornamental 0.30~~
Classroom, Lecture, Training, Vocational Area	0.60 ~~0.70~~	White or Chalk Board: 7 ~~4.50~~ W/ft

Definition: (underlined indicates proposed changes)

Barber, Beauty Salon, Spa Area is a room or area in which the primary activity is manicures, pedicures, facials, ~~or~~ the cutting or styling of hair or massage and other spa activities

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional for Qualified Display/Decorative ~~Ornamental~~ Lighting (W/ft²)**
Concourse and Atria Area	0.60 ~~0.90~~	0.25 ~~0.30~~
Convention, Conference, Multipurpose and Meeting Area	0.75 ~~0.85~~	0.25 ~~0.30~~
Corridor Area	0.40 ~~0.60~~	0.25
Dining Area: Bar/Lounge and Fine Dining	0.45 ~~0.55~~	0.35 ~~0.30~~
Dining Area: Cafeteria/Fast Food	0.45 ~~0.40~~	0.25 ~~0.30~~
Dining Area: Family and Leisure	0.40 ~~0.50~~	0.25 ~~0.30~~
Financial Transaction Area	0.70 ~~0.80~~	0.25 ~~0.30~~
Hotel Function Area	0.85	0.25 ~~0.30~~

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C (continue) **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional for Qualified Display/ Decorative ~~Ornamental~~ Lighting (unless noted) (W/ft²)**
Laboratory, Scientific Area	0.90 ~~1.00~~	Specialized Task Work: 0.35
Library: Reading Area	0.80	0.25 ~~0.30~~
Library: Stacks Area	1.00 ~~1.10~~	nil
Lobby, Main Entry	0.70 ~~0.85~~	0.25 ~~0.30~~
Lounge, Breakroom, or Waiting Area	0.55 ~~0.65~~	0.25 ~~0.30~~

Definition: (underlined indicates proposed changes)
~~Scientific~~ Laboratory, Scientific Area is a room or area where research, experiments, and measurement in medical and physical sciences are performed requiring examination of fine details. The area may include workbenches, countertops, scientific instruments, and associated floor spaces. ~~Scientific laboratory~~ Laboratory does not refer to film, computer, and other laboratories where scientific experiments or physical measurements are not performed.

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C (continue) **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional Allowance for Qualified Lighting Systems (W/ft²)**
Museum Area: Exhibition/Display	0.60	Display/Decorative 0.45 ~~Accent/display and feature 0.50~~
Museum Area: Restoration Room	0.70 ~~0.75~~	Detailed Task Work 0.35 ~~0.20~~
Office Area ≤ 250 square feet	0.65 ~~0.70~~	Display/Decorative and Portable lighting for office areas: 0.20
Office Area > 250 square feet	0.60 ~~0.65~~	

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C (continue) **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional Allowance for Qualified Lighting Systems (W/ft²)**
Parking Garage Area: Parking Zone and Ramps	0.10	First ATM or Ticket Machine: 100W Additional ATM or Ticket Machine: 50W each
~~Parking Garage Area: Dedicated Ramps~~	~~0.25~~	nil
Parking Garage Area: Daylight Adaptation Zones	1.00 ~~0.50~~	~~nil~~

Definitions:

Parking Zone and Ramps in a Parking Garage is used for the purpose of parking and maneuvering of vehicles ~~on a single floor~~. Parking areas include sloping floors of a parking garage. Ramps are driveways specifically for the purpose of moving vehicles between floors of a parking garage. Parking areas and ramps do not include Daylight Transition Zones, ~~Dedicated Ramps,~~ or the roof of a Parking Garage, which may be present in a Parking Garage.

Daylight Adaptation Zone in a Parking Garage is the interior path of travel for vehicles ~~to enter a~~ adjacent to the entrance or exit of a parking garage ~~as needed to~~ where the transition ~~from~~ between exterior daylight levels ~~to~~ and interior light levels results in visual adaptation. Daylight ~~Transition~~ Adaptation Zones only include the path of vehicular travel and do not include adjacent Parking Areas.

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C (continue) **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional Allowance for Qualified Lighting Systems (W/ft²)**
Pharmacy Area	1.00 ~~1.10~~	Specialized Task Work: 0.35
Retail Sales Area: Grocery Sales	1.00 ~~1.05~~	Display/Decorative 0.35 ~~0.15~~ ~~Accent, display and feature: 0.20~~
Retail Sales Area: Retail Merchandise Sales	0.95 ~~1.00~~	
Retail Sales Area: Fitting Room	0.60	External Illuminated Mirror: 40W/ea Internal Illuminated Mirror: 120W/ea

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C (continue) **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional Allowance for Decorative ~~Ornamental~~ Lighting (W/ft²)**
Religious Worship Area	0.-95	Display/Decorative 0.25 ~~0.30~~
Restrooms	0.65	Display/Decorative 0.35 ~~0.15~~ ~~Accent, display and feature: 0.20~~
Stairwell	0.60~~0.5~~	Display/Decorative 0.35 ~~0.15~~ ~~Accent, display and feature: 0.20~~
Storage, Commercial/Industrial: Warehouse	0.40 ~~0.45~~	nil
Storage, Commercial/Industrial: Shipping & Handling	0.60	nil

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C (continue) **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional Allowance for Qualified Lighting Systems (W/ft²)**
Theater Area: Motion picture	0.50 ~~0.60~~	Display/Decorative 0.25 ~~Ornamental 0.30~~
Theater Area: Performance	0.80 ~~1.00~~	Display/Decorative 0.25 ~~Ornamental 0.30~~
Transportation Function: Ticketing Area	0.45	Display/Decorative ~~Accent and feature~~ 0.20

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C (continue) **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional Allowance for Qualified Lighting Systems (W/ft²)**
Aging Eye/Low-vision: Corridor Area	0.70 ~~0.80~~	Display/Decorative 0.30 ~~0.15~~
Aging Eye/Low-vision: Dining	0.80	Display/Decorative 0.30 Tunable white, or dim-to-warm: 0.10
Aging Eye/Low-vision: Lounge/Waiting Area	0.80 ~~0.75~~	Display/Decorative 0.30 Tunable white, or dim-to-warm: 0.10
Aging Eye/Low-vision: Lobby, Main Entry	0.85	Display/Decorative 0.30 Tunable white, or dim-to-warm: 0.10 Transition Lighting OFF at night: 0.95

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C (continue) **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional Allowance for Qualified Lighting Systems (W/ft²)**
Aging Eye/Low-vision: Multipurpose Room	0.85 ~~0.95~~	Display/Decorative 0.30 Tunable white, or dim-to-warm: 0.10
Aging Eye/Low-vision: Religious Worship Area	1.00	Display/Decorative 0.30 Tunable white, or dim-to-warm: 0.10
Aging Eye/Low-vision: Restroom	1.00 ~~0.80~~	Display/Decorative ~~Accent and feature~~ 0.20
Aging Eye/Low-vision: Stairwell	0.80	Display/Decorative 0.30

Indoor Lighting Power Densities (LPD) - Area Category Method

Table 140.6-C (continue) **Primary Function Area**	**LPD for General Lighting (W/ft²)**	**Additional Allowance for Qualified Lighting Systems (W/ft²)**
Healthcare Facility and Hospitals ("Healthcare"): Exam/Treatment Room	1.15	nil
Healthcare: Imaging Room	0.60 ~~1.00~~	Display/Decorative 0.20 Tunable white, or dim-to-warm: 0.10
Healthcare: Nursery	0.80 ~~0.95~~	Tunable white, or dim-to-warm: 0.10
Healthcare: Nurse's Station	0.85 ~~0.75~~	Detailed Task Work: 0.20 Tunable white, or dim-to-warm: 0.10
Healthcare: Patient Room	0.70 ~~0.55~~	Display/Decorative 0.15 Tunable white, or dim-to-warm: 0.10
Healthcare: Physical Therapy Room	0.75 ~~0.85~~	Tunable white, or dim-to-warm: 0.10

Lighting Power Allowances for Tailored Method

Tailored Method Lighting Power Allowances

Summary of proposed changes to Tailored Method in Section 140.6:

- Proposed LPD values based on 90+ CRI LED luminaires in all existing allowed Tailored Method lighting applications.
- Changes to all tailored method general lighting LPD's, display lighting LPD's including floor display and wall display lighting – in Table 140.6-D and 140.6-G.
- Changes to lighting terms for additional lighting power allowances in Section 140.6(a)3E and 3J: decorative/~~ornamental~~/special effect lighting
- Changes to Very Valuable Display Case Lighting Allowance in Section 140.6(a)3J:
  - Area of the primary function - 0.50 ~~0.55~~ watt/ft^2
  - Area of the display case - 7 ~~8~~ watt/ft^2

Tailored Method Lighting Power Allowances

Table 140.6-D Primary Function Area	General Illumination Level (Lux)	Wall Display LPD (W/ft)	Allowed Combined Floor Display Power and Task LPD (W/ft²)	Allowed <u>Decorative/</u> ~~Ornamental,~~ Special Effect LPD (W/ft²)
Auditorium Area	300	3.00	0.20	0.35 ~~0.40~~
Convention, Conference, Multipurpose, and Meeting Center Areas	300	2.00	<u>0.30</u> ~~0.35~~	<u>0.35</u> ~~0.40~~
Dining Areas	200	1.25	<u>0.45</u> ~~0.50~~	0.35 ~~0.40~~
Exhibit, Museum Areas	150	<u>11.20</u> ~~11.50~~	<u>0.70</u> ~~0.80~~	0.35 ~~0.40~~
Hotel Area:				
Ballroom/Events	400	1.80	0.12	0.35 ~~0.40~~
Lobby	200	~~3.50~~ <u>3.40</u>	0.20	0.35 ~~0.40~~

