DOCKETED	
Docket Number:	22-BSTD-01
Project Title:	2025 Energy Code Pre-Rulemaking
TN #:	252021
Document Title:	Presentation - August 23, 2023, 2025 Energy Code Pre-Rulemaking Workshop
Description:	Slides from August 23, 2023, staff pre-rulemaking workshop on cooling towers, process load pipe insulation, solar pool and spa heating, residential HVAC performance, and multifamily domestic hot water requirements.
Filer:	Javier Perez
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	8/29/2023 4:18:38 PM
Docketed Date:	8/29/2023

Good morning and thank you for joining us.

The workshop will begin shortly.

Housekeeping Rules

Public Comments

Zoom App/Online

- Click “raise hand”

Telephone

- Press *9 to raise hand
- Press *6 to Mute/Unmute

When called upon

- CEC will open your line
- Unmute on your end
- Spell name and state affiliation, if any
- 2 minutes or less per speaker, 1 speaker per entity

Today's Agenda

	Topics	Presenter
1	Introduction	Javier Perez
2	Cooling Towers	Haile Bucaneg
3	Process Load Pipe Insulation	Haile Bucaneg
4	Solar Pool & Spa Heating	Danny Tam
5	Residential HVAC Performance	Bach Tsan
6	Multifamily Domestic Hot Water	Danny Tam
7	Adjourn	

2025 Energy Code – Pre-Rulemaking

Energy Code Authority, Drivers and Themes, Metrics, and Timeline

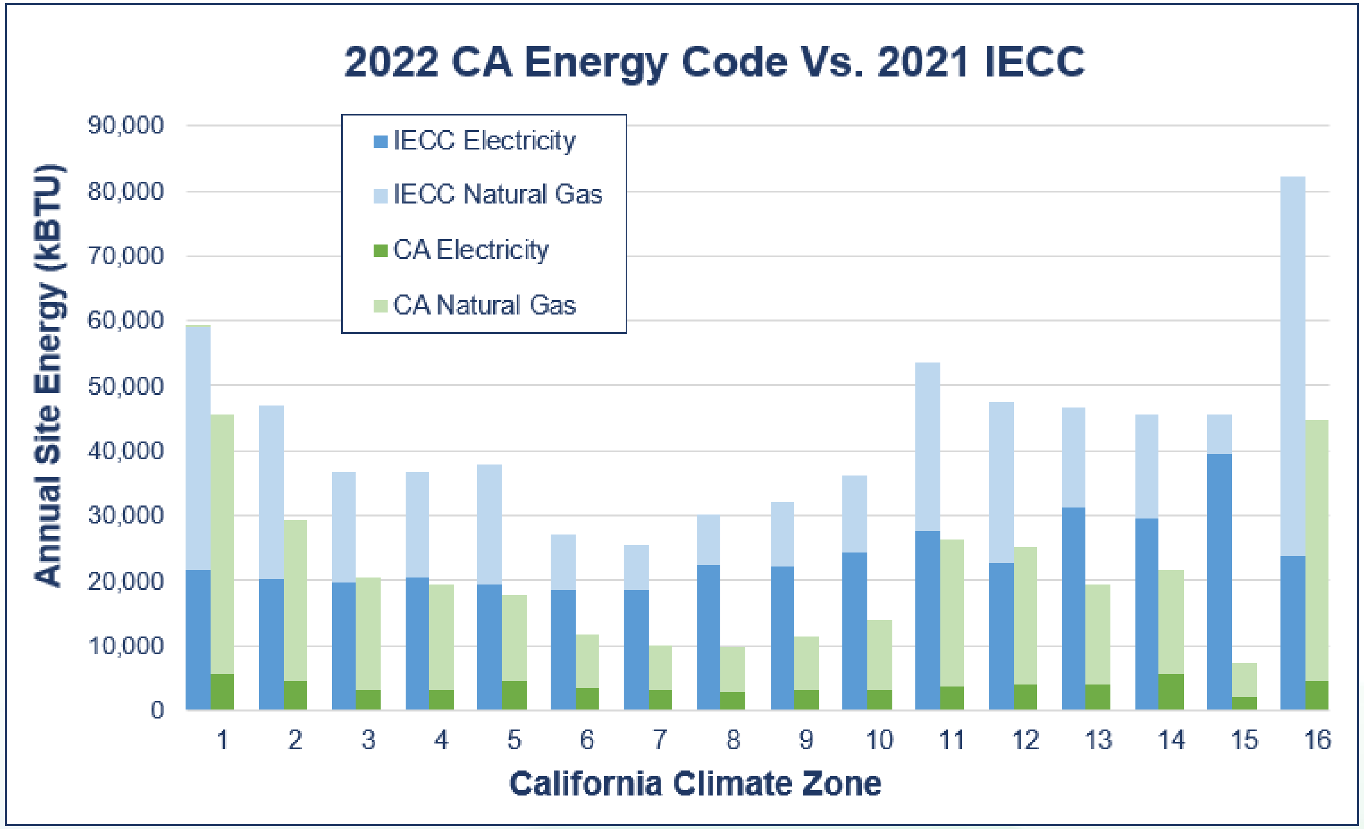
Javier Perez, Project Manager – 2025 Energy Code

