DOCKETED	
Docket Number:	19-BSTD-03
Project Title:	2022 Energy Code Pre-Rulemaking
TN #:	235238
Document Title:	Presentation - 2022 Energy Code Pre-Rulemaking
Description:	Staff Presentation on Multifamily Restructuring, Multifamily domestic hot water distribution and High Efficiency Boilers, Service Water Heater Proposal and By: Payam Bozorgchami on October 13, 2020 Energy Code on Pre-Rulemaking Workshop
Filer:	Tajanee Ford-Whelan
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	10/14/2020 9:39:56 AM
Docketed Date:	10/14/2020

2022 Pre-Rulemaking for Building Energy Efficiency Standards

Payam Bozorgchami, P.E.

October 13, 2020

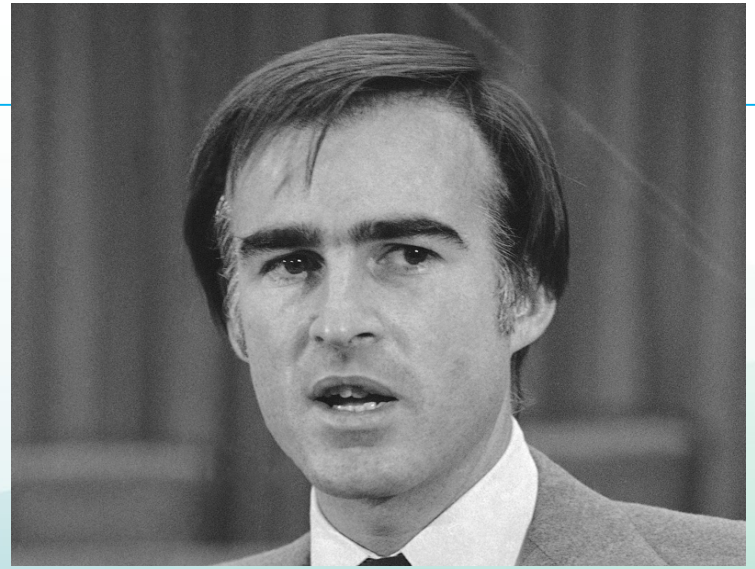
Start Time: 9:00 AM

What We Will Cover Today

- **Some Basic Background**
- **How Title 24, Part 6 is Developed**
- **Javier Perez**
  - Multifamily Restructuring
    - Restructuring the Energy Standers for Multifamily to have its own Sections.
    - Low-rise and High-rise Multifamily uniform measure where it showed cost effective
- **Danny Tam**
  - Multifamily domestic hot water distribution
  - High Efficiency Boilers and Service Water Heater Proposal

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 and Nonresidential 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

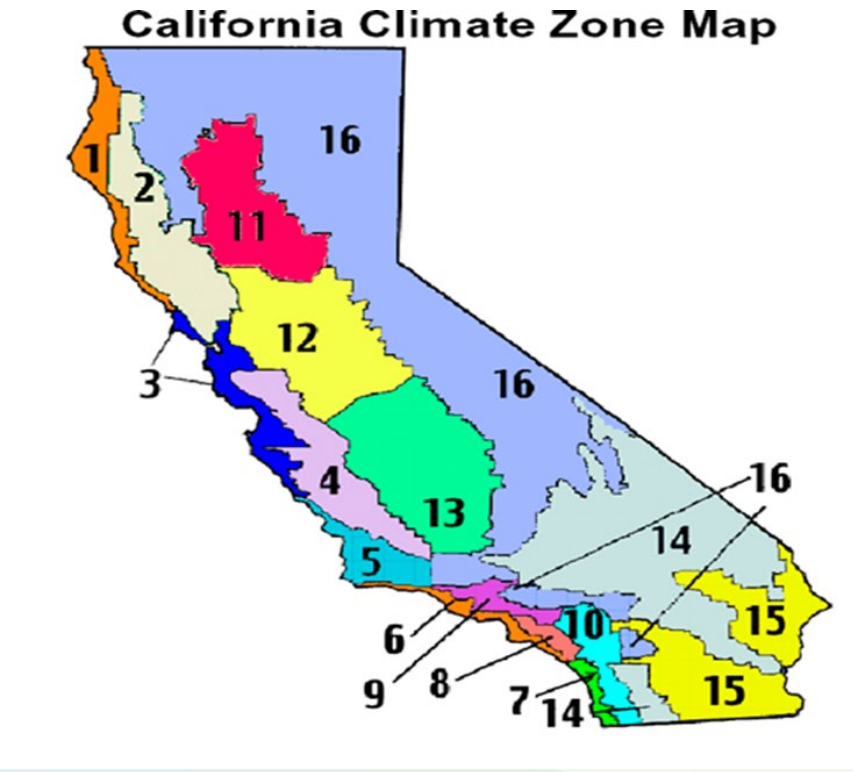
CEC staff, with input from utility partners and industry stakeholders, develop the triennial standards update

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 (Commissioner roundtable discussion on September 30 on IAQ)**
  - Indoor Air Quality Roundtable discussion with the outside world
- **November 3**
  - Nonresidential Reduced Infiltration

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 27, 2020

Building Standards Staff Contact Information – Energy Commission

Mazi Shirakh, PE
ZNE Technical Lead & Advisor to the 2022 Building Standard Staff.
Mazi.Shirakh@energy.ca.gov
916-654-3839

Payam Bozorgchami, PE
Project Manager, 2022 Building Standards
Payam.Bozorgchami@energy.ca.gov
916-654-4618

Larry Froess, PE
CBECC Software Lead
Larry.Froess@energy.ca.gov
916-654-4525

Peter Strait
Supervisor, Building Standards Development
Peter.Strait@energy.ca.gov
916-654-2817

Haile Bucaneg
Senior Mechanical Engineer
Haile.Bucaneg@energy.ca.gov
916-651-8858

Will Vicent
Building Standards Office Manager
Will.Vicent@energy.ca.gov

Comments For Todays Workshop

Due Date: October 27, 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!

Multifamily Restructuring Proposals for 2022

Staff Pre-Rulemaking Workshop

Presenter: Javier Perez, Energy Commission Specialist II

Date: October 13, 2020

Proposal Summary

Submeasures pertaining to multifamily restructuring

- Relocate language pertaining to multifamily buildings from high-rise residential and low-rise residential subchapters to newly created multifamily subchapters.

Submeasures pertaining to multifamily efficiency requirements

- Where appropriate and cost effective, apply more stringent/efficient requirements across low- and high-rise multifamily buildings, increasing uniformity and simplicity.
  - Envelope
  - Mechanical

2022 Code Update Sections Affected

Restructuring of Multifamily Requirements

Relocate language pertaining to multifamily buildings (including low- and high-rise)

2019 Subchapters

- High-Rise Residential Subchapters (§120.0-§141.1)
  - Subchapters 3 and 4 – Mandatory Measures
  - Subchapter 5 – Performance and Prescriptive Compliance Approaches
  - Subchapter 6 – Additions and Alterations
- Low-rise Residential Subchapters (§150.0-§150.2)
  - Subchapter 7 – Mandatory Measures
  - Subchapter 8 – Performance and prescriptive Compliance Approaches
  - Subchapter 9 – Additions, Alterations, and Repairs

2022 Newly Created Subchapters

- Newly Created Subchapters (§160.0-§180.4)
  - Subchapter 10 – Multifamily Buildings – Mandatory Measures
  - Subchapter 11 – Multifamily Buildings – Performance and Prescriptive Compliance Approaches
  - Subchapter 12 – Multifamily Buildings – Additions, Alterations, and Repairs

Multifamily New Construction Prototypes

Prototypes	Stories	Floor Area (ft^2)	Description
2-Story Garden Style	2	7,680	8-unit residential building with, slab on-grade foundation, wood framed wall construction and a sloped roof. Individual space conditioning and domestic hot water systems serving each unit. Window to Wall Ratio 0.15.
3-Story Loaded Corridor	3	40,000	36-unit residential building with slab on-grade foundation, wood framed wall construction, and a flat roof. Window to Wall Ratio 0.25. Dwelling units flank and central corridor and common area spaces included on bottom floor. Individual space conditioning systems and shared domestic hot water system.
5-Story Mixed Use	5	113,100	88-unit building with 4-story residential plus 1-story commercial. Concrete podium construction with underground parking, wood framed wall construction, and flat roof. Window to Wall Ratio-0.10 (ground floor) 0.25 (residential floors). Individual space conditioning systems and a central domestic hot water system.
10-Story Mixed Use	10	124,400	117-unit building with 9-story residential + 1-story commercial. Concrete podium construction with underground parking, steel framed wall construction, and a flat roof. Window to Wall Ratio-0.10 (ground floor) 0.40 (residential floors). Individual space conditioning systems and a central domestic hot water system.

Multifamily Existing Building Prototypes - Fenestration

Prototypes	Stories	Floor Area (ft^2)	Description
Prototype D Existing Building	2	6960	8-unit residential building with, slab on-grade foundation, wood framed wall construction and a steep-sloped roof with attic. Individual space conditioning and domestic hot water systems serving each unit.
High-Rise Existing	10	125,400	117-unit building with 9-story residential + 1-story commercial. Concrete podium construction with underground parking, steel framed wall construction, and a flat roof. Window to Wall Ratio-0.10 (ground floor) 0.40 (residential floors). Individual space conditioning systems.

Multifamily Prototype Weighting

Prototypes	Stories	Weighted Factors for New Construct Impact Analysis	Weighting Factor for Existing Building Impact Analysis
2-Story Garden Style	2	4%	40%
3-Story Loaded Corridor	3	33%	18%
5-Story Mixed Use	5	58%	18%
10-Story Mixed Use	10	5%	24%

Envelope Unification Measure Proposals

Roofing Product Unification: Low-Sloped Roofs

Apply more stringent prescriptive requirements where cost effective and reasonable

- Buildings 3 habitable stories or less
  - Increase minimum aged solar reflectance in climate zones 9 – 11, and 14.
    - ❖No requirement → 0.55
  - Increase minimum thermal emittance in climate zones 9-11, and 14.
    - ❖No requirement → 0.75
- Buildings taller than 3 habitable stories
  - Increase minimum aged solar reflectance in climate zones 13 and 15.
    - ❖0.55 → 0.63

Roofing Product Unification: Low-Sloped Roofs

First-Year Energy Impact Per Dwelling Unit

Two-Story Prototype Building – Increase to 0.55 Aged Solar Reflectance

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
9	42.08	0.03	(0.75)	1651
10	49.01	0.03	(0.95)	1574
11	49.50	0.03	(1.21)	1795
14	40.33	0.03	(1.87)	1296

Three-Story Prototype Building – Increase to 0.55 Aged Solar Reflectance

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
9	36.09	0.02	(0.18)	1433
10	42.13	0.03	(0.28)	1500
11	39.54	0.02	(0.41)	1567
14	30.16	0.03	(0.65)	1211

Roofing Product Unification: Low Sloped Roofs

First-Year Energy Impact Per Dwelling Unit

Five-Story Prototype Building – Increase to 0.63 Aged Solar Reflectance

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
13	8.82	0.00	(0.26)	192
15	11.35	0.00	(0.10)	299

Ten-Story Prototype Building – Increase to 0.63 Aged Solar Reflectance

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
13	3.66	0.00	(0.10)	82
15	4.60	0.00	(0.04)	119

Roofing Product Unification: Low-Sloped Roofs

Cost-Effectiveness Summary Per Dwelling Unit, New/Add/Alt

Two-Story Prototype Building – Increase to 0.55 Aged Solar Reflectance

Climate Zone	Benefits	Cost – Total Incremental Costs	Benefit-to-Cost Ratio
9	$285.66	$44.08	6.48
10	$272.37	$44.75	6.09
11	$310.57	$48.49	6.40
14	$224.21	$43.00	5.21