Tailored Method Lighting Power Allowances

Table 140.6-D Primary Function Area	General Illumination Level (Lux)	Wall Display LPD (W/ft)	Allowed Combined Floor Display Power and Task LPD (W/ft²)	Allowed Decorative/ ~~Ornamental,~~ Special Effect LPD (W/ft²)
~~Main Entry~~ Lobby, Main Entry	200	3.40 ~~3.50~~	0.20	0.35 ~~0.40~~
Religious Worship Area	300	1.30	0.40	0.35 ~~0.40~~
Retail Sales:				
Grocery	600	6.60 ~~6.80~~	0.60 ~~0.70~~	0.35 ~~0.40~~
Merchandise Sales, and Showroom Areas	500	11.50 ~~11.80~~	0.70 ~~0.80~~	0.35 ~~0.40~~
Theater Area:				
Motion picture	200	2.00	0.20	0.35 ~~0.40~~
Performance Arts	200	7.30 ~~7.50~~	0.20	0.35 ~~0.40~~

Tailored Method Lighting Power Allowances

Table 140.6-G **Tailored Method by Illuminance and Room Cavity Ratio (RCR)**	**General Lighting Power Density (W/ft^2) for the following RCR values**			
General Illuminance Level (lux)	RCR ≤ 2.0	RCR > 2.0 and ≤ 3.5	RCR > 3.5 and ≤ 7.0	RCR > 7.0
150	~~0.40~~ 0.35	~~0.45~~ 0.40	~~0.60~~ 0.50	~~00.75~~ 0.65
200	~~0.45~~ 0.40	~~0.55~~ 0.50	~~0.75~~ 0.65	~~1.00~~ 0.85
300	~~0.65~~ 0.55	~~0.80~~ 0.70	~~1.00~~ 0.85	~~1.40~~ 1.20
400	~~0.75~~ 0.65	~~0.95~~ 0.80	~~1.25~~ 1.05	~~1.50~~ 1.25
500	~~0.90~~ 0.80	~~1.05~~ 0.90	~~1.45~~ 1.25	~~1.85~~ 1.55
600	~~1.08~~ 0.90	~~1.24~~ 1.05	~~1.64~~ 1.40	~~2.38~~ 2.00

Incremental First Cost

Luminaire Cost, Efficacy, CRI

- Collected three to eight manufacturer's products from multiple distributors for each luminaire type.
- Luminaire types include area lighting luminaires and wall washers; both contractor grade and specification grade were collected where possible; 70/80CRI and high CRI models.
- Luminaire product information of average lumen, average wattage, average efficacy (simple average), and cost were compiled.
- Differences in unit cost between the 2020 surveyed products and the 2019 products; new entries of luminaire models and types in surveyed 2020.

Luminaire Types Surveyed	
Wall Washing Luminaires:	Area Lighting Luminaires:
Forward throw; Aperture Linear wall-washer and wall-grazer; High CRI Forward throw; High CRI linear; High CRI aperture; High CRI wall-grazer	Cove Light; Downlight (open; lensed; flood); Low bay; Pendant direct/indirect; Parking garage luminaires; Linear light slot; Strip undercabinet; Troffer basket; Industrial strip

Measure Cost-Effectiveness

Estimated 15-Year Cost-Effectiveness Per Prototype Spaces

Primary Function Area	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Hotel Function Area	$1,618	$229	$229	$1,618	0.14
Auditorium Area	$7,118	$1,909	$1,909	$7,118	0.27
Pharmacy Area	$625	$387	$387	$625	0.62
Barber, Beauty Salon and Spa Area	$1,969	$2,321	$2,321	$1,969	1.18
Civic Meeting Place Area	$403	$687	$687	$403	1.7

Measure Cost-Effectiveness

Estimated 15-Year Cost-Effectiveness Per Prototype Spaces

Primary Function Area	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Storage, Commercial/Industrial: Warehouse	$31	$144	$144	$31	4.66
Healthcare Facility and Hospitals: Nursery	$80	$770	$770	$80	9.64
Dining Area: Bar/Lounge and Fine Dining	$4,409	$3,267	$3,267	$4409	0.74

Measure Cost-Effectiveness

Estimated 15-Year Cost-Effectiveness Per Prototype Spaces

Primary Function Area	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Audience Seating Area	($1,310)	$4,073	$5,383	$0	Note 1
Classroom, Lecture, Training, Vocational Area	($2,694)	$326	$3,020	$0	Note 1
Concourse and Atria Area	($39,863)	$33,849	$73,712	$0	Note 1
Convention, Conference, Multipurpose and Meeting Area	($5,824)	$1,146	$6,969	$0	Note 1

Note 1. These areas are estimated to have energy cost savings in the measure prototype modeling. With usage of more effective lighting in the measure modeling, there is no incremental cost – the result of negative incremental cost.

Measure Cost-Effectiveness

Estimated 15-Year Cost-Effectiveness Per Prototype Spaces

Primary Function Area	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Dining Area: Family and Leisure	($4,622)	$4,356	$8,977	$0	Note 1
Financial Transaction Area	($3,611)	$560	$4,171	$0	Note 1
Scientific Laboratory Area	($7,369)	$589	$7,958	$0	Note 1
Library : Reading Area	($2,118)	$187	$2,304	$0	Note 1
Library : Stacks Area	($1,665)	$187	$1,852	$0	Note 1
Main Entry Lobby	($1,198)	$3,055	$4,253	$0	Note 1
Lounge, Breakroom, or Waiting Area	($227)	$611	$838	$0	Note 1

Measure Cost-Effectiveness

Estimated 15-Year Cost-Effectiveness Per Prototype Spaces

Primary Function Area	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Office Area > 250 sf	($1,167)	$156	$1,323	$0	Note 1
Office Area: ≤ 250 square feet	($94)	$36	$130	$0	Note 1
Parking Garage Area: Dedicated Ramps	($1,206)	$4,853	$6,060	$0	Note 1
Retail Sales Area: Grocery Sales	($50,972)	$1,934	$52,906	$0	Note 1
Retail Sales Area: Retail Merchandise Sales	($13,296)	$1,934	$15,230	$0	Note 1
Religious Worship Area	($19,777)	$3,394	$23,171	$0	Note 1

Measure Cost-Effectiveness

Estimated 15-Year Cost-Effectiveness Per Prototype Spaces

Primary Function Area	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Theater Area: Motion picture	($3,036)	$1,986	$5,022	$0	Note 1
Theater Area: Performance	($29,904)	$33,943	$63,847	$0	Note 1
Aging Eye/Low-vision: Multipurpose Room	($1,631)	$821	$2,452	$0	Note 1
Healthcare Facility and Hospitals: Imaging Room	($732)	$144	$876	$0	Note 1
Healthcare Facility and Hospitals: Physical Therapy Room	($1,208)	$770	$1,978	$0	Note 1

Measure Cost-Effectiveness

Estimated 15-Year Cost-Effectiveness Per Prototype Spaces

Primary Function Area	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Museum Area: Restoration Room	$4,078	($2,037)	$0	$6,115	Note 2
Parking Garage Area: Daylight Adaptation Zones	$2,800	($16,684)	$0	$19,484	Note 2
Aging Eye/Low-vision: Restroom	$161	($224)	$0	$386	Note 2
Healthcare Facility and Hospitals: Nurse's Station	$1,739	($385)	$0	$2,124	Note 2
Healthcare Facility and Hospitals: Patient Room	$304	($185)	$0	$489	Note 2

Note 2. Due to the proposed increase of lighting power density (LPD) to the function area, the area is expected to entail an increase of energy and energy cost - a negative energy cost savings.

Measure Cost-Effectiveness

Estimated 15-Year Cost-Effectiveness Per Prototype Spaces

Primary Function Area	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Corridor Area	($3,392)	($166)	$3,392	$166	Note 2
Stairwell	($5,304)	($187)	$5,304	$187	Note 2
Aging Eye/Low-vision: Lounge/Waiting Area	($1,505)	($410)	$1,505	$410	Note 2
Aging Eye/Low-vision: Stairwell	($1,396)	($166)	$1,396	$166	Note 2
Aging Eye/Low-vision: Corridor Area	($1,468)	($166)	$1,468	$166	Note 2

Benefits for Implementation

Statewide Energy and Energy Cost Impacts

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	15-Year Present Valued Energy Cost Savings (PV$ million in 2023)
New Construction	25.0	20.2	$60.2
Additions and Alterations	76.9	6.2	$185.7
TOTAL	101.9	26.4	$246

Greenhouse Gas (GHG) Emissions Reduction

First-Year Statewide GHG Emissions Impacts

Construction Type	Electricity Savings (GWh/yr)	Reduced GHG Emissions from Electricity Savings (Metric Tons CO2e)
New Construction	25.0	5,999
Additions and Alterations	76.9	18,497
Statewide Total	101.9	24,496

Preliminary Findings

Technical Feasibility

- The survey conducted in the CASE effort indicates effective lighting are available in marketplace for meeting the proposed requirements.