August 23, 2023

California Energy Commission's Authority and Process

California's Warren Alquist Act Signed into law in 1974

- Reduction of wasteful, uneconomic, inefficient, or unnecessary consumption of energy as it relates to buildings
- Residential Chart Details:
  - Blue bars: Site energy of a single-family building built to 2021 International Energy Conservation Code (IECC)
  - Green bars: Site energy of a single-family building built to 2022 California Energy Code
- For more on how the 2022 Energy Code compares to federal standards, see our 2022 Impact Analysis at: https://www.energy.ca.gov/publications/2023/impact-analysis-2022-update-california-energy-code



2025 Energy Code Drivers and Themes

State Goals

- Increase building energy efficiency cost-effectively
- Contribute to the state's GHG reduction goals

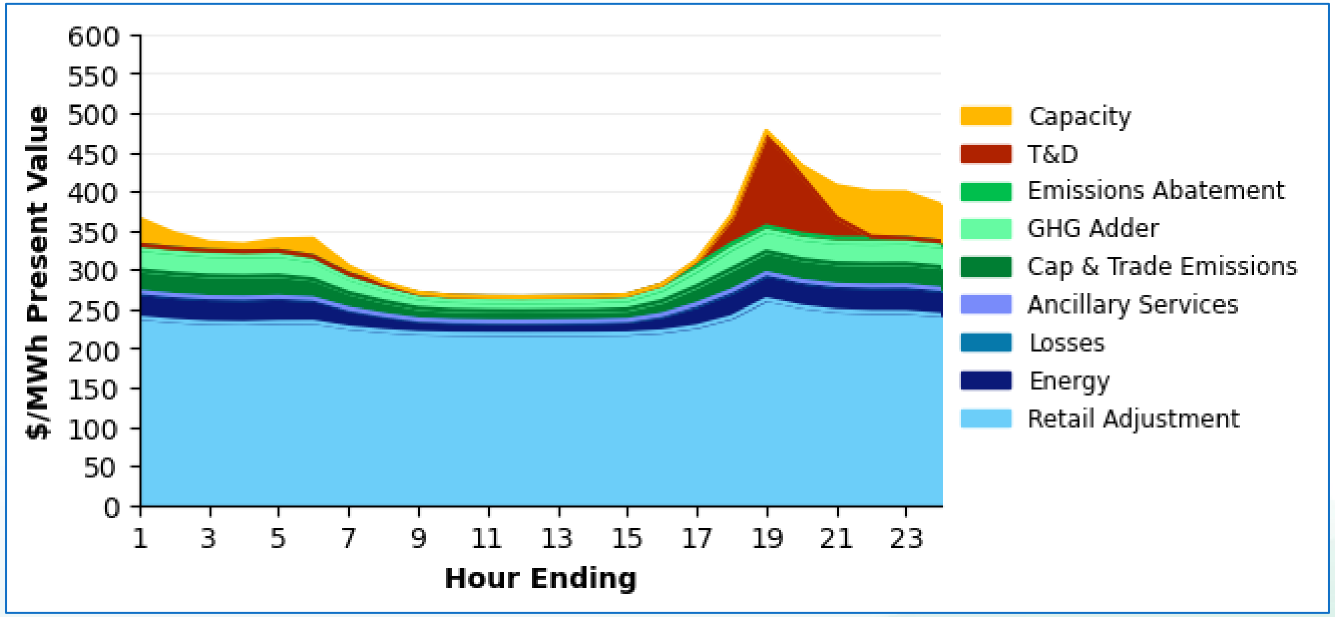
2025 Energy Code Strategies

- Heat pump baselines
- Promote demand flexibility, Solar PV generation and energy storage
- Covered process loads
- Equity & affordable new housing program integration
- Additions, alterations, and smaller homes (e.g., ADUs)
- Electric vehicle readiness support
- Interagency coordination

Long-Term System Cost

Long-term System Cost (LSC) Hourly factors are used to convert predicted site energy use to long-term dollar costs to CA's energy system.

Since the *time* that energy is used is as important as the *amount* of energy used, these factors are generated on an hourly basis for a representative year and created for each of CA's diverse climate zones.