Three-Story Prototype Building – Increase to 0.55 Aged Solar Reflectance

Climate Zone	Benefits	Cost – Total Incremental Costs	Benefit-to-Cost Ratio
9	$247.97	$30.87	8.03
10	$259.50	$31.35	8.28
11	$271.03	$33.97	7.98
14	$209.52	$30.12	6.96

Roofing Product Unification: Low-Sloped Roofs

Cost-Effectiveness Summary Per Dwelling Unit, New/Add/Alt

Five-Story Prototype Building – Increase to 0.63 Aged Solar Reflectance

Climate Zone	Benefits	Cost – Total Incremental Costs	Benefit-to-Cost Ratio
13	$33.15	$0.00	Infinite
15	$51.74	$0.00	Infinite

Ten-Story Prototype Building – Increase to 0.63 Aged Solar Reflectance

Climate Zone	Benefits	Cost – Total Incremental Costs	Benefit-to-Cost Ratio
13	$14.15	$0.00	Infinite
15	$20.51	$0.00	Infinite

Roofing Product Unification: Low-Sloped Roofs

Cost savings over 30 years per dwelling

Two-Story Prototype Building – Increase to 0.55 Aged Solar Reflectance

Climate Zone	30-Year Cost Savings	30-Year TDV Nat. Gas Cost Savings	Total 30-Year Energy Cost Savings
9	$332.16	($46.50)	$285.66
10	$332.16	($59.79)	$272.37
11	$386.97	($76.40)	$310.57
14	$343.79	($119.58)	$224.21

Three-Story Prototype Building – Increase to 0.55 Aged Solar Reflectance

Climate Zone	30-Year Cost Savings	30-Year TDV Nat. Gas Cost Savings	Total 30-Year Energy Cost Savings
9	$259.50	($11.53)	$247.97
10	$276.80	($17.30)	$259.50
11	$296.02	($24.99)	$271.03
14	$249.89	($40.37)	$209.52

Roofing Product Unification: Low-Sloped Roofs

Cost savings over 30 years per dwelling

Five-Story Prototype Building – Increase to 0.63 Aged Solar Reflectance

Climate Zone	30-Year Cost Savings	30-Year TDV Nat. Gas Cost Savings	Total 30-Year Energy Cost Savings
13	$44.91	($11.76)	$285.66
15	$56.48	($4.74)	$272.37

Ten-Story Prototype Building – Increase to 0.63 Aged Solar Reflectance

Climate Zone	30-Year Cost Savings	30-Year TDV Nat. Gas Cost Savings	Total 30-Year Energy Cost Savings
13	$18.54	($4.39)	$14.15
15	$22.44	($1.93)	$20.51

Roofing Product Unification: Steep-Sloped Roofs

Apply more stringent prescriptive requirements by slope and climate zone, where cost effective and reasonable

- Buildings taller than 3 habitable stories
  - Remove existing minimum aged solar reflectance in climate zones 2-9.
    - ❖Less than 1% of these buildings have steep-sloped roofs.
    - ❖No prototype versions of these buildings exist to model potential.
- Continue with 2019 minimum reflectance/emittance requirements in climate zones 10-15, already uniform.

Roofing Product Unification

Any questions on the roofing product unification measures?

Roof/Ceiling Insulation Unification

Create uniform requirements across multifamily buildings based on building and assembly type

- Mandatory Measures
  - Apply low-rise residential max U-factor of 0.043 for ceiling/rafter roof to multifamily buildings with attics.
  - Apply mandatory nonresidential max U-factor of 0.098 for metal roofs.
  - Apply mandatory nonresidential max U-factor of 0.075 for wood framed and other non-attic roofs in buildings < 4 habitable stories.
- Prescriptive Measures
  - Apply prescriptive low-rise residential requirements to multifamily buildings with attics, including Option B (below deck insulation HPA) and Option C (ducts in conditioned space).
  - Apply high-rise residential prescriptive U-factor requirements using both metal and wood-framed/other roof categories.

Roof/Ceiling Insulation Unification

Create uniform requirements across multifamily buildings based on building and assembly type

- This aligns requirement across low- and high-rise multifamily buildings for flat roofs.
- Will result in increased TDV energy use in climate zones 1-7 and 12-16, and energy savings in climate zones 8-11.

Roof/Ceiling Insulation Unification

Table 45: First-Year Energy Impacts Per Dwelling Unit– Roof/Ceiling Insulation, 2-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(0.42)	0.04	(0.62)	(250)
2	1.48	0.04	0.09	(29)
3	(1.20)	0.04	(0.21)	(422)
4	(1.12)	0.03	0.51	(317)
5	(0.83)	0.03	(0.37)	(230)
6	(8.73)	0.02	(0.07)	(557)
7	(10.27)	0.02	(0.23)	(730)
8	5.84	0.04	0.06	461
9	3.42	0.03	0.25	221
10	5.03	0.03	0.27	125
11	4.47	0.04	(0.68)	250
12	3.02	0.04	(0.76)	(86)
13	(88.83)	(0.02)	0.84	(3,379)
14	(11.30)	0.03	(0.19)	(374)
15	(149.13)	(0.03)	0.18	(5,366)
16	0.72	0.04	(0.73)	(240)

Roof/Ceiling Insulation Unification

Table 46: First-Year Energy Impacts Per Dwelling Unit– Roof/Ceiling Insulation, 3-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(6.11)	0.00	(3.06)	(1,256)
2	5.17	0.00	(1.78)	(133)
3	(3.34)	(0.00)	(0.89)	(489)
4	2.32	(0.00)	(0.60)	(389)
5	(4.47)	(0.00)	(0.99)	(544)
6	(9.02)	(0.01)	(0.19)	(367)
7	(11.79)	(0.02)	(0.08)	(589)
8	16.33	0.00	(0.11)	1111
9	11.92	0.00	(0.21)	533
10	18.04	0.01	(0.44)	489
11	13.37	(0.01)	(1.96)	300
12	13.25	0.00	(2.05)	11
13	(76.93)	(0.05)	(1.12)	(3,489)
14	(6.37)	(0.00)	(1.64)	(500)
15	(138.90)	(0.07)	(0.03)	(4,778)
16	(2.51)	(0.00)	(3.71)	(1,411)

Roof/Ceiling Insulation Unification

- The unification of these measures does not increase stringency.
- For this reason, cost and cost effectiveness analysis was not done.
- Proposed changes only impact low-rise residential construction that do not have an attic.

Roof/Ceiling Insulation Unification

Any questions on the roof/ceiling unification measures?

Wall U-Factor Unification

Create uniform requirements across multifamily buildings, varying by assembly type and climate zone

- Differentiate assembly types by fire rating for select wall assemblies.
  - Allows high-fire rating wall types to adhere to less stringent U-factor requirements.
    - ❖ Variances in insulation by assembly include:
      - ➢ Metal Buildings
      - ➢ Framed (wood/metal), high fire rating (2 or 3 hour)
      - ➢ Framed (wood/metal), low fire rating (0 or 1 hour), and other wall types
      - ➢ Heavy mass (<15 btu/ft^2-F)
      - ➢ Light mass (7-15 btu/ft^{2}F)

Wall U-Factor Unification

Technical Feasibility – Framed Walls

- The California Fire Code mandates zero-hour to four-hour fire ratings for walls.
- These requirements vary based on building size and proximity to neighboring structures.
- It is challenging for an assembly to achieve both high fire rating and low U-factors.
  - Can lead to higher cost, complicated construction methods, thicker assemblies, limited options.
- For this reason proposal includes two different categories for wood/metal framed walls:
  - Zero to one-hour fire rated walls
  - Two to three-hour fire rated walls

Wall U-Factor Unification

Table 5: Proposed Wall U-factors by Wall Assembly Type and Climate Zone

Wall Type	Climate Zones	Mandatory Assembly U-factor	Prescriptive Assembly U-factor
Metal Buildings	CZ 1-10	Metal Buildings = 0.113 Spandrel Panels and Curtain Walls = 0.280	0.061
	CZ 11-16		0.057
Framed (wood or metal), high fire rating (2- or 3-hours)	CZ 1-5,8-10, 12, & 13	2x4 framing = 0.102 2x6 framing = 0.071 non-framed = 0.102	0.059
	CZ 6 & 7		0.065
	CZ 11, & 14-16		0.051
Framed (wood or metal), low fire rating (0- or 1-hours), and other wall types	CZ 1-5, 8-16		0.051
	CZ 6 & 7		0.065

Wall U-Factor Unification

Table 5: Proposed Wall U-factors by Wall Assembly Type and Climate Zone

Wall Type	Climate Zones	Mandatory Assembly U-factor	Prescriptive Assembly U-factor
Heavy mass (>15 Btu/ft^2-F)	CZ 1-3, 16	0.690	0.160
	CZ 4, 11, 14, & 15		0.184
	CZ 5, 13		0.211
	CZ 6-10		0.690
	CZ 12		0.253
Light mass (7-15 Btu/ft^2-F)	CZ 1-15	0.440	0.077
	CZ 16		0.059

Wall U-Factor Unification

Table 47: First-Year Energy Impacts Per Dwelling Unit – Framed, High Fire Rating (2- and 3-hr), 3-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(3.57)	(0.00)	(1.72)	(689)
2	(2.04)	0.00	(0.92)	(400)
3	(1.83)	0.00	(0.58)	(278)
4	(0.80)	0.00	(0.52)	(233)
5	(1.74)	0.00	(0.52)	(222)
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	(0.32)	(0.00)	(0.07)	(89)
9	(0.64)	(0.00)	(0.21)	(167)
10	(1.90)	(0.00)	(0.35)	(244)
11	N/A	N/A	N/A	N/A
12	(2.11)	0.00	(0.83)	(444)
13	(6.62)	(0.00)	(0.70)	(533)
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A

Wall U-Factor Unification

Table 48: First-Year Energy Impacts Per Dwelling Unit– Framed, Low Fire Rating (0- or 1- hour), 5-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	8.80	(0.00)	4.57	1,366
2	15.17	0.00	3.67	1,340
3	8.61	(0.00)	2.91	892
4	9.86	(0.00)	2.37	900
5	10.67	(0.00)	3.14	935
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	9.24	(0.00)	1.42	629
9	10.22	0.00	1.62	704
10	12.77	0.00	1.89	798
11	N/A	N/A	N/A	N/A
12	15.42	0.00	3.21	1,353
13	16.19	0.00	2.22	1,056
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A

Wall U-Factor Unification

Table 49: First-Year Energy Impacts Per Dwelling Unit– Framed, High and Low Fire Rating, 5-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
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	0.00	(0.00)	(0.55)	(188)
7	0.47	(0.00)	(0.47)	(144)
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	(16.77)	(0.01)	(3.02)	(1,596)
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	(15.72)	(0.01)	(3.07)	(1,543)
15	(24.80)	(0.01)	(0.94)	(1,276)
16	(11.89)	(0.01)	(5.05)	(1,663)

Wall U-Factor Unification

Table 50: First-Year Energy Impacts Per Dwelling Unit– Framed, High and Low Fire Rating, 10-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
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	(0.03)	(0.00)	(0.50)	(171)
7	0.52	(0.00)	(0.40)	(123)
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	(29.48)	(0.02)	(5.38)	(2,661)
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	(30.07)	(0.01)	(5.79)	(2,740)
15	(39.86)	(0.02)	(1.96)	(2,055)
16	(21.32)	(0.01)	(8.39)	(2,732)

Wall U-Factor Unification

Table 82: Component and Incremental Measure Costs for Proposed Wall U-Factor, 5-Story Mixed Use Prototype, Low Fire Rating

5-Story Mixed Use Framed construction; Low 0- or 1-hr fire rating			
Prototype ID Proposed Category: Application Scenario	**Component**	**Product & Technique**	**Cost per ft²**
U-factor: 0.059	Continuous Insulation	R1.45 (EPS ½")	$1.23
	Number of Gypsum Board	1	$1.46
	Frame Type	Wood Frame 2x6 16" OC	$2.41
	Cavity Insulation	16" OC R-21 unfaced	$1.41
	Number of Gypsum Board (interior facing)	1	$1.46
	Assembly Cost		$7.97
U-factor: 0.051	Continuous Insulation	R4.5	$2.16
	Number of Gypsum Board	1	$1.46
	Frame Type	Wood Frame 2x4 16" OC	$2.41
	Cavity Insulation	16" OC R-19 unfaced	$1.14
	Number of Gypsum Board (interior facing)	1	$1.46
	Assembly Cost		$8.63
Incremental Cost			$0.66

Wall U-Factor Unification

Table 90: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Framed (Wood or Metal) and Others, ≤ 1 hr Fire Rating, 5-Story Prototype Building

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	$236.37	$183.43	1.29
2	$231.75	$183.43	1.26
3	$154.24	$183.43	0.84
4	$155.75	$183.43	0.85
5	$161.73	$183.43	0.88
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	$108.86	$183.43	0.59
9	$121.84	$183.43	0.66
10	$138.12	$183.43	0.75
11	N/A	N/A	N/A
12	$234.13	$183.43	1.28
13	$182.74	$183.43	1.00
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	N/A	N/A	N/A

Wall U-Factor Unification: Staff Questions

Any feedback on incremental costs or data that can be shared would be welcome.