Energy Savings & Cost Effectiveness

- Overall there are expected energy savings and energy cost savings.
- A number of function areas are proposed with decrease in the lighting power density (LPD) values, some are proposed with increase in LPD's, and the rest are proposed with the same LPD's as of the 2019 Code.

Comments for Today's Workshop

Due Date: October 21, 2020 By 5:00 PM

Comments to be submitted to:
https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-03

Contact Information

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Thank You!

Nonresidential Air Distribution Proposals for 2022

Staff Pre-Rulemaking Workshop

Presenter: Ronald Balneg, Mechanical Engineer

Date: October 7, 2020

Proposal Summary

Staff received proposals for submeasures pertaining to Nonresidential, High-Rise Residential, Hotel/Motel Occupancies, and Covered Processes.

- 2022 Code Update
  - Fan Power Budget
  - Fan Energy Index
  - Duct Leakage
  - Healthcare Facilities subject to proposed requirements

2022 Code Update Sections Affected

Building Energy Efficiency Standards for Residential and Nonresidential Buildings:

- Section 110.1 (b)
- Section 120.4(b) & (g)
- Section 120.5(a)
- Section 120.10 – New Section
- Section 140.4(c) & (l)
- Section 141.0(b)

Reference Appendices:

- NA1
- NA2
- NA7
- NA9

Definitions

Definitions

Air Curtain Unit means equipment providing a directionally-controlled stream of air moving across the entire height and width of an opening that reduces the infiltration or transfer of air from one side of the opening.
AHRI 430 *(draft/ in-progress)* is the Air-conditioning, Heating and Refrigeration Institute document titled "Performance Rating of Central Station Air-handling Unit Supply Fans". (AHRI 430-20)
AHRI 440 is the Air-conditioning, Heating and Refrigeration Institute document titled "Performance Rating of Fan-coil Units". (AHRI 440-19)
AMCA is the Air Movement and Controls Association.
ANSI/AMCA 208 is the is the American National Standards Institute / Air Movement and Control Association document titled "Calculation of the Fan Energy Index". (ANSI/AMCA 208-18)
ANSI/AMCA 210 is the is the American National Standards Institute / Air Movement and Control Association document titled "Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating". (ANSI/AMCA 210-16)
ANSI/ASHRAE 84 is the is the American National Standards Institute / American Society of Heating, Refrigeration, and Air-conditioning Engineers document titled "Method of Testing Air-to-Air Heat/Energy Exchanger". (ANSI/ASHRAE 84-2020)

Definitions (Cont.)

Ceiling Fan means a nonportable device that is suspended from a ceiling or overhead structure for circulating air via the rotation of fan blades as defined in 10 CFR 430.2.

Circulating Fan means a fan that is not a ceiling fan that is used to move air within a space that has no provision for connection to ducting or separation of the fan inlet from its outlet, designed to be used for the general circulation of air.

Duct wall penetrations are openings to the duct wall made by pipes, holes, conduit, tie rods, or wires.

Fan arrays are multiple fans in parallel and in a single enclosure between two plenum sections in an air distribution system, where plenum means a compartment or chamber that forms a part of the air distribution system, and that is not used for occupancy or storage.

Fan, embedded is a fan that is part of a manufactured assembly where the assembly includes functions other than air movement.

Fan energy index (FEI) is the ratio of the electric input power of a reference fan to the electric input power of the actual fan as calculated per ANSI/AMCA 208-18 at fan system design conditions.

Fan electrical input power (Fan kWdesign) is the electrical input power in kilowatts required to operate an individual fan or fan array at design conditions. It includes the power consumption of motor controllers, if present.

Fan nameplate electrical input power (kW) is the nominal electrical input power rating stamped on a fan assembly nameplate.

Definitions (Cont.)

Fan system includes all the fans that contribute to the movement of air through a point of a common duct, plenum, or cabinet.

Fan system, complex means a fan system that combines a single-cabinet fan system with other supply fans, exhaust fans, or both.

Fan system, exhaust is a fan system dedicated to the removal of air from interior spaces to the outdoors that may operate at times other than economizer operation.

Fan system, relief is a fan system dedicated to the removal of air from interior spaces to the outdoors that operates only during economizer operation.

Fan system, return is a fan system dedicated to removing air from interior where some or all the air is to be recirculated except during economizer operation, when all of the air is exhausted.

Fan system, supply-only is a fan system that exclusively provides air to interior spaces and where any recirculated air is returned by a return fan system.

Fan system, single-cabinet is a fan system where a single fan, single fan array, a single set of fans operating in parallel, or fans or fan arrays in series and embedded in the same cabinet that both supply air to a space and recirculate the air.

Fan system, transfer is a fan system that exclusively moves air from one occupied space to another.

Definitions (Cont.)

Fan system airflow (cfm) is the sum of the airflow of all fans at fan system design conditions with fan input power greater than 1 kW, excluding the airflow that passes through downstream fans with fan input power less than 1 kW.

Fan system design conditions are operating conditions that can be expected to occur during normal system operation that result in the highest supply airflow rate to or from the conditioned spaces served by the fan system.

Fan system electrical input power (Fan kWdesign, system) the sum of the fan electrical input power (Fan kWdesign) in kilowatts of all fans that are required to operate at fan system design conditions to supply air from the heating or cooling source to the conditioned spaces, return it to the source, exhaust it to the outdoors, or transfer it to another space.

ISO 5801 is the International Standards Organization document titled “Fans- Performance testing using standardized airways”. (ISO 5801:2017)

Seal Class A is a ductwork sealing category that requires sealing all transverse joints, longitudinal seams, and duct wall penetrations. Duct wall penetrations are openings made by pipes, conduit, tie rods, or wires. Longitudinal seams are joints oriented in the direction of airflow. Transverse joints are connections of two duct sections oriented perpendicular to airflow. Openings for rotating shafts shall be sealed with bushings or other devices that seal off air leakage. All connections shall be sealed, including but not limited to spin-ins, taps, other branch connections, access doors, access panels, and duct connections to equipment. Sealing that would void product listings is not required. All duct pressure class ratings shall be designated in the design documents.

Fan Power Budget

Fan Power Budget

New Prescriptive Requirements for Space Conditioning Systems

- Multizone Variable Air Volume (VAV) Classification
- Fan Systems ≥ 1 kW
- Addition of fan power allowances categories
  - Supply and Return tables
- Portions of fan system airflow through components will be adjusted
- Four methods of determining Input Power for Fan Power Budget Calculation
- Air Density Correction Added for elevations ≥ 3,000 ft
- Applies to healthcare facilities
- Additions and Alterations are subject to new Fan Power Allowances, but include additional allowances

Multizone Variable Air Volume Fan System

- Multizone VAV Fan System:
  - Must serve 3 or more conditioned spaces individually controlled based on heating, cooling, or ventilation
  - Sum of minimum airflows be 40% or less of the fan system design conditions
  - Fan meets Section140.4(m)

Calculation of Fan Power Budget

Determining Fan Power Budget

- Multiply the sum of the design system airflow to Fan Power Allowances in Tables 140.4A and 140.4B depending on the fan system type:
  - Single Cabinet
  - Supply-only
  - Relief
  - Exhaust
  - Complex Fan Systems (Single Cabinet combined with Supply and/or Exhaust)

Calculation of Fan System Input Power

- Determine Fan Input Power with mid-life filter pressure drop:
    1. Use default table 140.4-C (Complex fans are excluded), or
    2. Fan input power provided by the manufacturer at design conditions, or
    3. Shaft input power provided by the manufacturer at design conditions, or
    4. Maximum electric input power from system nameplate.

- The Fan System Input Power shall not exceed the Fan System Budget

Energy Savings Methodology

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
OfficeLarge	All	Total Static Pressure	5.362	4.267
OfficeLarge	All	Fan Total Efficiency	65%	65%
OfficeLarge	All	Motor Efficiency	94.1%	94.1%

- Multiple ways of complying with Fan Power Budget
- Approach uses better duct design and component selections to comply with proposal
- Allows a conservative approach to show all energy savings can be achieved through lowering static pressure