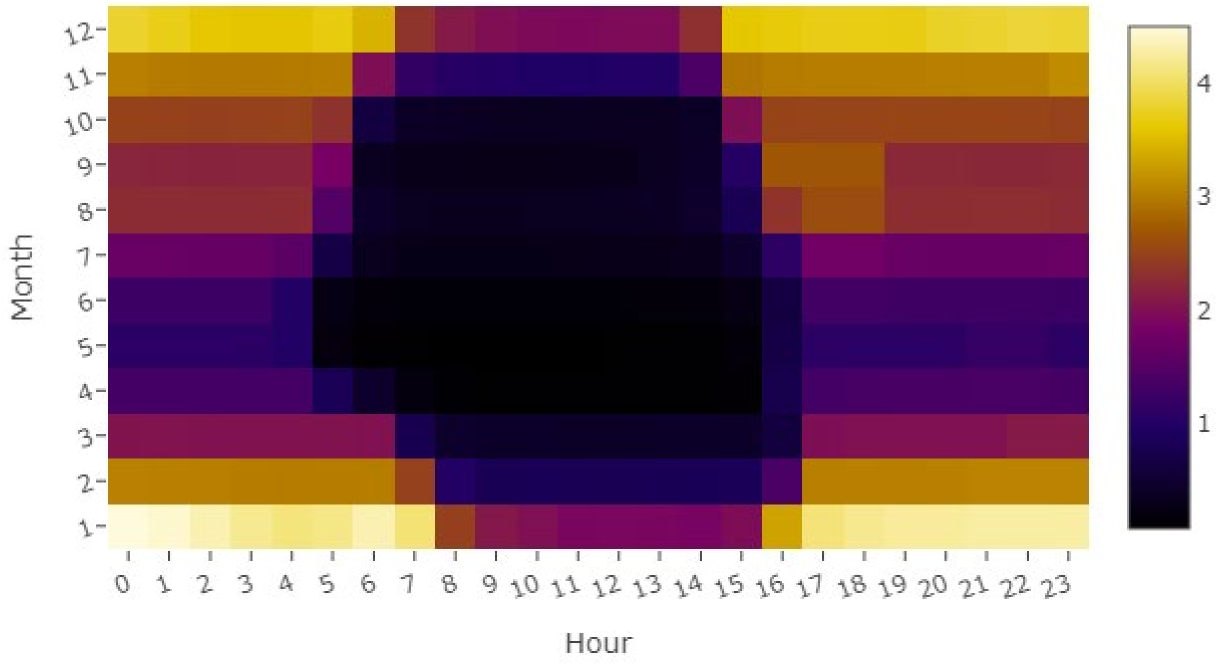
Sample LSC shape by component, average day, levelized 30-year residential, climate zone 12

Source Energy Metric

Long run marginal source energy is defined as the source energy of fossil fuels following the long-term effects of any associated changes in resource procurement.

Source Energy focuses specifically on the amount of fossil fuels that are combusted in association with demand-side energy consumption and assists in aligning our standards with the CA's environmental goals.

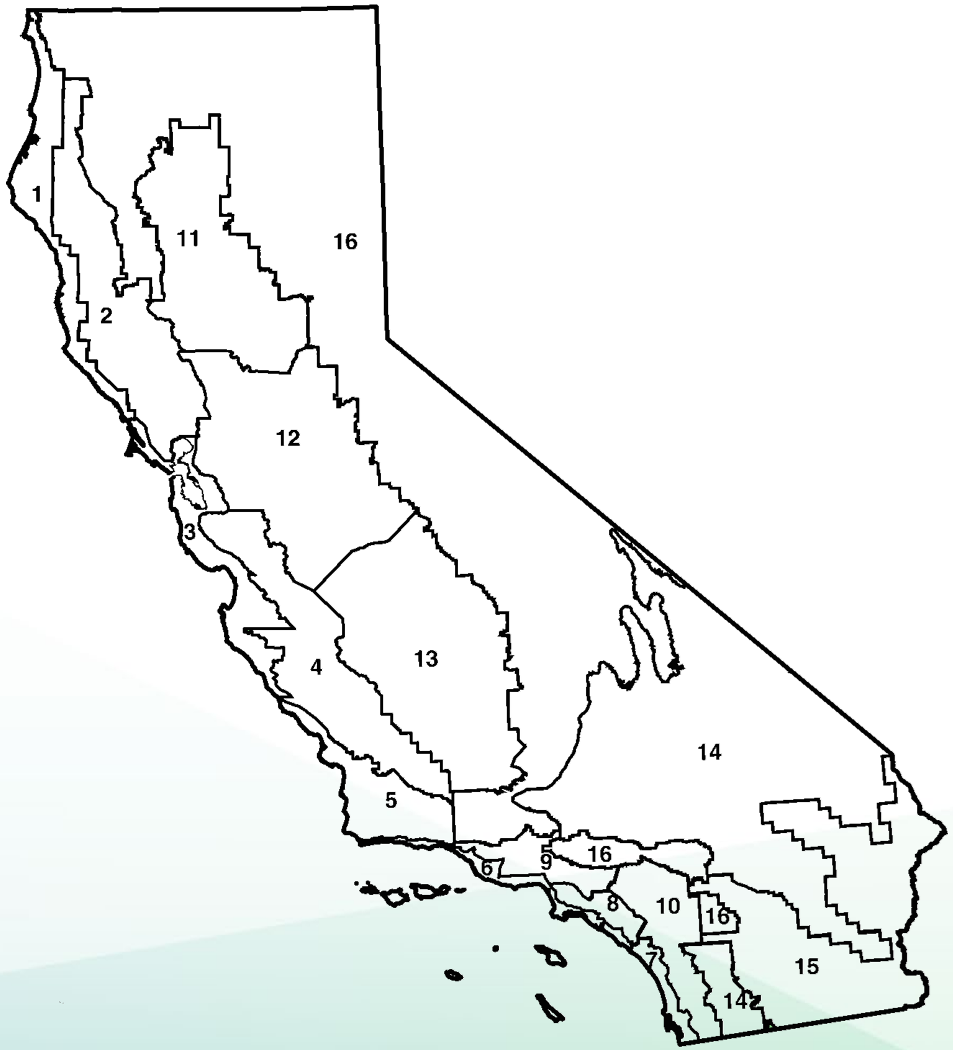
5-Month Average of electricity long run marginal source energy for 2025 Energy Code