Quality Insulation Installation

Create uniform requirements across multifamily buildings, varying by building size

- Extend low-rise residential prescriptive Quality Insulation Installation (QII) requirements to multifamily buildings up to 40,000 ft^2 of total building conditioned floor area (CFA).
- Extend low-rise QII requirements for additions > 700 ft^2 to all multifamily building additions of same size.
- Not applicable to alterations.
- Not applicable to curtain wall assembly types.
  - These assemblies can be shipped to site fully sealed, preventing verification.
  - Developing protocols for this verification of diverse curtain wall assemblies would be prohibitive.
- 2019 CASE Study found QII to not be cost effective in multifamily buildings in climate zone 7.
  - 2022 proposal continues with this finding; no QII in climate zone 7.

Quality Insulation Installation

Technical Feasibility

- CASE team found this to not be a barrier for proposed QII requirement
  - Relating to materials/methods/construction practices, all within current technical limits.
- Extending QII to high-rise multifamily buildings presents challenges
  - 3rd party verification process for non-HVAC equipment is not used in high-rise projects.
- Verification of larger buildings becomes logistically challenging and cost prohibitive
  - Timing for verification can be challenging
    - ❖Staging can be floor-by-floor instead of uniform stages across entire building.
  - Current QII protocol relies on up to 3 visits to the site for verification.
- As a result, 40,000 ft^2 was determined to be the upper limit for this measure.

Quality Insulation Installation

Energy Savings Methodology

- Current QII requirements do not apply to mid/high-rise residential buildings.
- Standard design assumed no cavity insulation deration.
- Proposed design assumed cavity insulation derated by 30% for all climate zones except 7, where QII is not required.

Quality Insulation Installation

Table 51: First-Year Energy Impacts Per Dwelling Unit– 5-Story Prototype Building – QII

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	10.40	0.00	6.47	1,900
2	19.43	0.00	4.72	1,905
3	15.92	0.00	4.91	1,698
4	15.90	0.00	3.25	1,478
5	18.44	0.00	5.09	1,711
6	27.61	0.00	3.72	1,707
7	N/A	N/A	N/A	N/A
8	18.15	0.01	2.01	1,200
9	18.59	0.01	2.27	1,286
10	21.64	0.01	2.53	1,400
11	19.17	0.01	2.82	1,482
12	21.80	0.01	3.96	1,869
13	29.22	0.01	3.09	1,855
14	18.45	0.01	2.74	1,431
15	30.85	0.01	0.93	1,295
16	14.17	0.00	4.83	1,652

Quality Insulation Installation

Table 52: First-Year Energy Impacts Per Dwelling Unit– 3-Story Prototype Building – QII

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(8.22)	0.00	(3.94)	(1,616)
2	(10.48)	0.00	(2.55)	(1,585)
3	(5.32)	0.00	(1.55)	(945)
4	(11.10)	0.00	(1.58)	(1,161)
5	(5.09)	0.00	(1.42)	(721)
6	(3.43)	0.00	(0.40)	(444)
7	N/A	N/A	N/A	N/A
8	(13.38)	0.00	(0.25)	(909)
9	(13.31)	0.00	(0.66)	(1,032)
10	(18.39)	0.00	(1.04)	(1,318)
11	(24.24)	0.00	(2.36)	(2,088)
12	(15.98)	0.00	(2.15)	(1,701)
13	(30.57)	0.00	(1.74)	(2,011)
14	(22.89)	0.00	(2.43)	(1,996)
15	(45.43)	0.00	(0.07)	(1,896)
16	(12.54)	0.00	(4.92)	(2,139)

Quality Insulation Installation

Table 75: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction - 5-Story Prototype Building – QII

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$51.81	$276.97	$328.78
2	$123.62	$206.00	$329.63
3	$80.04	$213.74	$293.78
4	$110.73	$145.01	$255.74
5	$75.82	$220.10	$295.92
6	$127.40	$167.98	$295.38
7	N/A	N/A	N/A
8	$115.40	$92.25	$207.65
9	$119.18	$103.32	$222.50
10	$126.51	$115.69	$242.20
11	$128.29	$128.11	$256.41
12	$146.08	$177.30	$323.38
13	$179.65	$141.21	$320.87
14	$122.29	$125.34	$247.62
15	$180.10	$43.96	$224.06
16	$70.26	$215.59	$285.85

Quality Insulation Installation

Incremental First Cost

- Incremental first cost of QII measure is equal to HERS QII verification cost.
- No additional material or installation costs.
- Estimated time to conduct verification protocol on larger multifamily buildings.
- Priced at HERS Rater labor rates ($80/hr estimate) with markups for profit/overhead.
- $0.55/mile accounted for vehicular travel to/from work site for each visit.
- Lots more…

Table 83: Incremental Costs for Full QII Inspection per Dwelling Unit

Climate Zone	5-Story Mixed Use
1	$79
2	$87
3	$89
4	$90
5	$74
6	$76
7	$72
8	$74
9	$76
10	$74
11	$77
12	$78
13	$76
14	$73
15	$74
16	$77

Quality Insulation Installation

Table 91: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – 5-Story Prototype Building – QII

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	$328.78	$78.80	4.2
2	$329.63	$87.20	3.8
3	$293.78	$89.31	3.3
4	$255.74	$90.20	2.8
5	$295.92	$73.92	4.0
6	$295.38	$75.68	3.9
7	N/A	N/A	N/A
8	$207.65	$74.39	2.8
9	$222.50	$75.56	2.9
10	$242.20	$74.39	3.3
11	$256.41	$77.27	3.3
12	$323.38	$78.15	4.1
13	$320.87	$76.03	4.2
14	$247.62	$73.10	3.4
15	$224.06	$73.63	3.0
16	$285.85	$77.33	3.7

Quality Insulation Installation

Any question on the QII unification measures?

Fenestration Properties – New Construction

Create uniform requirements across multifamily buildings based on fenestration type

- Mandatory Measures
  - Apply low-rise residential mandatory weighted average maximum U-factor requirement to multifamily buildings taller than three habitable stories.
    - ❖Not applicable to curtain wall fenestration types.
  - Prescriptive Measures – Two Categories
    - ❖Curtain wall and storefront windows
      - ➢Apply more stringent requirement
    - ❖All other windows
      - ➢Apply current low-rise weighted average prescriptive requirement.
        - Removes operable/fixed/glazed door differentiations in high-rise residential sections of 2019 Code.

Fenestration Properties – New Construction

Create uniform requirements across multifamily buildings based on fenestration type

- Harmonize recognition of shading for windows
  - Current code has different methodologies for solar heat gain coefficient (SHGC) and the effects of shading for residential buildings compared to all other types.
  - Proposal will relative SHGC methodology for prescriptive compliance with all multifamily buildings.
- This measure was packaged with wall u-factor and all-electric HVAC submeasures to prove cost effective.

Fenestration Properties – New Construction

Create uniform requirements across multifamily buildings based on fenestration type

- Curtain wall and storefront windows
  - Lower U-factor down to 0.38, SHGC to 0.25, in all climate zones but 1
    - ❖ Climate zone 1 SHGC proposal is 0.35.
- All other windows
  - Apply low-rise residential maximum U-factor of 0.30 and SHGC of 0.23 in all climate zones but 1
    - ❖ Climate zone 1 SHGC proposal is 0.35.

Table 6: Proposed Fenestration Thermal Properties by Type and Climate Zo New Construction

Window Type	Climate Zones	U-Factor (maximum)	SHGC (maximum)	VT (minimum)
Curtainwall/ Storefront	CZ 1	0.38	0.35	0.46
	CZ 2-16	0.38	0.25	0.46
All Other	CZ 1	0.30	0.35	NR*
	CZ 2-16	0.30	0.23	NR*

*NR = No requirement

Fenestration Properties – New Construction

Table 35: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change – Fenestration Properties

Prototype ID Proposed category: Application scenario	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
5-Story Mixed Use, 10-Story Mixed Use Curtainwall/Store Fronts	1	U-Factor/SHGC*	0.41/0.26	0.38/0.35
	2-16			0.38/0.25
5-Story Mixed Use, 10-Story Mixed Use All Others: Blended Nonresidential to "All Others"	1	U-Factor/SHGC (a combined category for Fixed, Operable fenestrations, and Glazed Doors) *	0.40/0.24	0.30/0.35
	2-16			0.30/0.23
Low Rise Prototype D Existing	1, 3, 5, 16	U-Factor/SHGC	0.30/NR**	0.34/NR**
	2, 4, 6-15		0.30/0.23	0.34/0.23
High-Rise Existing Curtainwall/Store Fronts	1	U-Factor/SHGC*	0.47/0.41	0.38/0.35
	2, 4, 6-15		0.47/0.31	0.38/0.25
	3, 5		0.58/0.41	0.38/0.25
	16		0.47/0.41	0.38/0.25
High-Rise Existing All Others: Blended NR to "All Others"	1	U-Factor/SHGC (a combined category for Fixed, Operable fenestrations, and Glazed Doors) *	0.47/0.41	0.34/0.35
	2, 4, 6-15		0.47/0.31	0.34/0.23
	3, 5		0.58/0.41	0.34/0.23
	16		0.47/0.41	0.34/0.23

Fenestration Properties – New Construction

Table 53: First-Year Energy Impacts Per Dwelling Unit – Curtainwall/Storefronts, 5-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(25.23)	(0.02)	12.13	2,437
2	(2.92)	(0.00)	3.11	827
3	(4.65)	(0.00)	2.78	640
4	(6.01)	(0.00)	2.00	492
5	(5.91)	(0.00)	2.59	528
6	(10.75)	(0.00)	1.16	88
7	(11.27)	(0.00)	0.97	4
8	(9.18)	0.00	1.10	134
9	(7.84)	0.00	1.33	263
10	(6.10)	0.00	1.51	354
11	(0.72)	0.00	2.70	893
12	(3.49)	0.00	2.53	724
13	(1.52)	0.00	2.04	692
14	(1.77)	0.00	2.61	806
15	0.65	0.00	0.74	421
16	(1.16)	(0.00)	4.80	1,287