Prototype Buildings Modeled

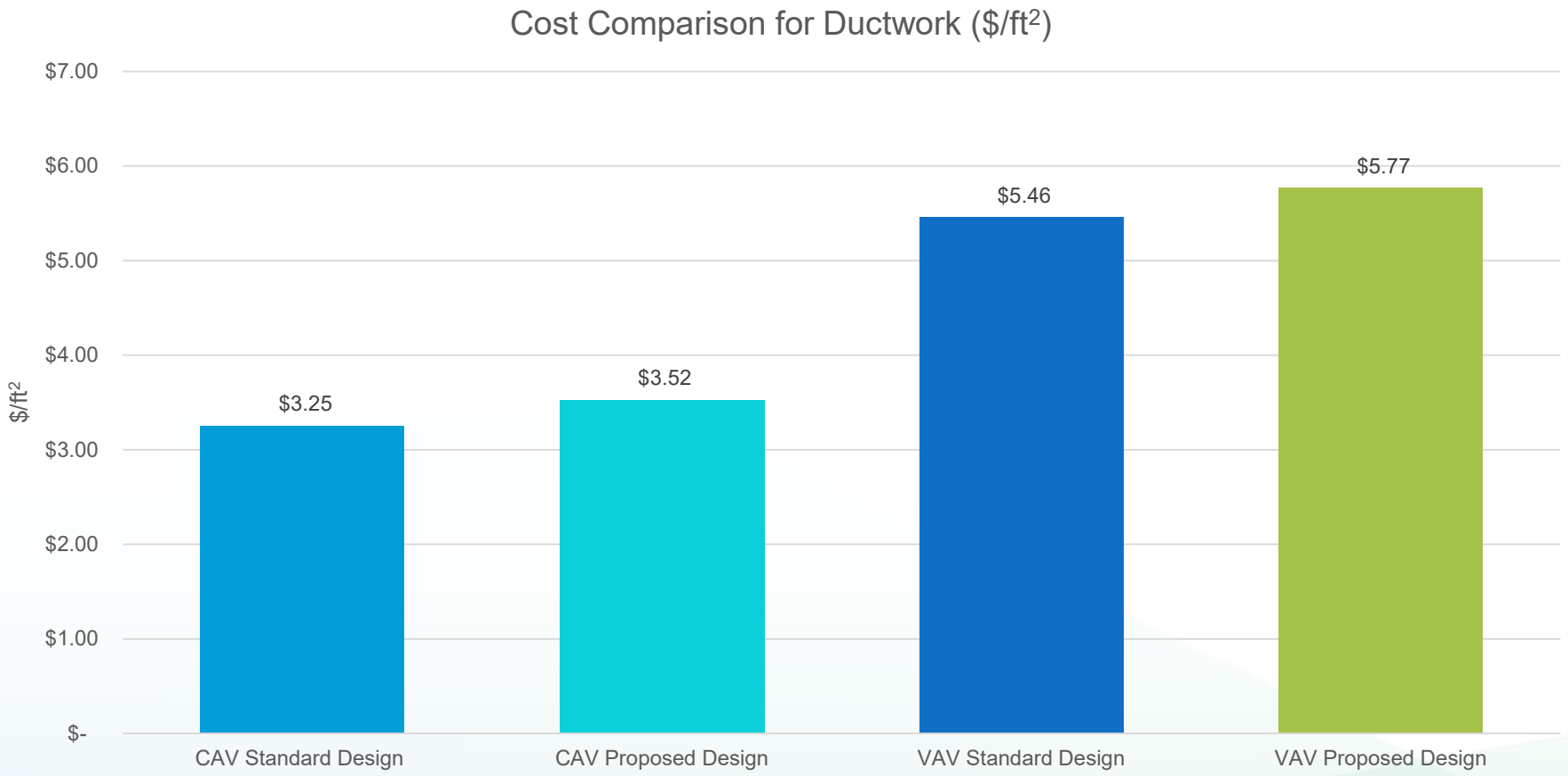
Prototype Name	Number of Stories	Floor Area (square feet)	Description
HotelSmall	4	42,554	4 story Hotel with 77 guest rooms. Window/wall ratio (WWR) - 11%
OfficeLarge	13	498,589	12 story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR - 40%
OfficeMedium	3	53,628	3 story office building with 5 zones and a ceiling plenum on each floor. WWR - 33%
OfficeMediumLab	3	53,628	3 story office building with 5 zones and a ceiling plenum on each floor. WWR- 33%
RetailLarge	1	240,000	Big-box type Retail building with WWR -12% and SRR- 0.82%
RetailMixedUse	1	9,375	Retail building with WWR -10%. Roof is adiabatic
RetailStandAlone	1	24,563	Similar to a Target or Walgreens.7% WWR on the front façade, none on other sides. SRR of 2.1%.
RetailStripMall	1	9,375	Strip Mall building with WWR -10%
SchoolPrimary	1	24,413	Elementary school with WWR of 36%
SchoolSecondary	2	210,866	High school with WWR of 35% and SRR 1.4%
Warehouse	1	49,495	Single story high ceiling warehouse. Includes one office space. WWR- 0.7%, SRR-5%

Fan Power Budget Energy Savings

Energy Savings Summary Per Year

Climate Zone	Electricity Savings (kWh/ft^2)	Peak Electricity Demand Reductions (W/ft^2)	Natural Gas Savings ($therms/ft^2$)	TDV Energy Savings (TDV $kBtu/ft^2$)
1	3.519	0.881	-0.092	72.972
2	4.23	1.392	-0.057	106.029
3	3.986	1.205	-0.045	101.666
4	4.425	1.321	-0.037	118.606
5	4.065	1.104	-0.044	100.903
6	4.938	1.397	-0.017	129.889
7	4.713	1.278	-0.016	130.532
8	4.977	1.155	-0.02	137.635
9	4.945	1.541	-0.022	136.327
10	4.299	1.412	-0.022	118.953
11	4.675	1.773	-0.047	129.847
12	4.543	1.421	-0.046	118.764
13	4.984	1.614	-0.04	135.117
14	5.187	1.76	-0.041	149.756
15	5.885	1.551	-0.013	161.277
16	4.483	1.52	-0.084	98.262
Total	73.854	22.325	-0.643	1946.535

Incremental Cost



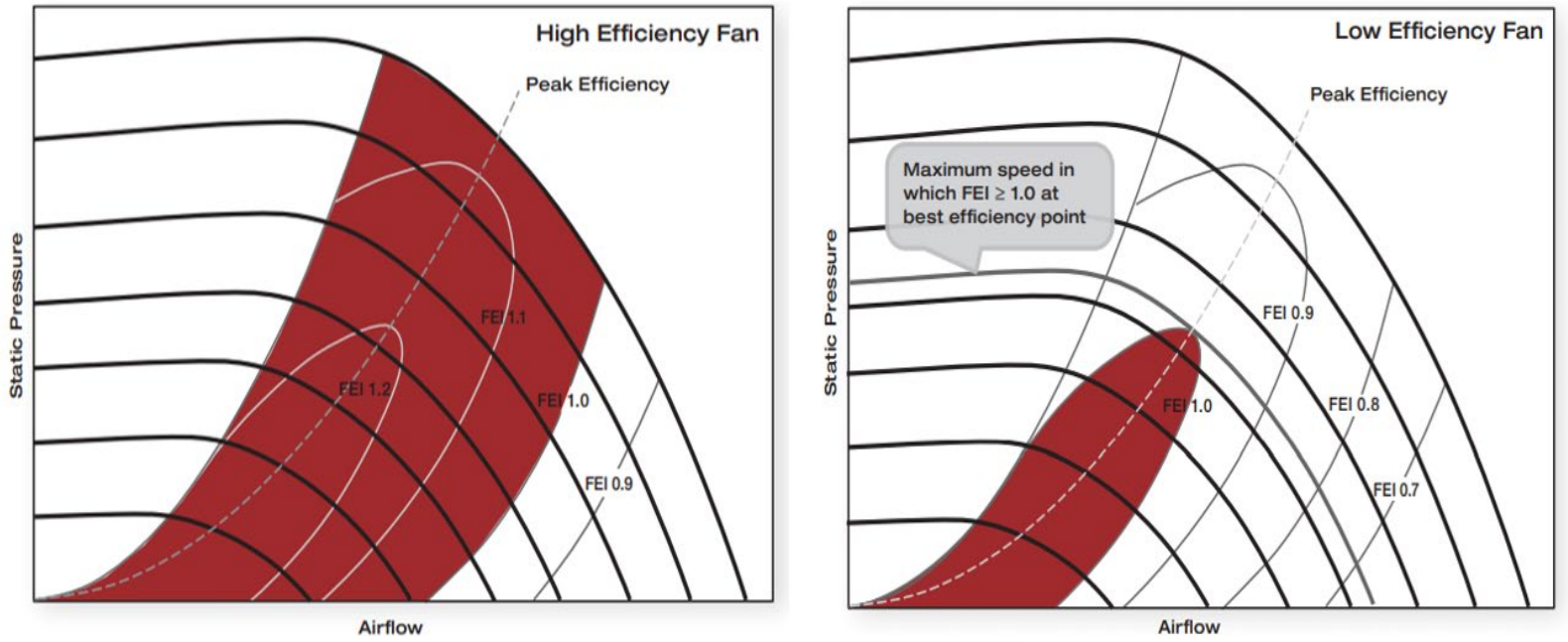
Cost Effectiveness

Climate Zone	Hotel Small	Office Large	Office Medium	Office Medium Lab	Retail Large	Retail Mixed Use	Retail Stand Alone	Retail Strip Mall	School Primary	School Secondary	Warehouse
1	0.80	0.98	0.70	2.64	0.83	6.24	1.54	5.66	3.99	0.62	0.39
2	1.73	1.38	1.30	3.83	1.65	7.20	2.92	7.94	6.12	1.12	1.08
3	1.40	1.31	1.08	3.83	1.84	7.43	2.07	7.53	6.02	1.00	1.44
4	2.12	1.48	1.49	4.52	3.65	7.62	3.46	7.69	6.15	1.28	0.92
5	1.37	1.29	1.03	3.70	2.04	7.42	2.14	7.83	5.42	1.02	1.14
6	2.27	1.61	1.57	5.00	2.55	8.09	3.36	10.14	7.10	1.38	2.24
7	2.04	1.52	1.36	4.95	4.15	8.06	3.29	9.36	7.04	1.29	1.53
8	2.46	1.65	1.80	5.11	3.82	7.94	4.63	9.81	6.96	1.47	1.66
9	2.56	1.64	1.87	4.99	3.24	8.00	4.94	9.41	7.06	1.52	2.63
10	2.54	1.65	1.86	4.95	4.36	7.75	5.47	3.34	6.52	1.49	2.39
11	2.06	1.44	1.63	4.97	4.48	8.18	2.83	8.79	6.93	1.32	2.80
12	1.95	1.41	1.49	4.56	3.92	7.34	2.55	8.43	6.34	1.24	1.77
13	2.28	1.52	1.79	5.33	4.08	8.16	4.05	8.63	7.21	1.46	2.65
14	2.47	1.70	2.02	5.43	6.80	7.83	4.26	9.57	7.41	1.60	4.81
15	3.05	1.79	2.29	5.75	6.37	9.06	3.48	11.12	8.24	1.92	5.17
16	1.38	1.45	1.21	3.84	1.80	5.99	3.03	7.23	5.32	1.27	1.39

Questions??