California Climate Zones

California has 16 climate zones

- Climate Zones allow software to more accurately simulate variances weather, and as a result, energy consumption of buildings
- A measure's cost effectiveness can vary as a result of weather differences
- Energy Code requirements vary by climate zone as a result



More on 2025 Energy Accounting Metrics

For more on the 2025 Energy Code metrics:

- July 18th, 2022, workshop page, including slides and recording
  - https://www.energy.ca.gov/event/workshop/2022-07/staff-workshop-energy-accounting-2025-building-energy-efficiency-standards
- November 10th, 2022, workshop page, including slides and recording
  - https://www.energy.ca.gov/event/workshop/2022-11/final-staff-workshop-energy-accounting-2025-building-energy-efficiency

2025 Energy Code Work To Date

Milestones	Timelines
Codes & Standards Enhancement (CASE) Team Requested & Received 2025 Measure Proposal Ideas	June 2021 – May 2022
CEC Updated Weather Data, LSC, and Source Energy Metrics	March - November 2022
CASE Team Held Welcome Webinars on 2025 Measures & Work To Come	October 2022
CASE Team Held Stakeholder Workshops on 2025 Proposals	January – May 2023
Energy Commission Worked Feverishly on 2025 Heat Pump and PV System Measures	November 2022 - Now
CASE Team Published Draft Measure Proposal Reports* + Comment Period	May – July 2023

*To view CASE team draft measure proposal reports, and upcoming final reports, visit https://title24stakeholders.com/2025-cycle-case-reports/

2025 Energy Code Work To Come

Milestones	Timelines
CASE Team Publishes Final Measure Proposal Reports	July – August 2023
CEC 2025 Prerulemaking Workshops	July – August 2023
CEC Publishes 2025 Energy Code Draft Updates (Draft Express Terms)	October 2023
CEC Rulemaking for 2025 Energy Code	January 2023 – June 2024
2025 Energy Code Business Meeting Adoption	June 2024
Building Standards Commission Approval of 2025 Energy Code	December 2024
2025 Energy Code Effective Date	January 2026

2025 Energy Code Senior Staff Contacts

- **Javier Perez** – Project Manager
- **Payam Bozorgchami** – Technical Lead, Envelope, Additions and Alterations, ADUs
- **Haile Bucaneg** – Covered Process, Demand Response, Nonresidential and Residential ACM
- **Muhammad Saeed** – Solar Photovoltaic and Energy Storage Systems
- **Bach Tsan** – HVAC Systems, Refrigeration
- **Email Convention at the Energy Commission:** firstname.lastname@energy.ca.gov

2025 Energy Code – Pre-Rulemaking

Cooling Towers

Haile Bucaneg, Senior Mechanical Engineer

August 23, 2023

Cooling Towers

Cooling Towers Agenda

1. Existing code requirements
2. What’s being proposed
3. Energy savings methodology
4. Energy impact results
5. Incremental costs
6. Conclusion

Existing Code Requirements – Blowdown Controls

- Section 110.2(e) – Open and closed-circuit cooling towers.

- Requirements for controls to maximize cycles of concentration based on local water quality conditions using a langelier saturation index (LSI) of 2.5:
    - Conductivity or flow based controls.
    - Documentation of maximum achievable cycles of concentration determined using calculator approved by the Energy Commission.

2025 Proposed Requirements – Blowdown Controls

- **Blowdown controls**:
  - Remove option for flow based controls.
  - Maximum achievable cycles of concentration documentation limited to calculator embedded in compliance document.
  - Identify parameters for when blowdown of cooling towers will occur based on thresholds established in ASHRAE/ANSI 189.1-2020 for:
    - Conductivity
    - Total dissolved solids
    - Total alkalinity
    - Calcium hardness
    - Chlorides
    - Sulfates
    - Silica
    - Langelier saturation index (LSI)
  - Acceptance test added for blowdown controls and overflow alarm.