Fenestration Properties – New Construction

Table 54: First-Year Energy Impacts Per Dwelling Unit – Curtainwall/Storefronts, 10-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(62.92)	(0.02)	17.05	2,763.62
2	(9.96)	(0.00)	5.14	1,195.59
3	(12.29)	(0.00)	4.57	910.49
4	(14.82)	(0.00)	3.30	649.83
5	(13.09)	(0.00)	4.32	780.70
6	(20.59)	(0.00)	1.93	61.20
7	(19.50)	(0.00)	1.69	(5.36)
8	(18.52)	(0.00)	1.84	92.07
9	(16.56)	(0.00)	2.23	324.11
10	(13.89)	0.00	2.51	475.88
11	(7.73)	0.00	4.42	1,251.11
12	(12.21)	(0.00)	4.15	990.77
13	(9.21)	0.00	3.31	927.75
14	(8.47)	0.00	4.30	1,166.54
15	(3.65)	0.01	1.23	569.34
16	(9.94)	(0.00)	7.73	1836.52

Fenestration Properties – New Construction

Table 55: First-Year Energy Impacts Per Dwelling Unit – Combined Category *All Others*, 5-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(22.52)	(0.02)	25.05	5,781
2	11.31	(0.00)	9.93	3,044
3	(92.68)	(0.03)	13.51	974
4	2.57	(0.00)	6.41	2029
5	(106.26)	(0.03)	12.57	613
6	(10.98)	(0.00)	3.74	774
7	(15.33)	(0.00)	3.14	430
8	(3.89)	(0.00)	3.56	1,059
9	(0.27)	0.00	4.27	1,390
10	6.43	0.00	4.85	1,699
11	22.08	0.01	8.66	3,327
12	12.19	0.00	8.13	2,780
13	21.13	0.01	6.52	2,735
14	18.49	0.01	8.24	3,081
15	34.66	0.01	2.37	2,068
16	13.45	(0.00)	15.25	4,460

Fenestration Properties – New Construction

Table 56: First-Year Energy Impacts Per Dwelling Unit – Combined Category *All Others* 10-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(80.99)	(0.04)	35.85	7,065
2	8.26	(0.00)	16.01	4,672
3	(7.11)	(0.01)	14.04	3,502
4	(5.03)	(0.00)	10.25	3,028
5	(8.48)	(0.01)	13.26	3,058
6	(25.41)	(0.00)	5.98	1,074
7	(29.01)	(0.01)	5.16	632
8	(13.83)	0.00	5.70	1,525
9	(8.21)	0.00	6.85	2,062
10	1.99	0.01	7.77	2,552
11	26.79	0.01	14.13	5,164
12	8.99	0.00	13.12	4,229
13	24.09	0.01	10.46	4,150
14	19.97	0.01	13.38	4,730
15	48.88	0.02	3.80	3,159
16	5.21	(0.01)	24.23	6,575

Fenestration Properties – New Construction

Table 76: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Curtainwall/Storefronts, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($88.05)	$509.61	$421.56
2	$6.45	$136.59	$143.03
3	($10.67)	$121.31	$110.64
4	($4.45)	$89.54	$85.09
5	($21.35)	$112.71	$91.36
6	($37.80)	$52.94	$15.14
7	($44.25)	$44.96	$0.71
8	($27.79)	$50.94	$23.15
9	($15.56)	$61.06	$45.49
10	($8.23)	$69.39	$61.17
11	$31.35	$123.20	$154.55
12	$11.56	$113.77	$125.34
13	$26.46	$93.32	$119.78
14	$20.01	$119.38	$139.39
15	$38.02	$34.82	$72.84
16	$8.67	$213.92	$222.59

Fenestration Properties – New Construction

Table 77: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Curtainwall/Storefronts, 10-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($237.52)	$715.63	$478.11
2	($17.61)	$224.45	$206.84
3	($40.98)	$198.49	$157.51
4	($34.30)	$146.72	$112.42
5	($51.73)	$186.79	$135.06
6	($77.88)	$88.46	$10.59
7	($78.99)	$78.06	($0.93)
8	($68.98)	$84.90	$15.93
9	($46.17)	$102.24	$56.07
10	($33.38)	$115.70	$82.33
11	$15.76	$200.68	$216.44
12	($14.46)	$185.87	$171.40
13	$9.64	$150.86	$160.50
14	$6.12	$195.69	$201.81
15	$40.61	$57.89	$98.50
16	($24.66)	$342.38	$317.72

Fenestration Properties – New Construction

Table 78: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Combined Category *All Others*, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($59.37)	$1,059.43	$1,000.06
2	$90.72	$435.95	$526.67
3	($422.45)	$590.97	$168.51
4	$64.26	$286.80	$351.06
5	($441.58)	$547.66	$106.08
6	($37.35)	$171.27	$133.92
7	($70.93)	$145.37	$74.44
8	$18.45	$164.71	$183.17
9	$44.69	$195.84	$240.53
10	$70.26	$223.61	$293.87
11	$180.54	$394.97	$575.52
12	$116.06	$364.96	$481.02
13	$174.98	$298.16	$473.15
14	$155.20	$377.74	$532.94
15	$246.14	$111.55	$357.69
16	$90.05	$681.46	$771.51

Fenestration Properties – New Construction

Table 79: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Combined Category *All Others*, 10-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($297.60)	$1,519.76	$1,222.16
2	$106.06	$702.22	$808.29
3	($7.60)	$613.43	$605.82
4	$65.82	$458.10	$523.92
5	($47.10)	$576.12	$529.02
6	($88.82)	$274.61	$185.79
7	($129.98)	$239.32	$109.34
8	($0.37)	$264.24	$263.87
9	$42.09	$314.71	$356.80
10	$82.70	$358.71	$441.41
11	$249.95	$643.39	$893.34
12	$142.59	$588.99	$731.58
13	$240.12	$477.85	$717.97
14	$207.49	$610.81	$818.30
15	$367.13	$179.34	$546.47
16	$58.78	$1,078.74	$1,137.52

Fenestration Properties – New Construction

Table 92: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction –Curtainwall/Storefronts, 5-Story Prototype Building

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	$421.56	$105.80	3.98
2	$143.03	$105.80	1.35
3	$110.64	$105.80	1.05
4	$85.09	$105.80	0.80
5	$91.36	$105.80	0.86
6	$15.14	$105.80	0.14
7	$0.71	$105.80	0.01
8	$23.15	$105.80	0.22
9	$45.49	$105.80	0.43
10	$61.17	$105.80	0.58
11	$154.55	$105.80	1.46
12	$125.34	$105.80	1.18
13	$119.78	$105.80	1.13
14	$139.39	$105.80	1.32
15	$72.84	$105.80	0.69
16	$222.59	$105.80	2.10

Fenestration Properties – New Construction

Table 93: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction –Category "Curtainwall/Storefronts, 10-Story Prototype Building

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	$478.11	$161.92	2.95
2	$206.84	$161.92	1.28
3	$157.51	$161.92	0.97
4	$112.42	$161.92	0.69
5	$135.06	$161.92	0.83
6	$10.59	$161.92	0.07
7	($0.93)	$161.92	(0.01)
8	$15.93	$161.92	0.10
9	$56.07	$161.92	0.35
10	$82.33	$161.92	0.51
11	$216.44	$161.92	1.34
12	$171.40	$161.92	1.06
13	$160.50	$161.92	0.99
14	$201.81	$161.92	1.25
15	$98.50	$161.92	0.61
16	$317.72	$161.92	1.96

Fenestration Properties – New Construction

Table 94: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category *All Others*, 5-Story Prototype Building

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	$1,000.06	$796.64	1.26
2	$526.67	$1,333.02	0.40
3	$168.51	$1,333.02	0.13
4	$351.06	$1,333.02	0.26
5	$106.08	$1,333.02	0.08
6	$133.92	$1,333.02	0.10
7	$74.44	$1,333.02	0.06
8	$183.17	$1,333.02	0.14
9	$240.53	$1,333.02	0.18
10	$293.87	$1,333.02	0.22
11	$575.52	$1,333.02	0.43
12	$481.02	$1,333.02	0.36
13	$473.15	$1,333.02	0.35
14	$532.94	$1,333.02	0.40
15	$357.69	$1,333.02	0.27
16	$771.51	$1,333.02	0.58

Fenestration Properties – New Construction

Table 95: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category *All Others*, 10-Story Prototype Building

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	$1,222.16	$1,219.25	1.00
2	$808.29	$2,040.18	0.40
3	$605.82	$2,040.18	0.30
4	$523.92	$2,040.18	0.26
5	$529.02	$2,040.18	0.26
6	$185.79	$2,040.18	0.09
7	$109.34	$2,040.18	0.05
8	$263.87	$2,040.18	0.13
9	$356.80	$2,040.18	0.17
10	$441.41	$2,040.18	0.22
11	$893.34	$2,040.18	0.44
12	$731.58	$2,040.18	0.36
13	$717.97	$2,040.18	0.35
14	$818.30	$2,040.18	0.40
15	$546.47	$2,040.18	0.27
16	$1,137.52	$2,040.18	0.56

Fenestration Properties – Alterations and Additions

Create uniform requirements across multifamily buildings based on fenestration type

- Additions
  - Proposal based on area weighted averages for fenestration efficiencies.
  - Meet in the middle for reduced stringency for small fenestration alterations/additions.
    - ❖Threshold for reduced stringency set at < 150 ft^2 added/altered.
  - Separate efficiency requirements for fixed, operable, glazed door, and curtain wall.
    - ❖Increases stringency for buildings with four or more habitable stories.
    - ❖Reduces stringency for buildings with three or fewer habitable stories.
    - ❖Increasing stringency across all buildings did not prove to be cost effective.

Fenestration Properties – Alterations and Additions

Table 7: Proposed Fenestration Thermal Properties by Type and Climate Zone; Alterations and Additions

Window Type	Climate Zones	U-Factor (maximum)	SHGC (maximum)	VT (minimum)
Curtain wall / Storefront	CZ 1	0.38	0.35	0.46
	CZ 2-16	0.38	0.25	0.46
Fixed Windows	CZ 1	0.30	0.35	NR
	CZ 2-16	0.30	0.24	NR
Operable Windows	CZ 1	0.40	0.35	NR
	CZ 2-16	0.40	0.21	NR
Glazed Doors	CZ 1	0.45	0.35	0.17
	CZ 2-16	0.45	0.23	0.17
Additions: Area-Weighted Average	CZ 1	0.34	0.35	NR
	CZ 2-16	0.34	0.23	NR
Alterations or Additions <150 ft^2	CZ 1	0.47	0.35	NR
	CZ 2-16	0.47	0.31	NR

Fenestration Properties – Alterations and Additions

Table 57: First-Year Energy Impacts Per Dwelling Unit – Curtainwall/Storefronts, High-Rise Existing Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	94.69	0.01	10.73	4,863
2	39.40	0.01	11.82	4,687
3	281.67	0.04	16.46	11,431
4	35.39	0.01	8.38	3,875
5	314.56	0.03	15.90	11,060
6	26.24	0.00	5.51	2,306
7	19.91	0.00	4.76	1,767
8	32.97	0.01	5.36	2,711
9	42.11	0.01	6.14	3,395
10	52.77	0.02	6.55	3,725
11	60.00	0.03	9.65	5,295
12	42.91	0.02	9.78	4,585
13	57.28	0.03	7.56	4,721
14	71.79	0.02	9.10	5,294
15	110.19	0.04	3.71	5,208
16	327.31	0.06	4.12	8,455