Fan Energy Index

Fan Energy Index



- Scope is similar to ASHRAE 90.1 -2019
- Encourage designers to select fans closer to peak efficiency
- Higher FEI, less power is consumed at a given duty point (airflow and pressure)
- Apply to a broader scope of fans, including those that move unconditioned air

Fan Energy Index

New Mandatory Requirements

- Each fan or fan array with a combined motor nameplate > 1.0 hp or with combined fan nameplate electrical input power > 0.89 kW shall have a Fan Energy Index (FEI) > 1.00 at design conditions.
- Fan arrays shall calculated in accordance with ANSI/AMCA 208-18 Annex C.
- All FEI values shall be provided by the manufacturer and third party verified.

Fan Energy Index - Exceptions

Exceptions

- FEI values for embedded fans do not need to be third party verified.
- FEI not required for:
  - Embedded fans that are part of equipment listed under Section 110.2, Section 110.1, or equipment that has an efficiency standard under 10 CFR 431 that takes effect prior to January 1, 2026.
  - Embedded fans and fan arrays with a combined motor nameplate horsepower of 5 hp or less or with a fan system electrical input power of 4.1 kW or less.
  - Circulation fans, ceiling fans and air curtains.
  - Fans that are intended to only operate during emergency conditions.

Energy Savings Methodology

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
OfficeLarge	All	Total Static Pressure (Supply)	3.6	3.6
OfficeLarge	All	Fan Total Efficiency (Supply)	66%	66%
OfficeLarge	All	Motor Efficiency (Supply)	93.6%	93.6%
OfficeLarge	All	FEI- Supply fan (Reference Only)	1.23	1.23
OfficeLarge	All	Total Static Pressure (Return)	1	1
OfficeLarge	All	Fan Total Efficiency (Return)	37%	42.5%
OfficeLarge	All	Motor Efficiency (Return)	92.4%	92.4%
OfficeLarge	All	FEI- Return Fan (Reference Only)	0.88	1.00

- Standard Design of 1 fan system split into 2 fan system with the same overall efficiency

Energy Savings

Yearly Energy Impacts Per Square Foot – Large Office

Climate Zone	Electricity Savings (kWh/ft^2)	Peak Electricity Demand Reductions (W/ft^2)	Natural Gas Savings ($therms/ft^2$)	TDV Energy Savings ($TDV\ kBtu/ft^2$)
1	0.022	0.002	0.000	0.486
2	0.027	0.003	0.000	0.693
3	0.026	0.003	0.000	0.651
4	0.028	0.003	0.000	0.714
5	0.027	0.003	0.000	0.629
6	0.031	0.003	0.000	0.813
7	0.029	0.002	0.000	0.723
8	0.031	0.004	0.000	0.868
9	0.029	0.002	0.000	0.841
10	0.031	0.002	0.000	0.864
11	0.029	0.001	0.000	0.726
12	0.028	0.003	0.000	0.713
13	0.029	0.003	0.000	0.782
14	0.033	0.003	0.000	0.921
15	0.034	0.003	0.000	0.925
16	0.032	0.004	0.000	0.746

Incremental Cost

	Cost	FEI
Standard	$12,181	0.84
Proposed	$13,189	0.99
Incremental Cost	$1,008	

- Large Office Fans
- Greenheck's eCAPS online software

FEI - Cost Effectiveness

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$0.04	$0.026	1.64
2	$0.06	$0.026	2.35
3	$0.06	$0.026	2.20
4	$0.06	$0.026	2.42
5	$0.06	$0.026	2.13
6	$0.07	$0.026	2.75
7	$0.06	$0.026	2.45
8	$0.08	$0.026	2.94
9	$0.07	$0.026	2.85
10	$0.08	$0.026	2.93
11	$0.06	$0.026	2.46
12	$0.06	$0.026	2.41
13	$0.07	$0.026	2.65
14	$0.08	$0.026	3.12
15	$0.08	$0.026	3.13
16	$0.07	$0.026	2.52

Questions??

Duct Leakage and Testing

Duct Leakage and Testing

Section 120.4(b) Duct and Plenum Materials

- All ductwork to meet Seal Class A to align with ASHRAE 90.1

Section 120.4(g) – Air Distribution System Duct Leakage Sealing

- Existing prescriptive Section 140.4(l) will move to this mandatory section.
- Addition of requirements for multifamily duct leakage sealing (presented in an alternate proposal)
- Addition of requirements for all other duct systems to meet CMC Section 603.10.1

Section 120.5(a) – Required Nonresidential Mechanical System Acceptance

- Reference updates

Section 140.4(l) – Air Distribution System Duct Leakage Sealing

- This section will be moved into 120.4(g)

Section 141.0(b)2D – Altered Duct Systems

- Reference updates to meet new leakage requirements

Duct Leakage and Testing

NA7 / CMC 603.10.1

- Leak tested by Testing, Adjusting, and Balance technician, or certified Duct Air Leakage technician.
- Representative sections of ductwork of at least 10% of total installed duct shall be tested.

Energy Savings Methodology

- Baseline Seal Class B for supply air systems.
- Baseline Seal Class C for exhaust air systems.
- Savings are from reduced fan energy, slightly reduced heating and cooling.
- Slight heating penalty from less air movement lowering the fan motor heat.
- No savings are assumed from duct leakage testing. Goal of duct leakage testing is to improve compliance with code referencing the CMC.

Energy Savings

Annual Energy Impacts Per Square Foot – Duct Leakage - OfficeLarge

Climate Zone	Electricity Savings (kWh/ft^2)	Peak Electricity Demand Reductions (W/ft^2)	Natural Gas Savings ($therms/ft^2$)	TDV Energy Savings ($TDV\ kBtu/ft^2$)
1	0.124	0.013	(0.002)	2.954
2	0.153	0.015	0.001	4.610
3	0.159	0.056	0.002	5.098
4	0.163	0.013	0.002	5.142
5	0.149	0.009	0.001	4.334
6	0.169	(0.058)	0.002	5.314
7	0.163	0.005	0.002	4.969
8	0.170	0.006	0.002	5.201
9	0.169	0.018	0.003	5.279
10	0.160	0.009	0.001	4.574
11	0.165	0.015	0.002	5.304
12	0.163	0.014	0.002	5.113
13	0.161	0.013	0.002	5.157
14	0.171	0.013	0.002	5.155
15	0.181	0.009	0.003	5.792
16	0.171	0.016	0.000	4.900

Incremental Cost – Duct Testing

Building Prototype	Number of downstream supply-air zones tested	Number of exhaust-air systems tested	Testing hours	Transportation hours	Incremental testing cost
OfficeLarge	9	2	16.5	6	$1956.15
OfficeMedium	3	1	6	2	$695.52
OfficeMedium Lab	3	1	6	2	$695.52

- Duct leakage incremental costs assumed Testing and Balance already being performed
- $86.94 hourly rate

Incremental Cost – Seal Class A

	Total Cost (Large Office)	Airflow (CFM)	Building Gross Area (ft^2)	Normalized Cost ($/CFM)	Normalized Cost ($/$ft^2$)
VAV Proposed Design Cost	$221,400	18,375	38,371	$12.05	$5.77
Incremental Cost from Seal Class B to Seal Class A (supply)	$2,768	18,375	38,371	$0.15	$0.07
Incremental Cost from Seal Class C to Seal Class A (exhaust, 1000 cfm)	$300	1000	38,371	$0.30	$0.14

- 1.25% more for VAV from Seal Class B to A
- 2.3% more for exhaust from Seal Class C to A

Cost Benefit

15-Year Cost-Effectiveness Summary Per Square Foot – New Construction/ Additions/Alterations – Duct Leakage – OfficeLarge

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings per ft² (2023 PV$)	Costs Total Incremental PV Costs per ft² (2023 PV$)	Benefit-to-Cost Ratio
1	$0.26	$0.08	3.22
2	$0.41	$0.08	5.02
3	$0.45	$0.08	5.55
4	$0.46	$0.08	5.60
5	$0.39	$0.08	4.72
6	$0.47	$0.08	5.79
7	$0.44	$0.08	5.41
8	$0.46	$0.08	5.66
9	$0.47	$0.08	5.75
10	$0.41	$0.08	4.98
11	$0.47	$0.08	5.77
12	$0.46	$0.08	5.57
13	$0.46	$0.08	5.61
14	$0.46	$0.08	5.61
15	$0.52	$0.08	6.31
16	$0.44	$0.08	5.33

Questions??