Key Assumptions – Blowdown Controls

Blowdown controls:

- Water savings only with no change in energy usage.
- Proposed maximum cycles of concentration:
  - 4.0 maximum cycles of concentration.
  - Based on weighted average of most populous city for each climate zone in CA.
  - ASHRAE/ASHRAE 189.1-2020 parameters.
- Baseline maximum cycles of concentration:
  - 3.5 maximum cycles of concentration.

Object Modified	Parameter Name	Baseline Design	Proposed Design
Cooling Tower: VariableSpeed	Blowdown Concentration Ratio	3.5	4.0

Software Used & Prototypes – Blowdown Controls

- Blowdown Controls:
  - EnergyPlus used to estimate building water usage.

Prototype	Number of Stories	Floor Area (ft^2)	Description
Hospital	5	241,374	5-story hospital plus basement DOE prototype model
OfficeLarge	12	498,589	12 story plus basement, office building with 5 zones and a ceiling plenum on each floor. Window-to-wall ratio of 0.40. Standard design HVAC system of two centrifugal water-cooled chillers.

Blowdown Controls First Year Savings Summary – New Construction and Additions, and Alterations

Climate Zone	First Year Water Savings (Gallons) – New Construction and Additions	First Year Water Savings (Gallons) – Alterations
1	295	528
2	20,690	59,441
3	126,549	292,985
4	198,034	486,910
5	6,699	16,356
6	146,975	472,557
7	106,382	406,567
8	356,062	1,186,505
9	609,133	2,011,589
10	178,332	753,905
11	51,032	96,390
12	189,539	650,594
13	73,988	243,663
14	49,787	190,627
15	43,211	153,305
16	5,685	18,651

Incremental Costs – Blowdown Controls

- Blowdown controls:
  - Minimal change in costs for equipment:
    - Conductivity based controls are widely available and an existing option.
  - Additional costs for acceptance testing:
    - RSMeans electrician rate adjusted to California.
    - 6 hours

Description	Increased Cost per Building
6 hours of electrician work to perform acceptance tests.	$654

30-year Present Value Water Savings – Statewide, Blowdown Controls

Climate Zone	30 Year Present Value Water Savings – New Construction and Additions (Million $)	30 Year Present Value Water Savings – Alterations (Million $)
1	$0.0001	$0.0002
2	$0.0086	$0.0247
3	$0.0525	$0.1215
4	$0.0821	$0.2019
5	$0.0028	$0.0068
6	$0.0610	$0.1960
7	$0.0441	$0.1686
8	$0.1477	$0.4920
9	$0.2526	$0.8342
10	$0.0740	$0.3126
11	$0.0212	$0.0400
12	$0.0786	$0.2698
13	$0.0307	$0.1010
14	$0.0206	$0.0791
15	$0.0179	$0.0636
16	$0.0024	$0.0077

Cost Effectiveness – Benefit to Cost Ratio Blowdown Controls

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
New Construction/ Additions	2	28	17	53	18	40	43	65	63	71	71	50	72	67	132	25
Alterations	3	32	17	53	21	40	43	65	62	73	70	51	75	68	137	25

Existing Code Requirements – Cooling Tower Efficiency

- Section 140.4(h)5 and Section 170.2(c)4Fv – Cooling tower efficiency

- Cooling tower efficiency:
    - Applies to axial fan, open-circuit cooling towers serving condenser water loops for chilled water plants with a total of 900 gpm or greater.
    - Rated efficiency of no less than 60 gpm/hp.
    - Exceptions for cooling towers serving buildings in Climate Zone 1 or Climate Zone 16.

2025 Proposed Requirements – Cooling Tower Efficiency

- Cooling tower efficiency:
  - Minimum efficiency based on climate zone.
  - No change in cooling tower efficiency for climate zones 1, 3, 11, 14, and 16.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Efficiency (gpm/hp)	42.1	70	60	70	70	80	80	90	80	90	60	70	80	60	90	42.1

Key Assumptions – Cooling Tower Efficiency

Cooling Tower Efficiency:

- Energy savings only
- Proposed efficiency by climate zone

Climate Zone	Object Modified	Parameter Name	Baseline Design	Proposed Design
Climate Zones 1 and 16	Cooling Tower: VariableSpeed	Design Fan Power	Design Water Flow Rate/ Fan Power: 42.1 GPM/HP	N/A
Climate Zones 3, 11, 14	Cooling Tower: VariableSpeed	Design Fan Power	Design Water Flow Rate/ Fan Power: 60 GPM/HP	N/A
Climate Zones 2, 4, 5, 12	Cooling Tower: VariableSpeed	Design Fan Power	Design Water Flow Rate/ Fan Power: 60 GPM/HP	Design Water Flow Rate/ Fan Power: 70 GPM/HP
Climate Zones 6, 7, 9, 13	Cooling Tower: VariableSpeed	Design Fan Power	Design Water Flow Rate/ Fan Power: 60 GPM/HP	Design Water Flow Rate/ Fan Power: 80 GPM/HP
Climate Zones 8, 10, 15	Cooling Tower: VariableSpeed	Design Fan Power	Design Water Flow Rate/ Fan Power: 60 GPM/HP	Design Water Flow Rate/ Fan Power: 90 GPM/HP