Fenestration Properties – Alterations and Additions

Table 58: First-Year Energy Impacts Per Dwelling Unit – Combined Fixed, Operable, and Glazed Doors, High-Rise Existing Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	94.10	0.01	19.48	7,081
2	96.51	0.02	16.39	7,557
3	328.04	0.04	20.51	13,651
4	93.56	0.02	11.57	6,505
5	366.21	0.04	19.81	13,183
6	83.23	0.01	7.63	4,311
7	69.01	0.01	6.52	3,352
8	97.14	0.02	7.45	5,169
9	109.54	0.02	8.46	6,006
10	126.27	0.03	9.04	6,463
11	135.05	0.05	13.48	8,659
12	107.93	0.03	13.60	7,560
13	133.90	0.05	10.43	7,885
14	152.05	0.04	12.47	8,638
15	222.32	0.06	5.16	8,952
16	379.81	0.07	9.61	11,117

Fenestration Properties – Alterations and Additions

Table 59: First-Year Energy Impacts Per Dwelling Unit – Combined Fixed, Operable, and Glazed Doors, Prototype D Existing Low-Rise Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(5.31)	0.00	(8.04)	(3,130)
2	0.17	0.00	(4.59)	(1,651)
3	(0.87)	0.00	(3.16)	(1,171)
4	4.51	0.01	(2.88)	(931)
5	(0.84)	0.00	(3.22)	(1,181)
6	6.16	0.01	(1.27)	(182)
7	6.88	0.01	(0.80)	67.20
8	13.91	0.01	(1.09)	(77)
9	10.91	0.01	(1.66)	(442)
10	8.79	0.00	(2.13)	(739)
11	0.97	0.00	(4.10)	(1,910)
12	4.89	0.01	(3.75)	(1,440)
13	0.40	(0.00)	(2.92)	(1,277)
14	1.20	(0.00)	(4.64)	(1,891)
15	(6.56)	(0.01)	(0.64)	(758)
16	2.83	0.01	(8.41)	(3,110)

Fenestration Properties – Alterations and Additions

Table 80: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – Alterations - Curtainwall/Storefronts, High-Rise Existing Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$380.11	$461.16	$841.27
2	$304.46	$506.36	$810.83
3	$1,275.14	$702.45	$1,977.58
4	$305.57	$364.87	$670.44
5	$1,237.68	$675.67	$1,913.35
6	$152.97	$245.96	$398.93
7	$90.30	$215.38	$305.68
8	$227.14	$241.92	$469.06
9	$312.43	$274.83	$587.26
10	$350.44	$294.02	$644.47
11	$485.43	$430.60	$916.03
12	$365.28	$427.88	$793.15
13	$477.27	$339.50	$816.78
14	$508.79	$407.00	$915.79
15	$727.78	$173.24	$901.01
16	$1,277.18	$185.55	$1,462.73

Fenestration Properties – Alterations and Additions

Table 81: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– Alterations - Combined Fixed, Operable, Glazed Doors Category, High-Rise Existing Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$394.20	$830.76	$1,224.96
2	$604.66	$702.78	$1,307.44
3	$1,485.40	$876.17	$2,361.57
4	$621.16	$504.14	$1,125.30
5	$1,438.31	$842.33	$2,280.64
6	$405.14	$340.65	$745.80
7	$284.44	$295.54	$579.98
8	$557.74	$336.56	$894.30
9	$660.10	$378.91	$1,039.00
10	$712.57	$405.59	$1,118.16
11	$895.95	$602.06	$1,498.01
12	$712.76	$595.20	$1,307.96
13	$895.58	$468.50	$1,364.08
14	$936.56	$557.80	$1,494.36
15	$1,307.40	$241.29	$1,548.69
16	$1,495.05	$428.19	$1,923.24

Fenestration Properties – Alterations and Additions

Table 94: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category *All Others*, 5-Story Prototype Building

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	$1,000.06	$796.64	1.26
2	$526.67	$1,333.02	0.40
3	$168.51	$1,333.02	0.13
4	$351.06	$1,333.02	0.26
5	$106.08	$1,333.02	0.08
6	$133.92	$1,333.02	0.10
7	$74.44	$1,333.02	0.06
8	$183.17	$1,333.02	0.14
9	$240.53	$1,333.02	0.18
10	$293.87	$1,333.02	0.22
11	$575.52	$1,333.02	0.43
12	$481.02	$1,333.02	0.36
13	$473.15	$1,333.02	0.35
14	$532.94	$1,333.02	0.40
15	$357.69	$1,333.02	0.27
16	$771.51	$1,333.02	0.58

Fenestration Properties – Alterations and Additions

Table 95: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category *All Others*, 10-Story Prototype Building

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	$1,222.16	$1,219.25	1.00
2	$808.29	$2,040.18	0.40
3	$605.82	$2,040.18	0.30
4	$523.92	$2,040.18	0.26
5	$529.02	$2,040.18	0.26
6	$185.79	$2,040.18	0.09
7	$109.34	$2,040.18	0.05
8	$263.87	$2,040.18	0.13
9	$356.80	$2,040.18	0.17
10	$441.41	$2,040.18	0.22
11	$893.34	$2,040.18	0.44
12	$731.58	$2,040.18	0.36
13	$717.97	$2,040.18	0.35
14	$818.30	$2,040.18	0.40
15	$546.47	$2,040.18	0.27
16	$1,137.52	$2,040.18	0.56

Fenestration Properties: Staff Questions

Any feedback on incremental costs or data that can be shared would be welcome.

Combined Wall U-Factor, Fenestration Properties, All-Electric HVAC

- Wall U-factor unification requirements and fenestration property requirements are not cost effective on their own.
- When packaged with all-electric HVAC measures from Multifamily All-Electric Package CASE Report, measures are cost effective in all climate zones except 16.
- For climate zone 16, CASE team proposes additional PV system requirement scaled to size of building.
  - 35 kW system for 10-story prototype.
  - 30 kW system for 5-story prototype.
- Multifamily All-Electric Package proposal can be found at https://title24stakeholders.com/2022-cycle-case-reports/

Combined Wall U-Factor, Fenestration Properties, All-Electric HVAC

Table 98: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Curtainwall/Storefronts + Electric HVAC + 30 kW PV (CZ 16 only), 5-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Benefits Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$1,319	$9,613	>1
2	$938	$12,366	>1
3	$1,141	$11,798	>1
4	$775	$11,845	>1
5	$732	$9,654	>1
6	$495	$9,643	>1
7	$397	$9,675	>1
8	$455	$9,751	>1
9	$565	$9,654	>1
10	$501	$9,896	>1
11	$973	$9,981	>1
12	$854	$9,848	>1
13	$741	$9,862	>1
14	$435	$9,791	>1
15	$358	$9,910	>1
16	$101	$8,832	>1

Combined Wall U-Factor, Fenestration Properties, All-Electric HVAC

Table 99: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category Curtainwall/Storefront+ Electric HVAC + 35 kW PV (CZ 16 only), 10-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Benefits Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$1,717	$9,604	>1
2	$1,104	$12,405	>1
3	$1,279	$11,817	>1
4	$867	$11,872	>1
5	$851	$9,672	>1
6	$517	$9,661	>1
7	$490	$9,698	>1
8	$480	$9,770	>1
9	$621	$9,680	>1
10	$562	$9,917	>1
11	$1,203	$10,008	>1
12	$985	$9,892	>1
13	$836	$9,890	>1
14	$624	$9,817	>1
15	$412	$9,960	>1
16	$89	$8,940	>1

Combined Wall U-Factor, Fenestration Properties, All-Electric HVAC

Table 100: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category All Other Windows + Framed (Wood or Metal) + Electric HVAC + 35 kW PV (CZ 16 only), 5-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Benefits Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$2,469	$8,723	>1
2	$1,730	$10,873	>1
3	$1,802	$10,305	>1
4	$1,343	$10,351	>1
5	$1,348	$8,161	>1
6	$754	$8,333	>1
7	$571	$8,366	>1
8	$821	$8,258	>1
9	$989	$8,161	>1
10	$965	$8,402	>1
11	$1,294	$8,671	>1
12	$1,544	$8,355	>1
13	$1,368	$8,368	>1
14	$718	$8,481	>1
15	$539	$8,600	>1
16	$399	$7,698	>1

Combined Wall U-Factor, Fenestration Properties, All-Electric HVAC

Table 101: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category All Other Windows + Electric HVAC + 10 kW PV (CZ 16 only), 10-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Benefits Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$2,540	$8,522	>1
2	$1,686	$10,400	>1
3	$1,671	$9,813	>1
4	$1,245	$9,867	>1
5	$1,243	$7,667	>1
6	$658	$7,657	>1
7	$570	$7,693	>1
8	$698	$7,765	>1
9	$889	$7,676	>1
10	$905	$7,912	>1
11	$1,836	$8,004	>1
12	$1,515	$7,888	>1
13	$1,370	$7,886	>1
14	$1,269	$7,812	>1
15	$830	$7,955	>1
16	$117	$7,599	>1

Combined Wall U-Factor, Fenestration Properties, All-Electric HVAC

Any feedback on incremental costs or data that can be shared would be welcome.

Fenestration Area

Create uniform requirements across multifamily buildings

- Apply the prescriptive low-rise residential 20% window-to-conditioned-floor-area limit to high-rise residential buildings.
- Apply the prescriptive high-rise residential 40% window-to-wall area limit and 5% skylight-to-roof ratio limit to low-rise buildings.
- Both limits must be met.
- Include penalties when those thresholds are exceeded via the performance approach.
- Remove the 5% window-to-floor area limit for west-facing glazing (currently in low-rise residential requirements.

Fenestration Area

Create uniform requirements across multifamily buildings

- Area limitations apply to:
  - Newly constructed buildings construction,
  - Additions greater than 700 ft^2 in building size, and
  - Alterations of more than 150 ft^2 of fenestration area.
- CASE team found no technical feasibility challenges with meeting this measure.
- No energy simulation was performed.
- No energy cost savings because there were no energy savings impacts.
- Measure did not increase stringency, and thus, no cost increase, and no cost effectiveness analysis necessary.

Fenestration Area: Staff Questions

Q: Are there any concerns about requiring compliance with two area limitation calculations for multifamily buildings moving forward?

Mechanical Unification Measure Proposals

Space Conditioning – Duct Insulation

Create uniform requirements across all multifamily buildings

- Mandatory Measures
  - Apply high-rise requirement of R-4.2 mandatory duct insulation on supply ducts inside of indirectly conditioned space to all multifamily buildings.
  - No change to uninsulated ducts exposed to directly conditioned space.
  - Apply low-rise R-6 mandatory duct insulation requirement to ducts in all other spaces.
- Prescriptive Measures
  - Apply low-rise R-8 duct insulation requirements to ducts in all other locations in climate zones 1-2, 4, and 8-16.
- Results in less restrictive requirements overall.
  - It was not cost-effective to apply more stringent requirements across all multifamily buildings.