Comments for Todays Workshop

Due Date October __, 2020 By 5:00 PM

Comments to be submitted to:
https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-03

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Thank You!

Nonresidential HVAC Controls

Staff Pre-Rulemaking Workshop

Presenter: Ronald Balneg, Mechanical Engineer

Date: October 7, 2020

Proposal Summary

Staff received proposals for submeasures pertaining to Nonresidential, High-Rise Residential, Hotel/Motel Occupancies, and Covered Processes.

- 2022 Code Update
  - Variable Air Volume Deadband Airflow
  - Dedicated Outdoor Air Systems
  - Exhaust Air Heat Recovery

Variable Air Volume Deadband Airflow

2022 Code Update Sections Affected

Building Energy Efficiency Standards for Residential and Nonresidential Buildings:

- Section 140.4(d)2Aii

Reference Appendices:

- None

Existing Language

Existing Language

The volume of primary air in the deadband shall not exceed the larger of:

a. 20 percent of the peak primary airflow; or

b. The design zone outdoor airflow rate as specified by Section 120.1(c)3.

Proposed Language

The volume of primary air in the deadband shall not exceed the design zone outdoor airflow rate as specified by Section 120.1(c)3.

Prototype Buildings Modeled

Prototype Name	Number of Stories	Floor Area (square feet)	Description
ApartmentHighRise[1] (College dormitories)	10	93,632	10 story apartment building with a basement and elevator penthouse, 75 residential units and other common spaces including lobby, office, multipurpose room, exercise center, laundry, and storage
OfficeLarge	13	498,589	12 story + 1 basement office building with 5 zones and a ceiling plenum on each floor. Window-to-Wall-Ratio (WWR)-0.40
OfficeMedium	3	53,628	3 story office building with 5 zones and a ceiling plenum on each floor. WWR-0.33
OfficeMediumLab	3	53,628	3 story office building with 5 zones and a ceiling plenum on each floor. WWR-0.33
SchoolSecondary	2	210,866	High school with WWR of 35% and SRR 1.4%

1. The Nonresidential “ApartmentHighRise” prototypical model is used to model college dormitories which account for 25% of the “Colleges” building type based on square footage.

Energy Savings Methodology

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
ApartmentHighRise (College dormitories)	All	Flow Minimum	Larger of 20 percent of peak primary airflow or design zone outdoor airflow rate	design zone outdoor airflow rate
OfficeLarge	All	Flow Minimum	Larger of 20 percent of peak primary airflow or design zone outdoor airflow rate	design zone outdoor airflow rate
OfficeMedium	All	Flow Minimum	Larger of 20 percent of peak primary airflow or design zone outdoor airflow rate	design zone outdoor airflow rate
OfficeMediumLab	All	Flow Minimum	Larger of 20 percent of peak primary airflow or design zone outdoor airflow rate	design zone outdoor airflow rate
SchoolSecondary	All	Flow Minimum	Larger of 20 percent of peak primary airflow or design zone outdoor airflow rate	design zone outdoor airflow rate

VAV Deadband Airflow Energy Savings

Energy Savings Summary Per Year Per Square Foot

Climate Zone	Electricity Savings (kWh/ft^2)	Peak Electricity Demand Reductions (kWh/ft^2)	Natural Gas Savings (therms/ft^2)	TDV Energy Savings (TDV kBtu/ft^2)
1	0.096	0	-0.012	-0.301
2	0.11	0	-0.002	1.68
3	0.111	0	0.002	4.023
4	0.099	0	0.005	3.397
5	0.097	0	-0.001	2.69
6	0.142	0	0.013	7.102
7	0.129	0	0.014	8.078
8	0.132	0	0.012	6.441
9	0.107	0	0.009	4.579
10	0.102	0	0.008	4.264
11	0.106	0	0.002	3.094
12	0.11	0	0.004	3.443
13	0.092	0	0.002	2.679
14	0.08	0	0.001	1.676
15	0.057	0	0.01	4.192
16	0.101	0	-0.004	2.305

Energy Cost Savings – 15 Year

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (PV$ million)
New Construction	1.25	0.11	0.09	$4.9
Additions and Alterations	2.97	0.26	0.21	$11.5
TOTAL	4.22	0.38	0.30	$16.4

Questions?

Dedicated Outdoor Air Systems

2022 Code Update Sections Affected

Building Energy Efficiency Standards for Residential and Nonresidential Buildings:

- Section 100.1
- Section 140.4(c)
- Section 140.4(e)
- Section 140.4(p) - New Section

Reference Appendices:

- NA 7.5.4

Dedicated Outdoor Air Systems

The main types of DOASu's are those that:

- Only ventilate and filter air (unit ventilators)
- Recover dry sensible heat only (heat recovery ventilators (HRV))
- Recover dry and moist heat (energy recovery ventilators (ERV))
- Actively dehumidify and condition ventilation (DX-DOAS or custom DOAS).

Proposed Changes Overview

Subsection 100.1: Add a definition for DX-DOAS, Integrated Seasonal Coefficient of Performance, Integrated Seasonal Moisture Removal Efficiency

Subsection 140.4 (c): Add additional pressure credits for systems without heating or cooling components. For HRV/ERV systems, this would reduce the fan power allowance and is in line with ASHRAE 90.1. (Fan Power Budget / FEI proposal may supersede this recommendation)

Subsection 140.4 (e): Add additional language to the exception for DOAS systems to require an airside economizer to reference the criteria of Section 140.4 (p)

Subsection 140.4 (p): New section for prescriptive criteria when DOAS are used as a building's primary means of ventilation

1. A minimum level of ventilation sensible energy recovery with bypass capabilities for free cooling.
2. DOAS unit fan systems shall have the ability to modulate fan speed
3. Zone terminal fans for cooling or heating must cycle to off if no call for conditioning
4. DX-DOAS or DOAS with active cooling must have a maximum reheat limit of 60F when in cooling mode.
5. A total system fan power in line with prescriptive fan power tables in 140.4 (c)

NA7.5.4 – Air Economizer Controls: Add a new requirement to verify presence of an economizer bypass controls for systems with heat recovery ventilators has been field or factory calibrated.

Proposed Changes

(p) HVAC Systems with a DOAS that conditions, tempers, or filters 100 percent outdoor air separate space-conditioning systems serving the same space shall meet the following criteria:

1. Either a) or b):
   a) A DOAS unit and a separate space-conditioning system which meets prescriptive economizer and exhaust air heat recovery requirements
   b) A DOAS unit which meets the following criteria
      i. Designed and operated at no less than 150 percent of the sum of the outdoor airflow rate to each zone
      ii. Ventilation sensible energy recovery ratio of at least 60 percent or 50 percent at full flow cooling design conditions and heating design condition.
      iii. Bypass controls to economize with ventilation air based on TABLE 140.4-E
      iv. DOAS units with airflow rate > 1,000 cfm must meet demand ventilation control requirements

   EXCEPTION: Systems installed for sole purpose of providing makeup air for exhausting toxic, flammable materials, paint, corrosive fumes or dust, dryer exhaust, or commercial kitchen hoods used for collecting and removing grease vapors and smoke.

2. Fan systems shall be capable of modulating fan speed control
3. Heating and cooling equipment fans, heating and cooling circulation pumps, and terminal unit fans shall cycle off and terminal unit primary cooling air shall be shut off when there is no call for heating or cooling in the zone.

EXCEPTION: Fans used for heating and cooling using less than 0.12 watts per cfm may operate when space temperatures are within the thermostat deadband to provide destratification and air mixing in the space.

Proposed Changes

4. The DOAS supply air shall be delivered directly to the occupied space or downstream of the terminal heating/or cooling coils.

EXCEPTION 1 : Active chilled beam systems.

EXCEPTION 2 : Sensible only cooling terminal units with pressure independent variable airflow regulating devices limiting the DOAS supply air to the greater of latent load or minimum ventilation requirements.

EXCEPTION 3 : Terminal heating or cooling units using less than 0.12 watts per cfm

5. DOAS with mechanical cooling providing ventilation to multiple zones and operating in conjunction with zone heating and cooling systems shall not use heating or heat recovery to warm supply air above 60°F when representative building loads or outdoor air temperature indicate that the majority of zones require cooling.

6. Total fan system power less than 1 kW shall not exceed a total combined fan power of 1.0 W/cfm. DOAS with fan power greater than or equal to 1 kW shall meet the requirements of Section 140.4 (c).

(alternative language pending a separate CASE measure for fan power allowances: For DOAS fans with a motor nameplate hp less than 5 hp shall not exceed a total combined fan power of 1.0 W/cfm of outdoor air. Fans greater than 5 hp shall meet requirements of Section 140.4 (c).)