Software Used & Prototypes – Cooling Tower Efficiency

- Cooling Tower Efficiency:
  - EnergyPlus used to estimate building energy usage.

Prototype	Number of Stories	Floor Area (ft^2)	Description
OfficeLarge	12	498,589	12 story plus basement, office building with 5 zones and a ceiling plenum on each floor. Window-to-wall ratio of 0.40. Standard design HVAC system of two centrifugal water-cooled chiller.

Cooling Tower Efficiency First Year Savings Summary – New Construction and Additions

Climate Zone	First Year Electricity Savings (kWh)	First Year Peak Electricity Demand Reductions (kW)	First Year Natural Gas Savings (Million Therms)	First Year Source Energy Savings (Million kBtu)
1	N/A	N/A	N/A	N/A
2	430	2.8	0	0
3	N/A	N/A	N/A	N/A
4	4,140	10.5	0	0
5	120	16.1	0	0
6	8,710	247.8	0	0
7	6,020	200.9	0	0
8	25,300	448.9	0	0
9	28,730	542.1	0	0
10	9,360	87.7	0	0
11	N/A	N/A	N/A	N/A
12	4,380	153.4	0	0
13	2,550	6.2	0	0
14	N/A	N/A	N/A	N/A
15	1,890	4.9	0	0
16	N/A	N/A	N/A	N/A

*No cooling tower efficiency changes in climate zone 1, 3, 11, 14, and 16.

Cooling Tower Efficiency First Year Savings Summary - Alterations

Climate Zone	First Year Electricity Savings (kWh)	First Year Peak Electricity Demand Reductions (kW)	First Year Natural Gas Savings (Million Therms)	First Year Source Energy Savings (Million kBtu)
1	N/A	N/A	N/A	N/A
2	1,279	7.6	0	0
3	N/A	N/A	N/A	N/A
4	10,243	26.1	0	0
5	313	31.6	0	0
6	29,049	808.3	0	0
7	24,199	784.0	0	0
8	87,284	1638.7	0	0
9	99,016	1798.1	0	0
10	43,128	489.4	0	0
11	N/A	N/A	N/A	N/A
12	16,584	381.4	0	0
13	9,268	69.1	0	0
14	N/A	N/A	N/A	N/A
15	7,536	72.4	0	0
16	N/A	N/A	N/A	N/A

*No cooling tower efficiency changes in climate zone 1, 3, 11, 14, and 16.

Incremental Costs – Cooling Tower Efficiency

Cooling tower efficiency:

- Increased cost driven by increased material usage:
  - Larger heat transfer surface area.
  - RSMeans used to estimate baseline cost
  - Cooling tower selection software used to estimate increased cooling tower cost.
  - Increased structural costs - average cost of steel per pound.
  - Increased shipping costs.

Cooling Tower Efficiency.	Average Cooling Tower Incremental Cost (%)	Average Weight (lbs)	Average Increase in Weight (lbs)	Estimated Increased Cost ($)
60 gpm/hp	N/A	13,078	N/A	N/A
70 gpm/hp	0%	13,703	624	$1,435
80 gpm/hp	10%	15,435	2,357	$19,984
90 gpm/hp	11%	15,766	2,688	$22,206

Long Term System Cost (LSC) Savings – Statewide, Cooling Tower Efficiency

Climate Zone	30 Year Long Term System Cost (LSC) Savings – New Construction and Additions (Million $)	30 Year Long Term System Cost (LSC) Savings – Alterations (Million $)
1	N/A	N/A
2	$0.0017	$0.0050
3	N/A	N/A
4	$0.0180	$0.0444
5	$0.0005	$0.0012
6	$0.0400	$0.1335
7	$0.0298	$0.1199
8	$0.1182	$0.4078
9	$0.1338	$0.4610
10	$0.0436	$0.2009
11	N/A	N/A
12	$0.0198	$0.0750
13	$0.0126	$0.0457
14	N/A	N/A
15	$0.0094	$0.0374
16	N/A	N/A

*No cooling tower efficiency changes in climate zone 1, 3, 11, 14, and 16.