Space Conditioning – Duct Insulation

Table 60: First-Year Energy Impacts Per Dwelling Unit – Three-Story Loaded Corridor Prototype Building – Duct Insulation for Ducts in Unconditioned Space

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(5)	0.000	(0.5)	(295)
2	(6)	(0.004)	(0.3)	(787)
3	(2)	(0.001)	(0.1)	(340)
4	(7)	(0.008)	(0.1)	(400)
5	(2)	(0.001)	(0.1)	(188)
6	(9)	(0.010)	(0.0)	(521)
7	(10)	(0.015)	0.0	(552)
8	(9)	(0.010)	(0.0)	(430)
9	(9)	(0.010)	(0.0)	(424)
10	(10)	(0.011)	(0.1)	(491)
11	(12)	(0.011)	(0.3)	(636)
12	(8)	(0.007)	(0.2)	(515)
13	(11)	(0.009)	(0.2)	(575)
14	(13)	(0.011)	(0.2)	(649)
15	(16)	(0.011)	0.0	(612)
16	(12)	(0.007)	(0.8)	(610)

Space Conditioning – Duct Insulation

Table 61: First-Year Energy Impacts Per Dwelling Unit – Three-Story Loaded Corridor Prototype Building – Duct Insulation for Ducts in Conditioned Space

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	2	0.000	(1.6)	(492)
2	0	(0.001)	(0.8)	(339)
3	(0)	0.000	(0.5)	(208)
4	(2)	(0.003)	(0.4)	(394)
5	0	0.000	(0.4)	(186)
6	(2)	(0.004)	(0.1)	(175)
7	(2)	(0.004)	(0.0)	(153)
8	(3)	(0.004)	(0.1)	(186)
9	(3)	(0.005)	(0.2)	(230)
10	(3)	(0.005)	(0.3)	(284)
11	(3)	(0.006)	(0.7)	(459)
12	(1)	(0.004)	(0.7)	(383)
13	(4)	(0.007)	(0.5)	(416)
14	(5)	(0.006)	(0.7)	(481)
15	(8)	(0.006)	(0.0)	(317)
16	2	(0.003)	(1.5)	(470)

Space Conditioning – Duct Insulation

Cost Savings and Effectiveness

- These measures are not increasing stringency.
- Costs and cost effectiveness analysis do not apply.

Space Conditioning – Duct Insulation

Any question on the duct insulation measures?

Space Conditioning – Duct Leakage Testing

Create uniform requirements across all multifamily buildings

- Apply mandatory verification of duct sealing for multifamily buildings three habitable stories or less to multifamily buildings four habitable stories or greater.
  - Only when ducted systems serving individual dwelling units.
- Regardless of duct location, max 12% total leakage, or max 6% leakage to outside.
- For alterations/additions, max 15% total leakage, or 10% max leakage to outside.
- 2019 Energy Code requires leakage testing for high-rise residential buildings prescriptively for:
  - Single zone, constant volume systems serving less than 5,000 ft^2, where > 25% of duct surface area is in unconditioned space.
  - Max of 6% total leakage.

Space Conditioning – Duct Leakage Testing

Table 37: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Duct Leakage Testing

Prototype ID	Climate Zone	Software	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
5-story & 10-story	All	CBECC-Com	Residential - Zone System - Fan – Flow Capacity	300 cfm/ton * (1-12%) = 264 cfm/ton	300 cfm/ton * (1-6%) = 282 cfm/ton

Space Conditioning – Duct Leakage Testing

Table 62: First-Year Energy Impacts Per Dwelling Unit – Five-Story Mixed-Use Prototype Building – Duct Leakage Testing

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	2	0.002	0.001	57
2	13	0.005	(0.003)	492
3	9	0.003	(0.003)	348
4	17	0.006	0.002	660
5	10	0.003	(0.002)	280
6	17	0.005	(0.002)	539
7	16	0.005	0.001	481
8	21	0.006	(0.003)	712
9	20	0.007	0.001	698
10	22	0.008	0.006	761
11	20	0.007	(0.014)	632
12	19	0.007	0.007	723
13	27	0.009	(0.002)	960
14	16	0.006	(0.006)	528
15	30	0.008	0.000	906
16	10	0.004	0.000	273

Space Conditioning – Duct Leakage Testing

Table 63: First-Year Energy Impacts Per Dwelling Unit – 10-Story Mixed-Use Prototype Building – Duct Leakage Testing

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	3	0.001	(0.004)	68
2	12	0.005	(0.006)	442
3	9	0.003	(0.002)	345
4	16	0.006	0.001	599
5	10	0.003	(0.002)	284
6	17	0.005	0.000	522
7	16	0.005	(0.001)	479
8	20	0.006	(0.001)	652
9	18	0.006	(0.001)	620
10	20	0.007	(0.002)	674
11	18	0.006	(0.004)	555
12	17	0.006	(0.003)	635
13	24	0.007	(0.003)	847
14	14	0.005	0.000	451
15	25	0.006	0.000	745
16	9	0.004	(0.003)	241

Space Conditioning – Duct Leakage Testing

Table 102: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 5-Story Mixed-Use Dwelling Unit– New Construction Duct Leakage

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$9	$0	$9
2	$76	($0)	$76
3	$54	($0)	$54
4	$102	$0	$102
5	$43	($0)	$43
6	$83	($0)	$83
7	$74	$0	$74
8	$110	($0)	$110
9	$107	$0	$108
10	$117	$0	$117
11	$98	($1)	$97
12	$111	$0	$111
13	$148	($0)	$148
14	$82	($0)	$81
15	$140	$0	$140
16	$42	$0	$42

Space Conditioning – Duct Leakage Testing

Table 103: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit– New Construction Duct Leakage

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$11	($0)	$10
2	$68	($0)	$68
3	$53	($0)	$53
4	$92	$0	$92
5	$44	($0)	$44
6	$80	($0)	$80
7	$74	$0	$74
8	$101	($0)	$100
9	$96	($0)	$96
10	$104	($0)	$104
11	$86	($0)	$85
12	$98	($0)	$98
13	$131	($0)	$130
14	$69	($0)	$69
15	$115	($0)	$115
16	$37	($0)	$37

Space Conditioning – Duct Leakage Testing

Table 108: First Cost Summary for Duct Leakage Testing

Cost component	Cost per Dwelling Unit
Material	$10
Labor	$60
HERS Rater	$125
Total Incremental First Cost	$195

Space Conditioning – Duct Leakage Testing

Table 111: Duct Leakage Testing Summary of Replacement Cost

	Cost per Dwelling Unit
Incremental First Cost	$195
Present Value of Replacement Cost at Year 20	$108
Present Value of Remaining Useful Life at Year 30	($40)
Total Present Value of Incremental Cost	$263

Space Conditioning – Duct Leakage Testing

Table 114: 30-Year Cost-Effectiveness Summary Per 5-Story Mixed-Use Dwelling Unit – New Construction Duct Leakage

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	$9	$263	0.03
2	$76	$263	0.29
3	$54	$263	0.20
4	$102	$263	0.39
5	$43	$263	0.16
6	$83	$263	0.32
7	$74	$263	0.28
8	$110	$263	0.42
9	$108	$263	0.41
10	$117	$263	0.45
11	$97	$263	0.37
12	$111	$263	0.42
13	$148	$263	0.56
14	$81	$263	0.31
15	$140	$263	0.53
16	$42	$263	0.16

Space Conditioning – Duct Leakage Testing

Table 115: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – New Construction Duct Leakage

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	$10	$263	0.04
2	$68	$263	0.26
3	$53	$263	0.20
4	$92	$263	0.35
5	$44	$263	0.17
6	$80	$263	0.31
7	$74	$263	0.28
8	$100	$263	0.38
9	$96	$263	0.36
10	$104	$263	0.39
11	$85	$263	0.33
12	$98	$263	0.37
13	$130	$263	0.50
14	$69	$263	0.26
15	$115	$263	0.44
16	$37	$263	0.14

Space Conditioning – Duct Leakage – Staff Questions

Any feedback on incremental costs or data that can be shared would be welcome.

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Create uniform requirements across all multifamily buildings

- Apply low-rise mandatory HERS verification of airflow and fan efficacy for ducted cooling systems to high-rise multifamily buildings.
  - Minimum 350 cfm/ton of cooling.
  - Minimum 0.45 W/cfm for central gas furnace fans, or minimum 0.58 W/cfm for all other air handlers.
- Requirements would also apply to alterations/additions where ducted cooling system is completely replaced or completely new.
- Altered space conditioning systems with mechanical cooling will be subject to minimum 300 cfm/ton requirement.
  - Measure not evaluated in draft report.
  - Will be included in final report.

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Table 38: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Space Cooling Airflow Rate and Fan Efficacy

Prototype ID	Climate Zone	Software	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
5-story & 10-story	All	CBECC-Com	Residential - Zone System - Fan – Flow Capacity	300 cfm/ton	350 cfm/ton
5-story & 10-story	All	CBECC-Com	Residential - Zone System - Fan – Power Per Flow	0.80 W/cfm	0.45 W/cfm

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Table 64: First-Year Energy Impacts Per Dwelling Unit – Five-Story Mixed-Use Prototype Building – Cooling Coil Airflow and Fan Efficacy

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	74	0.009	(3.4)	1,336
2	134	0.034	(2.9)	4,115
3	95	0.020	(2.3)	2,774
4	141	0.041	(1.9)	4,760
5	98	0.019	(2.0)	2,333
6	138	0.035	(1.1)	4,039
7	124	0.032	(0.8)	3,511
8	165	0.045	(1.0)	5,253
9	164	0.048	(1.2)	5,285
10	185	0.055	(1.5)	5,701
11	199	0.060	(2.8)	6,030
12	173	0.050	(2.8)	5,496
13	224	0.065	(2.3)	7,134
14	187	0.051	(2.4)	5,666
15	274	0.071	(0.7)	8,471
16	159	0.032	(4.7)	3,616

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Table 65: First-Year Energy Impacts Per Dwelling Unit – 10-Story Mixed-Use Prototype Building – Cooling Coil Airflow and Fan Efficacy

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	75	0.009	(3.3)	1,340
2	127	0.031	(2.8)	3,709
3	95	0.019	(2.1)	2,709
4	134	0.038	(1.8)	4,298
5	96	0.018	(1.9)	2,348
6	135	0.033	(1.0)	3,893
7	126	0.032	(0.8)	3,541
8	155	0.040	(0.9)	4,784
9	153	0.041	(1.1)	4,738
10	169	0.047	(1.4)	5,085
11	186	0.051	(2.9)	5,339
12	158	0.043	(2.6)	4,796
13	199	0.053	(2.2)	6,127
14	174	0.044	(2.4)	5,041
15	232	0.055	(0.7)	6,958
16	149	0.029	(4.2)	3,285

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Table 104: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 5-Story Mixed-Use Dwelling Unit– New Construction (Ducted) Cooling Coil Airflow and Fan Efficacy

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$338	($133)	$206
2	$749	($115)	$634
3	$518	($91)	$427
4	$808	($75)	$733
5	$440	($80)	$359
6	$667	($45)	$622
7	$574	($33)	$541
8	$851	($42)	$809
9	$865	($51)	$814
10	$942	($64)	$878
11	$1,046	($117)	$929
12	$959	($112)	$846
13	$1,194	($95)	$1,099
14	$972	($100)	$873
15	$1,333	($29)	$1,305
16	$745	($188)	$557

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Table 105: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit– New Construction (Ducted) Cooling Coil Airflow and Fan Efficacy

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$334	($128)	$206
2	$682	($111)	$571
3	$501	($84)	$417
4	$733	($72)	$662
5	$435	($74)	$362
6	$642	($42)	$600
7	$581	($35)	$545
8	$775	($38)	$737
9	$777	($47)	$730
10	$843	($60)	$783
11	$941	($119)	$822
12	$845	($107)	$739
13	$1,034	($90)	$944
14	$874	($98)	$776
15	$1,099	($27)	$1,072
16	$675	($170)	$506

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Table 109: First Cost Summary for Cooling Coil Airflow and Fan Efficacy

Cost component	Cost per Dwelling Unit
Material	$0
Labor	$0
HERS Rater	$100
Total Incremental First Cost	$100

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Table 112: Cooling Coil Airflow and Fan Efficacy Summary of Replacement Cost

	Cost per Dwelling Unit
Incremental First Cost	$100
Present Value of Replacement Cost at Year 20	$55
Present Value of Remaining Useful Life at Year 30	($21)
Total Present Value of Incremental Cost	$135

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Table 116: 30-Year Cost-Effectiveness Summary Per 5-Story Mixed-Use Dwelling Unit – New Construction Cooling Coil Airflow and Fan Efficacy

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	$206	$135	1.53
2	$634	$135	4.70
3	$427	$135	3.17
4	$733	$135	5.44
5	$359	$135	2.67
6	$622	$135	4.62
7	$541	$135	4.01
8	$809	$135	6.00
9	$814	$135	6.04
10	$878	$135	6.51
11	$929	$135	6.89
12	$846	$135	6.28
13	$1,099	$135	8.15
14	$873	$135	6.47
15	$1,305	$135	9.68
16	$557	$135	4.13

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Table 117: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – New Construction Cooling Coil Airflow and Fan Efficacy

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	$206	$135	1.53
2	$571	$135	4.24
3	$417	$135	3.10
4	$662	$135	4.91
5	$362	$135	2.68
6	$600	$135	4.45
7	$545	$135	4.05
8	$737	$135	5.47
9	$730	$135	5.41
10	$783	$135	5.81
11	$822	$135	6.10
12	$739	$135	5.48
13	$944	$135	7.00
14	$776	$135	5.76
15	$1,072	$135	7.95
16	$506	$135	3.75

Space Conditioning – Cooling Air Flow Rate and Fan Efficacy

Any questions on the air flow rate and fan efficacy measures?