Prototype Buildings

Prototype Name	Number of Stories	Floor Area (square feet)	Description
Office Small	1	5,502	Three models were created to account for different DOAS HVAC configurations found most often: • DOAS HRV with Mini Splits • DOAS with RTU • DOAS with VRF
Office Medium	3	53,628	Three models were created to account for different DOAS HVAC configurations found most often: • DX-DOAS with furnace and VRF • DX-DOAS with heat pump and VRF • HRV-DOAS with VRF
Office Large	12	498,589	Models created to account for difference in DOAS HVAC configurations: • HRV-DOAS with FPFC
School Primary	1	24,413	Models created to account for difference in DOAS HVAC configurations: • DX-DOAS with furnace and VRF.
School Secondary	2	210,866	Models created to account for difference in DOAS HVAC configurations: • DX-DOAS with furnace and VRF • HRV-DOAS with FPFC

Prototype Buildings Cont…

Prototype Name	Number of Stories	Floor Area (square feet)	Description
Retail Stand Alone	1	24,563	Three models were created to account for different DOAS HVAC configurations found most often: • DX-DOAS with furnace and VRF • DX-DOAS with heat pump and VRF • HRV-DOAS with VRF
Hotel Small	4	93,632	Three models were created to account for different DOAS HVAC configurations found most often and only applied to: • DX-DOAS with furnace and VRF • DX-DOAS with heat pump and VRF • HRV-DOAS with VRF
Retail Large	1	240,000	Three models were created to account for different DOAS HVAC configurations found most often and only applied to: • DX-DOAS with furnace and VRF • DX-DOAS with heat pump and VRF • HRV-DOAS with VRF

Standard and Proposed Design Models

Prototype ID	Reference Case	Climate Zone	Parameter Name	Market Typical Design Parameter Value	Proposed Design Parameter Value
All	Reference 1 & Proposed 1	All	Ventilation Heat Recovery	No sensible heat recovery	No sensible heat recovery
			Ventilation Heat Recovery Bypass Control	None	None
			Ventilation Rate	100% T24	100% T24
			Zone Fan Control	On Continuous	Cycle with Thermostat
All	Reference 2 & Proposed 2	All	Ventilation Heat Recovery	DX-DOAS: 50% sensible heat recovery HRV-DOAS: 50% sensible heat recovery	DX-DOAS: 60% sensible heat recovery HRV-DOAS: 60% sensible heat recovery
			Ventilation Heat Recovery Bypass Control	None	Control to Supply Air Temperature
			Ventilation Rate	100% T24	150% T24
			Zone Fan Control	On Continuous	Cycle with Thermostat

Energy Savings

Summary of Energy Savings Across All Climate Zones

		Electricity Savings (kWh/ft²)	Peak Electricity Demand Reductions (kW/ft²)	Natural Gas Savings (therms/ft²)	TDV Energy Savings (TDV kBtu/ft²)
Office Small	New Construction	1.72	0.16	(0.00)	43.1
	Alterations	1.72	0.16	(0.00)	43.2
Office Medium	New Construction	2.58	0.29	0.00	71.9
	Alterations	2.58	0.29	0.00	71.9
RetailStandAlone	New Construction	1.56	0.08	(0.00)	38.3
	Alterations	1.56	0.08	(0.00)	38.2
Retail Large	New Construction	1.56	0.08	(0.00)	38.3
	Alterations	1.56	0.08	(0.00)	38.2
School Primary	New Construction	0.40	0.08	0.07	31.2
	Alterations	0.40	0.08	0.07	30.7
School Secondary	New Construction	1.79	0.21	0.00	51.6
	Alterations	1.79	0.21	0.00	51.5
Office Large	New Construction	2.74	0.33	-0.01	72.8
	Alterations	2.74	0.33	-0.01	72.7
Hotel Small	New Construction	0.64	0.05	0.00	17.1
	Alterations	0.64	0.05	0.00	17.1

Energy Savings Exception

		Electricity Savings (kWh/ft^2)	Peak Electricity Demand Reductions (kW/ft^2)	Natural Gas Savings (therms/ft^2)	TDV Energy Savings (TDV kBtu/ft^2)
Office Small	New Construction	0.1	0.27	0.06	13.7
	Alterations	0.11	0.27	0.06	13.5
Office Medium	New Construction	0.04	0.24	0.03	5.3
	Alterations	0.05	0.22	0.03	4.9
Retail Stand Alone	New Construction	N/A	N/A	N/A	N/A
	Alterations	N/A	N/A	N/A	N/A
Retail Large	New Construction	N/A	N/A	N/A	N/A
	Alterations	N/A	N/A	N/A	N/A
School Primary	New Construction	0.09	0.05	0.01	12.4
	Alterations	0.09	0.05	0.01	12.1
School Secondary	New Construction	0.45	0.7	0.04	27.2
	Alterations	0.46	0.69	0.04	27.3
Hotel Small	New Construction	N/A	N/A	N/A	N/A
	Alterations	N/A	N/A	N/A	N/A

Incremental Cost

Building Prototype	Ventilation cfm/sf	Free Cooling / Energy Recovery Cost [$/sf]	Modulating Fan Speed Cost [$/sf]	Added Duct Work [$/sf]	Total Incremental Cost per Building [$/sf]
Small Office	0.15	$0.17	$0.006	$0.7	$0.88
Medium Office	0.15	$0.17	$0.006	$0.7	$0.88
Large Office	0.15	$0.17	$0.006	$0.7	$0.88
Retail Stand Alone	0.23	$0.26	$0.009	$0.7	$0.97
Secondary School	0.35	$0.39	$0.014	$0.7	$0.97
Primary School	0.35	$0.39	$0.014	$0.7	$1.10

- Additional duct work or duct configurations to enable terminal unit fans to have separate supply pathways for terminal unit fans to cycle off
- Bypass or free cooling controls with energy recovery DOAS units
- Modulating fan speed controls

Cost Effectiveness

New Construction (DOAS market percentages applied)

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings (2023 PV$)	Costs Total Incremental PV Costs (2023 PV$)	Benefit-to-Cost Ratio
1	$4.2	$0.9	4.4
2	$4.2	$0.9	4.5
3	$4.7	$0.9	5.0
4	$4.4	$0.9	4.7
5	$4.5	$0.9	4.8
6	$4.7	$0.9	5.0
7	$4.3	$0.9	4.6
8	$4.5	$0.9	4.8
9	$4.8	$0.9	5.2
10	$3.8	$1.0	4.0
11	$3.8	$1.0	4.0
12	$4.1	$0.9	4.3
13	$3.4	$1.0	3.5
14	$4.3	$0.9	4.5
15	$3.6	$1.0	3.8
16	$4.6	$1.0	4.8

Cost Effectiveness

Alterations (DOAS market percentages applied)

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings (2023 PV$)	Costs Total Incremental PV Costs (2023 PV$)	Benefit-to-Cost Ratio
1	$4.1	$1.0	4.3
2	$4.0	$1.0	4.2
3	$4.5	$1.0	4.7
4	$4.1	$1.0	4.4
5	$4.4	$1.0	4.6
6	$4.2	$1.0	4.4
7	$4.1	$1.0	4.3
8	$4.0	$1.0	4.2
9	$4.3	$1.0	4.5
10	$3.6	$1.0	3.7
11	$3.6	$1.0	3.7
12	$3.8	$1.0	4.0
13	$3.2	$1.0	3.3
14	$3.9	$1.0	4.1
15	$3.4	$1.0	3.5
16	$4.3	$1.0	4.4

Questions?

Exhaust Air Heat Recovery

2022 Code Update Sections Affected

Building Energy Efficiency Standards for Residential and Nonresidential Buildings:

- Section 140.4 – New Section

Reference Appendices:

- NA 7.5.4

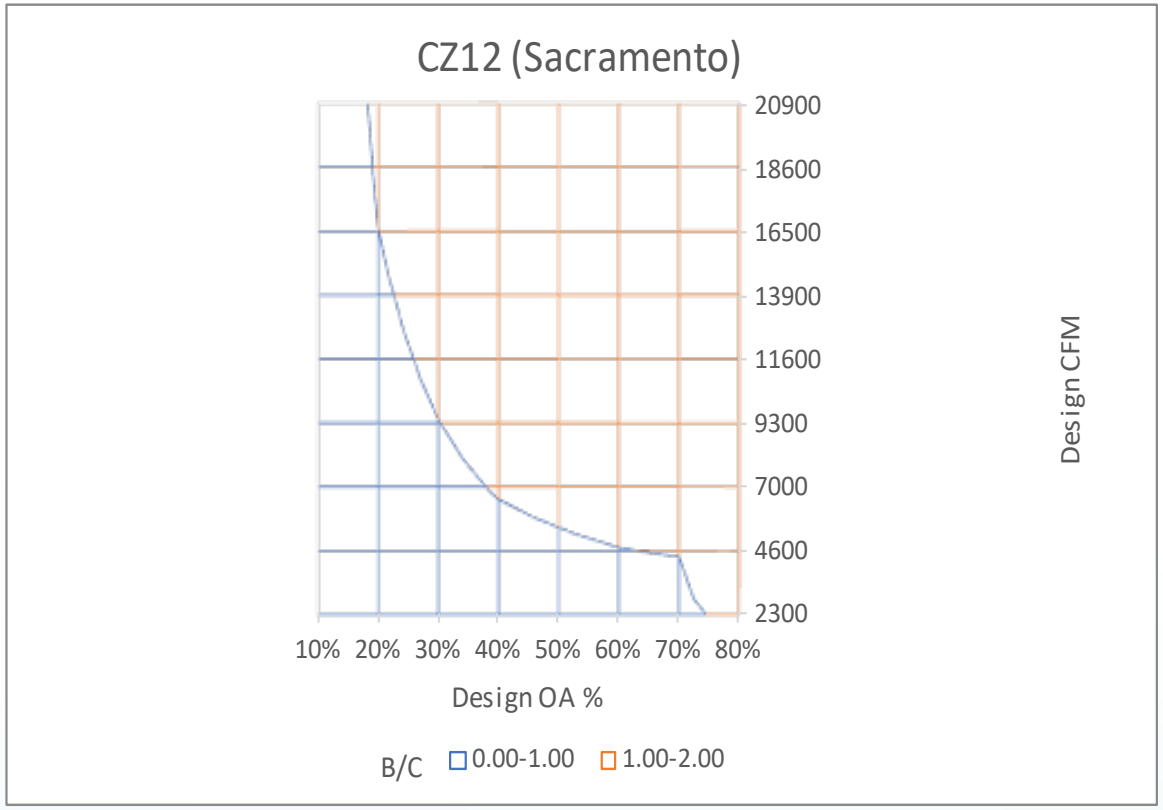
Proposed Changes

- Building Energy Efficiency Standards
  - Similar requirements and exceptions from ASHRAE 90.1
  - Modeled after California climate zones
  - Higher energy recovery requirements
  - Requirements for sensible energy recovery
  - Bypass damper for free cooling
  - Applies to non-critical areas for Health Care Facilities
- Nonresidential Appendix
  - NA7.5.4 – Air Economizer Controls: Add a new requirement to verify presence of an economizer bypass controls for systems with exhaust air heat recovery ventilators has been field or factory calibrated.

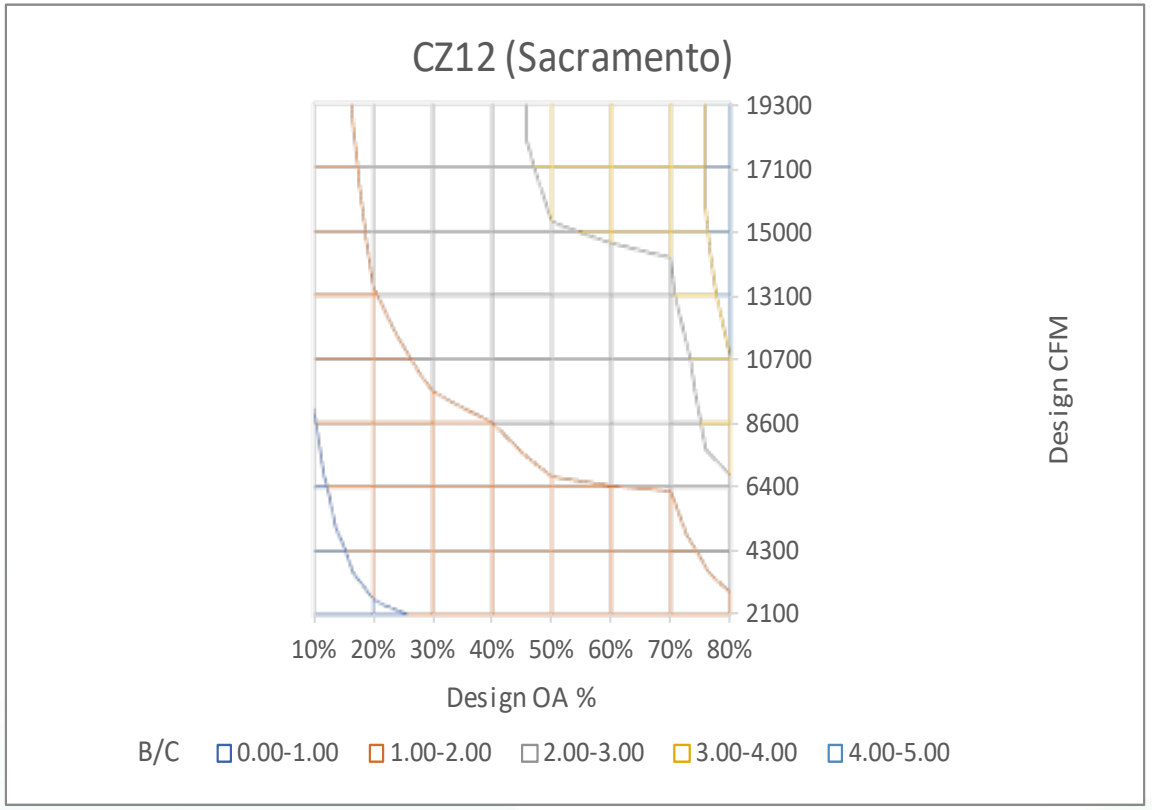
Energy Savings Methodology

- Energy recovery when outside air temperatures above 75°F or below 55°F
- Fixed plate heat exchanger equipped with bypass dampers
- 60 percent sensible energy recovery ratio
- Energy recovery device, other than coil runaround loop static pressure:
  - 2.2 IWC * Energy Recovery Ratio – 0.5 IWC, per airstream
  - constant pressure drop adjustment of +1.2 IWC throughout the simulation based on this equation due to Energy Plus limitations
  - Adjacent proposal would reduce the pressure drop adjustment from 1.2 IWC to 1.0 IWC. The Statewide CASE Team did not implement the lower pressure drop for this analysis.

Exhaust Air Heat Recovery Tables



Cost effectiveness of EAHR in Climate Zone 12 with 4,644 hours of operation.



Cost effectiveness of EAHR in Climate Zone 12 with 8,760 hours of operation.

Exhaust Air Heat Recovery Tables

Systems Operating Less than 8,000 Hours per Year

Climate Zone	% Outdoor Air at Full Design Airflow							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
01	NR	≥15,000	≥13,000	≥10,000	≥9,000	≥7,000	≥6,500	≥4,500
02	NR	≥20,000	≥15,000	≥12,000	≥10,000	≥7,500	≥7,000	≥6,500
03, 5, 6, 7, 8	NR	NR	NR	NR	NR	NR	NR	NR
04	NR	NR	NR	NR	≥18,500	≥16,500	≥15,000	≥14,000
09	NR	NR	NR	NR	NR	≥20,000	≥17,000	≥15,000
10	NR	NR	NR	≥22,000	≥17,000	≥15,000	≥14,000	≥13,000
11 - 16	NR	≥18,500	≥15,000	≥10,000	≥8,000	≥7,000	≥5,000	≥2,000

Systems Operating Greater than or Equal to 8,000 Hours per Year

Climate Zone	% Outdoor Air at Full Design Airflow							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
01	≥10,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000
02	≥10,000	≥5,000	≥3,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000
03	NR	≥13,000	≥10,000	≥8,000	≥7,000	≥6,000	≥6,000	≥6,000
04, 5	NR	≥9,000	≥6,500	≥6,000	≥6,000	≥6,000	≥5,000	≥5,000
06, 7	NR	NR	NR	NR	NR	NR	NR	NR
08	NR	NR	NR	NR	≥20,000	≥18,000	≥15,000	≥12,000
09	NR	NR	≥15,000	≥12,000	≥10,000	≥9,000	≥8,000	≥7,000
10, 11	≥40,000	≥15,000	≥7,500	≥6,000	≥5,000	≥4,000	≥3,000	≥3,000
12	≥20,000	≥5,000	≥3,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000
13 - 16	≥10,000	≥5,000	≥3,000	≥2,000	≥2,000	≥2,000	≥2,000	≥2,000

Prototype Buildings

Prototype Name	Number of Stories	Floor Area (square feet)	Description
Office Large	12	498,589	12 story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-0.40
Office Medium	3	53,628	Office building with 5 zones and a ceiling plenum on each floor. WWR-0.33
Retail Large	1	240,000	Big-box type Retail building with WWR -0.12
School Secondary	2	210,866	High school with auditorium, fitness center, kitchen, library and support spaces. WWR-0.35

Incremental Cost

- Heat recovery device with bypass dampers and controls to the air handler
- Heating and cooling equipment from RSMeans
- percentage and supply air temperature.
- Boilers were estimated to cost $237 per to
- Air-cooled chillers were estimated to cost $728 per ton
- Water-cooled chiller systems were estimated to cost $715 per ton.
- Material and labor cost
- Reduced cost due to right-sizing the system
- Peak load reduction from each climate's design condition and each building's outdoor air

Air Handler Size (cfm)	Incremental Cost (Material, Labor, Controls)	Base Cost per Flow ($/cfm)
1,000	$6,775	$6.78
2,000	$7,925	$3.96
4,000	$9,175	$2.29
6,000	$10,700	$1.78
8,000	$11,800	$1.48
10,000	$14,200	$1.42
20,000	$25,700	$1.29
25,000	$31,400	$1.26
30,000	$34,800	$1.16
40,000	$48,000	$1.20
50,000	$56,000	$1.12

Cost Benefit

Climate Zone	Office Large	Office Medium	Retail Large	School Secondary
1	1.28	N/A	2.77	2.16
2	1.11	N/A	N/A	1.71
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	1.34	1.13	N/A	2.05
12	1.04	N/A	N/A	1.64
13	1.21	N/A	N/A	1.9
14	1.26	N/A	N/A	1.78
15	0.93	N/A	N/A	1.61
16	1.47	1.08	N/A	2.89

- Cost effective in all climate zones where requirements apply

Questions?

Comments for Todays Workshop

Due Date: October 21, 2020 By 5:00 PM

Comments to be submitted to:
https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-03

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Thank You!