Cost Effectiveness – Benefit to Cost Ratio Cooling Tower Efficiency

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
New Construction and Additions	N/A	6.1	N/A	8.8	3.5	1.7	1.4	2.2	1.4	2.9	N/A	11.4	2.0	N/A	2.9	N/A
Alterations	N/A	6.1	N/A	8.8	3.5	1.7	1.4	2.2	1.4	2.9	N/A	11.4	2.0	N/A	2.9	N/A

*No cooling tower efficiency changes in climate zone 1, 3, 11, 14, and 16.

Comments

Comments on today's workshop due

September 5, 2023, by 5:00 PM

Submit comments to CEC Docket 22-BSTD-01

https://efiling.energy.ca.gov/Ecomment/Ecomment.aspx?docketnumber=22-BSTD-01

Contact: Haile.Bucaneg@energy.ca.gov

Questions

Thank You!

2025 Energy Code – Pre-Rulemaking

Process Load Pipe Insulation

Haile Bucaneg, Senior Mechanical Engineer

August 23, 2023

Process Load Pipe Insulation

Process Load Pipe Insulation Agenda

1. Existing code requirements
2. What’s being proposed
3. Energy savings methodology
4. Energy impact results
5. Incremental costs
6. Conclusion

Existing 2022 Code Requirements for Pipe Insulation

Section 120.3(c) – Pipe Insulation Thickness

- Pipe insulation thickness requirements in nonresidential and hotel/motel buildings:
  - Space heating, service water heating, and space cooling systems.
  - Based on fluid operating temperature, insulation conductivity and nominal pipe diameter.

2025 Proposed Requirements

- Extend pipe insulation thickness requirements for process loads:
  - Process heating and process cooling systems.
  - New construction, newly installed process piping, and pipes relocated as part of alterations.
  - Requirements are the same as insulation thickness requirements applied to space heating, service water heating, and space cooling systems.

Key Assumptions

- Summer temperature in climate zone 13 was used when analyzing hot water and steam piping.
- Winter temperature for climate zone 1 was used when analyzing chilled water piping.
- Steel pipe material used for analysis.
- New construction projects include 10% uninsulated pipes and 90% of pipes insulated to current standard practice.
- Alteration projects include 10% uninsulated pipes.

Key Assumptions Insulation

Current Practice Insulation Thickness (inches)

Pipe Diameter (inches)	105-140 ºF	141-200 ºF	201-250 ºF	251-350 ºF	Above 350 ºF
< 1	0.5	1	1	1	1
1 to < 1.5	1	1	1	1	1
1.5 to < 4	1	1	2	2	2
4 to < 8	1	2	2	2	2
8 ≤	1	2	2	2	2

Proposed Insulation Thickness (inches)

Pipe Diameter (inches)	105-140 ºF	141-200 ºF	201-250 ºF	251-350 ºF	Above 350 ºF
< 1	1	1.5	2.5	3	4.5
1 to < 1.5	1.5	1.5	2.5	4	5
1.5 to < 4	1.5	2	2.5	4.5	5
4 to < 8	1.5	2	3	4.5	5
8 ≤	1.5	2	3	4.5	5

Software Used & Prototypes

North American Insulation Manufacturers Association (NAIMA) 3E Plus used to calculate industrial pipe energy losses.

Prototype	Number of Stories	Floor Area (sqft)	Description
Industrial Facility	1	175,000	Average industrial facility size with hot water, steam, chilled water and brine piping of varying diameter, length, and operating temperature

Software Used & Prototypes – Pipe Distribution

Hot Water Pipe Diameter (inches)	Hot Water Pipe Length (feet)	Steam Pipe Diameter (inches)	Steam Pipe Length (feet)	Chilled Water and Brine Pipe Diameter (inches)	Chilled Water and Brine Pipe Length (feet)
0.75	500	0.75	500	0.75	500
1	1000	1	1000	1	1000
3	500	3	1000	3	200
6	200	6	500	6	200
10	100	10	300	10	200

Software Used & Prototypes – Temperature Distribution

Hot Water Temperature (°F)	Hot Water Percent of Facility	Steam Temperature (°F)	Steam Percent of Facility	Chilled Water and Brine Temperature (°F)	Chilled Water and Brine Percent of Facility
120	30%	250	20%	40	20%
140	30%	298	30%	18	30%
200	40%	338	40%	-10	30%
N/A	N/A	366	10%	-20	20%

First Year Savings Summary – New Construction and Additions

Climate Zone	First Year Electricity Savings (kWh)	First Year Peak Electricity Demand Reductions (kW)	First Year Natural Gas Savings (Therms)	First Year Source Energy Savings (Million kBtu)
1	31.7	0.0	42.4	0.004
2	670.1	0.0	894.6	0.082
3	9550.7	0.0	12750.8	1.164
4	4292.2	0.0	5730.3	0.523
5	1051.0	0.0	1403.2	0.128
6	1294.4	0.0	1728.0	0.158
7	1798.7	0.0	2401.4	0.219
8	4031.2	0.0	5381.9	0.491
9	465.5	0..0	621.5	0.0567
10	1364.9	0.0	1822.2	0.166
11	0.0	0.0	0.0	0.0
12	2415.2	0.0	3225.4	0.294
13	4165.2	0.0	5560.8	0.507
14	268.0	0.0	357.9	0.033
15	285.7	0.0	381.4	0.035
16	183.4	0.0	244.8	0.022