Space Conditioning – Refrigerant Charge Verification

Create uniform requirements across all multifamily buildings

- Apply prescriptive HERS verification requirement of refrigerant charge for multifamily buildings with 3 or fewer habitable stories to multifamily buildings of 4 or more habitable stories.
- Applicable to cooling systems serving individual dwelling units.
- Applies to climate zones 2 and 8-15.
- Applies to new construction and to alterations of space cooling systems when refrigerant containing components are altered.

Space Conditioning – Refrigerant Charge Verification

Table 39: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Refrigerant Charge Verification

Prototype ID	Climate Zone	Software	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
5-story & 10-story	All	CBECC-Com	Residential - Zone System - Cooling Coil – EER & SEER	No refrigerant charge verification (multiply by factor of 0.913)	Refrigerant charge verification (multiply by factor of 0.965)

Space Conditioning – Refrigerant Charge Verification

Table 66: First-Year Energy Impacts Per Dwelling Unit – 5-Story Mixed-Use Prototype Building – Refrigerant Charge

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	4	0.003	0.0	102
2	26	0.011	0.0	1,149
3	17	0.006	0.0	682
4	34	0.013	0.0	1,375
5	19	0.006	0.0	559
6	38	0.011	0.0	1,207
7	35	0.010	0.0	1,068
8	47	0.015	0.0	1,618
9	47	0.016	0.0	1,659
10	52	0.017	0.0	1,752
11	52	0.022	0.0	2,076
12	40	0.017	0.0	1,627
13	60	0.023	0.0	2,290
14	53	0.019	0.0	1,996
15	99	0.028	0.0	3,327
16	25	0.011	0.0	675

Space Conditioning – Refrigerant Charge Verification

Table 67: First-Year Energy Impacts Per Dwelling Unit – 10-Story Mixed-Use Prototype Building – Refrigerant Charge

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	5	0.003	0.0	137
2	25	0.010	0.0	1,029
3	18	0.006	0.0	688
4	33	0.012	0.0	1,242
5	20	0.006	0.0	600
6	38	0.011	0.0	1,185
7	36	0.010	0.0	1,102
8	45	0.013	0.0	1,487
9	44	0.013	0.0	1,492
10	48	0.015	0.0	1,565
11	47	0.018	0.0	1,792
12	36	0.014	0.0	1,401
13	53	0.018	0.0	1,936
14	49	0.016	0.0	1,766
15	83	0.021	0.0	2,711
16	1	0.000	0.0	17

Space Conditioning – Refrigerant Charge Verification

Table 106: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 5-Story Mixed-Use Dwelling Unit– New Construction Refrigerant Charge

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
\	$16	$0	$16
2	$177	$0	$177
3	$105	$0	$105
4	$212	$0	$212
5	$86	$0	$86
6	$186	$0	$186
7	$164	$0	$164
8	$249	$0	$249
9	$256	$0	$256
10	$270	$0	$270
11	$320	$0	$320
12	$251	$0	$251
13	$353	$0	$353
14	$307	$0	$307
15	$512	$0	$512
16	$104	$0	$104

Space Conditioning – Refrigerant Charge Verification

Table 107: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit– New Construction Refrigerant Charge

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$21	$0	$21
2	$158	$0	$158
3	$106	$0	$106
4	$191	$0	$191
5	$92	$0	$92
6	$183	$0	$183
7	$170	$0	$170
8	$229	$0	$229
9	$230	$0	$230
10	$241	$0	$241
11	$276	$0	$276
12	$216	$0	$216
13	$298	$0	$298
14	$272	$0	$272
15	$417	$0	$417
16	$3	$0	$3

Space Conditioning – Refrigerant Charge Verification

Table 118: 30-Year Cost-Effectiveness Summary Per 5-Story Mixed-Use Dwelling Unit – New Construction Refrigerant Charge

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	$16	$135	0.12
2	$177	$135	1.31
3	$105	$135	0.78
4	$212	$135	1.57
5	$86	$135	0.64
6	$186	$135	1.38
7	$164	$135	1.22
8	$249	$135	1.85
9	$256	$135	1.90
10	$270	$135	2.00
11	$320	$135	2.37
12	$251	$135	1.86
13	$353	$135	2.62
14	$307	$135	2.28
15	$512	$135	3.80
16	$104	$135	0.77

Space Conditioning – Refrigerant Charge Verification

Table 119: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – New Construction Refrigerant Charge

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	$21	$135	0.16
2	$158	$135	1.18
3	$106	$135	0.79
4	$191	$135	1.42
5	$92	$135	0.69
6	$183	$135	1.35
7	$170	$135	1.26
8	$229	$135	1.70
9	$230	$135	1.70
10	$241	$135	1.79
11	$276	$135	2.05
12	$216	$135	1.60
13	$298	$135	2.21
14	$272	$135	2.02
15	$417	$135	3.10
16	$3	$135	0.02

Space Conditioning – Refrigerant Charge Verification

Any questions on the refrigerant charge verification measures?

Space Conditioning – HERS Verification Package

Create uniform requirements across all multifamily buildings

- Combine duct leakage, airflow, fan efficacy, and refrigerant charge requirements together to demonstrate cost effectiveness compliance.
- Measures do not prove to be cost effective alone.
- Air flow rate and fan efficacy measure cost effective alone.
- Refrigerant charge measure cost effective alone (in climate zones where proposed).
- Duct leakage testing not cost effective alone.
- Proposal applies to all multifamily buildings with ducted cooling systems in climate zones 2-16.
  - Only airflow rate and fan efficacy requirements apply to climate zones 1, 3, and 5.
- Proposal found to not be cost effective in climate zones 1, 3, and 5.
  - Limitation in modeling programs likely lead to conservative.

Space Conditioning – HERS Verification Package

Table 120: 30-Year Cost-Effectiveness Summary Per 5-Story Mixed-Use Dwelling Unit – New Construction Refrigerant Charge

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	$106	$398	0.27
2	$832	$532	1.56
3	$414	$398	1.04
4	$799	$398	2.01
5	$328	$398	0.83
6	$677	$398	1.70
7	$597	$398	1.50
8	$1,166	$532	2.19
9	$1,175	$532	2.21
10	$1,259	$532	2.36
11	$1,350	$532	2.54
12	$1,182	$532	2.22
13	$1,611	$532	3.03
14	$1,250	$532	2.35
15	$2,019	$532	3.79
16	$527	$398	1.33

Space Conditioning – HERS Verification Package

Table 121: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – New Construction Refrigerant Charge

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	$100	$398	0.25
2	$724	$532	1.36
3	$397	$398	1.00
4	$710	$398	1.79
5	$330	$398	0.83
6	$650	$398	1.64
7	$595	$398	1.50
8	$1,055	$532	1.98
9	$1,044	$532	1.96
10	$1,110	$532	2.09
11	$1,161	$532	2.18
12	$1,006	$532	1.89
13	$1,365	$532	2.56
14	$1,087	$532	2.04
15	$1,648	$532	3.10
16	$479	$398	1.21

Space Conditioning – HERS Verification Package

Climate Zone	Cooling Coil Airflow/Fan Watt Draw	Duct Leakage	Refrigerant Charge
1	Yes	No	No
2	Yes – All Applicable		
3	Yes	No	No
4	Yes	Yes	No
5	Yes	No	No
6	Yes	Yes	No
7	Yes	Yes	No
8 through 15	Yes – All Applicable		
16	Yes	Yes	No

Space Conditioning – HERS Verification Package – Staff Qs

Any feedback on incremental costs or data that can be shared would be welcome.

Comments for Todays Workshop

Due Date: October 27, 2020 By 5:00 PM

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

Contact Information

Javier Perez, Energy Commission Specialist II
- Phone: (916) 654-5168
- Email: Javier. Perez@energy.ca.gov

Payam Bozorgchami, P.E. 2022 BEES Project Manager
- Phone: (916) 654-4618
- Email: Payam.Bozorgchami@energy.ca.gov

Larry Froess, **P.E.** CBECC Project Manager
- Phone: (916) 654-4525
- Email: Larry.Froess@energy.ca.gov

Thank You!

Multifamily Water Heater Distribution Proposals

Staff Pre-Rulemaking Workshop

Presenters: Danny Tam, Mechanical Engineer

Date: October 13, 2020

Proposal Summary

- Staff received proposal for changes in multifamily domestic hot water distribution
- Applies to newly construction low-rise and high-rise multifamily buildings with central water heating systems:
  - Increase mandatory pipe insulation thickness for pipe diameter larger than 2 inches.
  - New compliance option for CPC Appendix M
  - Modify existing prescriptive requirements for 2 recirculation loops to a compliance option.

Sections Affected

- New multifamily section(s) in 2022 Title 24
- 120.3

Detailed Description – Increase Pipe Insulation

- Increases mandatory pipe insulation requirements for multifamily DHW pipes 2 inches and larger.
- Create new section in Table 120.3 specific to multifamily DHW systems
- Aligns pipe insulation requirements for all multifamily buildings

	Multifamily Domestic Hot Water Systems				
	Nominal Pipe Diameter (inches)				
	< 1	1 to <1.5	1.5 to < 4	4 to < 8	8 and larger
	Minimum Pipe Insulation Required (Thickness in inches or R-value)				
Inches	1	1.5	2	2	2
R-value	R 7.7	R 12.5	R 16	R 12.5	R 11

Detailed Description – CPC Appendix M Sizing

- Adds a performance compliance option for pipe sizing based on CPC Appendix M. Appendix M (IAPMO 2019)
- Appendix M contains an alternative performance-based pipe sizing calculation procedure. This typically results in smaller pipe sizes than standard practice sizing, which results in lower distribution system heat loss and less wait time.

Detailed Description – Dual Loop Recirculation System

- Change the existing requirement for two recirculation loops in central DHW systems to a compliance option.
- Reduce prescriptive compliance barriers and designer concerns.
- Compliance option would allow future improvement in CSE to support multiple loop design.

Statewide Energy and Energy Cost Impacts – Increase Pipe Insulation

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023	First- Year[a] Electricity Savings	First-Year Peak Electrical Demand Reduction	First-Year Natural Gas Savings	30-Year Present Valued Energy Cost Savings
	(multifamily dwelling units)	(GWh)	(MW)	(MMTherms)	(million 2023 PV$)
1	209	0	0	0.0002	$0.01
2	1,241	0	0	0.0009	$0.04
3	6,021	0	0	0.0044	$0.20
4	3,137	0	0	0.0022	$0.10
5	557	0	0	0.0004	$0.02
6	2,659	0	0	0.0019	$0.09
7	2,859	0	0	0.0020	$0.09
8	3,739	0	0	0.0026	$0.12
9	8,778	0	0	0.0061	$0.28
10	3,101	0	0	0.0022	$0.10
11	885	0	0	0.0006	$0.03
12	4,999	0	0	0.0036	$0.16
13	1,459	0	0	0.0010	$0.05
14	663	0	0	0.0005	$0.02
15	432	0	0	0.0003	$0.01
16	268	0	0	0.0002	$0.01
Total	41,006	0	0	0.0290	$1.31

CPC Appendix M First Year Energy Impact – Low-rise Garden

Climate Zone	Electricity Savings (kWh/Dwelling Unit)	Peak Electricity Demand Reductions (kW/Dwelling Unit)	Natural Gas Savings (therms/Dwelling Unit)	TDV Energy Savings (TDV kBtu/Dwelling Unit)
1	0	0	1.2	406
2	0	0	1.1	372
3	0	0	1.1	374
4	0	0	1.1	368
5	0	0	1.2	391
6	0	0	1.1	363
7	0	0	1.1	355
8	0	0	1.1	353
9	0	0	1.1	356
10	0	0	1.1	358
11	0	0	1.1	366
12	0	0	1.1	365
13	0	0	1.1	363
14	0	0	1.1	364

CPC Appendix M First Year Energy Impact – Low-rise Loaded Corridor

Climate Zone	Electricity Savings (kWh/Dwelling Unit)	Peak Electricity Demand Reductions (kW/Dwelling Unit)	Natural Gas Savings (therms/Dwelling Unit)	TDV Energy Savings (TDV kBtu/Dwelling Unit)
1	0	0	1.7	554
2	0	0	1.5	507
3	0	0	1.6	511
4	0	0	1.5	502
5	0	0	1.6	534
6	0	0	1.5	495
7	0	0	1.5	484
8	0	0	1.5	482
9	0	0	1.5	485
10	0	0	1.5	489
11	0	0	1.5	499
12	0	0	1.5	498
13	0	0	1.5	494
14	0	0	1.5	497
15	0	0	1.4	457
16	0	0	1.6	513

CPC Appendix M First Year Energy Impact – Mid-rise Mixed use

Climate Zone	Electricity Savings (kWh/Dwelling Unit)	Peak Electricity Demand Reductions (kW/Dwelling Unit)	Natural Gas Savings (therms/Dwelling Unit)	TDV Energy Savings (TDV kBtu/Dwelling Unit)
1	0	0	2.8	681
2	0	0	2.6	624
3	0	0	2.6	628
4	0	0	2.6	617
5	0	0	2.7	656
6	0	0	2.5	609
7	0	0	2.5	596
8	0	0	2.5	593
9	0	0	2.5	598
10	0	0	2.5	601
11	0	0	2.5	613
12	0	0	2.5	613
13	0	0	2.5	608
14	0	0	2.5	611
15	0	0	2.3	562
16	0	0	2.6	631

CPC Appendix M First Year Energy Impact – High-rise Mixed use

Climate Zone	Electricity Savings (kWh/Dwelling Unit)	Peak Electricity Demand Reductions (kW/Dwelling Unit)	Natural Gas Savings (therms/Dwelling Unit)	TDV Energy Savings (TDV kBtu/Dwelling Unit)
1	0	0	3.1	751
2	0	0	2.8	688
3	0	0	2.9	693
4	0	0	2.8	681
5	0	0	3.0	724
6	0	0	2.8	672
7	0	0	2.7	657
8	0	0	2.7	654
9	0	0	2.7	660
10	0	0	2.7	663
11	0	0	2.8	676
12	0	0	2.8	675
13	0	0	2.8	670
14	0	0	2.8	674
15	0	0	2.6	620
16	0	0	3.1	751

First Year Statewide GHG Impacts

Measure	Electricity Savings (GWh/yr)	Reduced GHG Emissions from Electricity Savings (Metric Tons CO2e)	Natural Gas Savings (MMTherms/yr)	Reduced GHG Emissions from Natural Gas Savings (Metric Tons CO2e)	Total Reduced CO2e Emissions (Metric Tons CO2e)
Increased Insulation	0	0	0.03	158	**158**
CPC Appendix M Pipe Sizing	0	0	0.09	515	**515**
TOTAL	**0**	**0**	**0.12**	**673**	**673**

Preliminary Findings

Technical Feasibility

- 2-inch pipe insulation is available from multiple manufacturers.
- Most instances of large diameter pipe plus insulation assemblies occur for horizontal pipes that have less space limitations or are pipes at the hot water plant which do not have space limitations.

Cost Effectiveness

- Cost effective in all CZ for increase pipe insulation.
- CPC Appendix M Pipe sizing results in reduction in both first cost and energy consumption.

Comments for Todays Workshop

Due Date: October 27, 2020 By 5:00 PM

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

Contact Information

Danny Tam, Mechanical Engineer
- Phone: (916) 654-8435
- Email: Danny.Tam@energy.ca.gov

Payam Bozorgchami, P.E. 2022 BEES Project Manager
- Phone: (916) 654-4618
- Email: Payam.Bozorgchami@energy.ca.gov

Larry Froess, **P.E.** CBECC Project Manager
- Phone: (916) 654-4525
- Email: Larry.Froess@energy.ca.gov

Thank You!

High Efficiency Boilers and Service Water Heater Proposals

Staff Pre-Rulemaking Workshop

Presenters: Danny Tam, Mechanical Engineer

Date: October 13, 2020

Proposal Summary

- Staff received proposal for change in prescriptive requirement for minimum thermal efficiency and mandatory requirement for oxygen concentration.
- Raised the prescriptive minimum weighted thermal efficiency to 90 percent
  - Align Title 24 Part 6 requirements with the current requirements in ASHRAE 90.1-2019.
  - Add two requirements for the hot water distribution system that aim to optimize condensing operation for boilers.
- Lower threshold for the mandatory oxygen concentration requirement for process boilers.

Sections Affected

- Section 110.2-K
- Section 120.6(d)
- Section 120.9(c)
- Section 140.4(k)
- Section 140.5

Detailed Description – Gas Boiler Submeasure

- Raise the minimum thermal efficiency of gas-fired hot water boiler systems for space heating to a weighted-thermal efficiency of 90 percent.
- Applies to capacities between 1 and 10 million Btu/h installed in newly constructed nonresidential and high-rise residential buildings.
- Additional requirement for the distribution system to optimize condensing operation.
  - Under design conditions the return temperature of hot water to hot water boilers is 120°F or less, or flow rates for supply hot water that recirculates directly into the return system must be no greater than 20 percent of the design flow of the operating boiler.

Detailed Description – Gas Boiler Submeasure – Cont.

- Exception if at least 25 percent of the annual space heating requirement is provided by site-solar, site recovered energy, or heat recovery chillers
- Exception if at least 50 percent of the design heating load is served using perimeter convective heating, radiant ceiling panels, or both.

Detailed Description – Gas Service Water Heating Submeasure

- Raise the minimum thermal efficiency of gas service hot water heating systems to a weighted-thermal efficiency of 90 percent.
- Applies to capacities between 1 million Btu/h or greater installed in newly constructed nonresidential and high-rise residential buildings.
- Exception if 25 percent of the annual service water-heating requirement is provided by site-solar or site recovered energy.

Detailed Description – Oxygen Trim Control

- Measure modifies existing oxygen concentration requirement for process boilers.
- Establish an oxygen concentration requirement of 3 percent for process boilers with input capacity of at least 5 million Btu/h or greater.
- Exception for boilers with steady state full-load combustion efficiency of at least 90 percent.

Statewide Energy and Energy Cost Impacts – New Construction for Gas Boiler Systems for Space Heating

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (million square feet)	First-Year[a] 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)
1	0.28	N/A	N/A	0.00	$0.09
2	1.71	N/A	N/A	0.02	$0.39
3	8.53	N/A	N/A	0.06	$1.39
4	4.43	N/A	N/A	0.03	$0.64
5	0.83	N/A	N/A	0.01	$0.14
6	5.36	N/A	N/A	0.02	$0.44
7	3.98	N/A	N/A	0.01	$0.28
8	7.87	N/A	N/A	0.03	$0.65
9	14.02	N/A	N/A	0.06	$1.36
10	4.80	N/A	N/A	0.03	$0.61
11	1.16	N/A	N/A	0.01	$0.27
12	7.57	N/A	N/A	0.06	$1.50
13	2.18	N/A	N/A	0.02	$0.42
14	1.27	N/A	N/A	0.01	$0.25
15	0.58	N/A	N/A	0.00	$0.04
16	0.39	N/A	N/A	0.01	$0.15
TOTAL	**64.96**	N/A	N/A	**0.37**	**$8.63**

Statewide Energy and Energy Cost Impacts – New Construction for Gas Service Hot Water Heating System Efficiency

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (million square feet)	First-Year[a] 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)
1	0.06	N/A	N/A	0.00	$0.00
2	0.37	N/A	N/A	0.00	$0.01
3	1.64	N/A	N/A	0.00	$0.06
4	0.84	N/A	N/A	0.00	$0.03
5	0.17	N/A	N/A	0.00	$0.01
6	0.94	N/A	N/A	0.00	$0.03
7	1.00	N/A	N/A	0.00	$0.03
8	1.31	N/A	N/A	0.00	$0.05
9	2.10	N/A	N/A	0.00	$0.08
10	1.22	N/A	N/A	0.00	$0.05
11	0.28	N/A	N/A	0.00	$0.01
12	1.49	N/A	N/A	0.00	$0.06
13	0.56	N/A	N/A	0.00	$0.03
14	0.26	N/A	N/A	0.00	$0.01
15	1.82	N/A	N/A	0.00	$0.01
16	0.09	N/A	N/A	0.00	$0.00
TOTAL	12.51	N/A	N/A	0.02	$0.47

Statewide Energy and Energy Cost Impacts – Newly Installed Process Boilers Oxygen Concentration

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (million square feet)	First-Year[a] 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)
All	N/A	N/A	N/A	0.62	13.3

Statewide GHG Emission Impacts – New Construction, Alterations and Additions

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO2e)
Gas Boiler Systems	0	0	0.37	2,032	2,032
Service Water Heating	0	0	0.02	122	122
Process Oxygen Concentration	0	0	0.62	3,392	3,392
TOTAL	0	0	1.01	5,551	5,551

Summary of Benefit-to-Cost Ratios

Submeasure	Benefit-to-Cost Ratio Range (varies by climate zone and building type)
Gas Boiler Systems	0.07 to 6.59
Gas Service Water Heating Systems	2.16 to 13.33
Oxygen Trim Control – Process Boilers	4.8

Preliminary Findings

Technical Feasibility

- Condensing boilers are a mature technology.
- Oxygen trim control is an existing requirement.

Cost Effectiveness

- Cost effective in all CZ and all building types for gas service water heating systems submeasure.
- Cost effective in all CZ for oxygen trim control submeasure.
- Cost effective for certain building type for gas boiler submeasure in all CZ .

Comments for Todays Workshop

Due Date: October 27, 2020 By 5:00 PM

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

Contact Information

Danny Tam, Mechanical Engineer
- Phone: (916) 654-8435
- Email: Danny.Tam@energy.ca.gov

Payam Bozorgchami, P.E. 2022 BEES Project Manager
- Phone: (916) 654-4618
- Email: Payam.Bozorgchami@energy.ca.gov

Larry Froess, **P.E.** CBECC Project Manager
- Phone: (916) 654-4525
- Email: Larry.Froess@energy.ca.gov

Thank You!