First Year Savings Summary – Alterations

Climate Zone	First Year Electricity Savings (kWh)	First Year Peak Electricity Demand Reductions (kW)	First Year Natural Gas Savings (Therms)	First Year Source Energy Savings (Million kBtu)
1	14494	0.02	29580	2.6833
2	61175	0.07	12849	11.3252
3	221629	0.26	452307	41.0294
4	281310	0.33	574106	52.0779
5	21078	0.02	43016	3.9020
6	260235	0.31	531095	48.1763
7	117421	0.14	239636	21.7377
8	434231	0.51	886192	80.3877
9	595639	0.70	1215597	110.2684
10	117161	0.21	361556	32.7973
11	46283	0.05	94455	8.5681
12	208635	0.25	425788	38.6238
13	105372	0.12	215046	19.5071
14	60536	0.07	123543	11.2068
15	18833	0.02	38435	3.4865
16	33214	0.04	67784	6.1488

Incremental Costs

- Mineral fiber insulation with service jackets used to estimate insulation costs.
- Cost for 1 inch insulation was obtained from insulation contractors.
- Formula used to estimate costs above 1 inch of insulation.
- Material costs from RS Means.
- Average contractor costs and costs from RS Means used to estimate labor costs.

Installed Cost per 100 ft

Pipe Diameter	1 Inch Insulation	1.5 Inch Insulation	2 Inch Insulation	2.5 Inch Insulation	3 Inch Insulation	4.5 Inch Insulation	5 Inch Insulation
0.75 Inch	$1,927	$2,307	$2,176	$2,621	$3,089	$4,363	$5,095
1 Inch	$1,705	$1,935	$2,304	$2,732	$3,222	$4,554	$5,324
1.5 Inch	$1,849	$2,113	$2,548	$3,037	$3,599	$5,131	$6,005
2 Inch	$2,049	$2,304	$2,773	$3,284	$3,881	$5,499	$6,440
2.5 Inch	$2,213	$2,502	$3,032	$3,604	$4,270	$6,081	$7,123
4 Inch	$2,794	$3,158	$3,828	$4,549	$5,388	$7,761	$8,983
6 Inch	$3,532	$3,950	$4,817	$5,709	$6,761	$9,620	$11,275
10 Inch	$5,146	$5,704	$6,914	$8,153	$9,622	$13,604	$15,934

Long Term System Cost (LSC) Savings - Statewide

Climate Zone	30 Year Long Term System Cost (LSC) Savings – New Construction and Additions (Million $)	30 Year Long Term System Cost (LSC) Savings – Alterations (Million $)
1	0.0	1.7
2	0.1	7.0
3	0.7	25.5
4	0.3	32.4
5	0.1	2.4
6	0.1	30.0
7	0.1	13.5
8	0.3	50.0
9	0.0	68.6
10	0.1	20.4
11	0.0	5.3
12	0.2	24.0
13	0.3	12.1
14	0.0	7.0
15	0.0	2.2
16	0.0	3.8

Cost Effectiveness – Benefit to Cost Ratio

Building Prototype	Benefits LSC Energy Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
Industrial Pipe Insulation – New Construction and Additions	$2,732	$304.30	8.98
Industrial Pipe Insulation – Alterations	$4,063	$208.41	19.49

Per 1,000 Square Feet

Comments

Comments on today's workshop due

September 5, 2023, by 5:00 PM

Submit comments to CEC Docket 22-BSTD-01

https://efiling.energy.ca.gov/Ecomment/Ecomment.aspx?docketnumber=22-BSTD-01

Contact: Haile.Bucaneg@energy.ca.gov

Questions

- Should insulation pipe requirements be included in existing tables located in nonresidential sections of the Energy Code, or should a new table be created and located in the covered process section of the energy code?

Thank You!

2025 Pre-rulemaking Workshop

Swimming Pool and Spa Heating

Danny Tam, Mechanical Engineer, Building Standards Branch

Date: August 23, 2023

Existing Code Requirements

- **Mandatory Section 110.4(a)4** – No electric resistance heating except:
  - Packaged units with R-6 insulation and tight covers; or
  - On-site renewable energy or site recovered energy providing at least 60% of the annual heating energy
- **Mandatory Section 150.0(p)** – specifies provisions for pump sizing and flow rate, system piping, and sizing of filters and valves.

2025 Proposed Requirements

New section 110.4(c) with three options for compliance applicable to Single Family, Multifamily, and Nonresidential applications when new pool/spa heating system is installed:

- A solar thermal pool heating system with collector surface area equal to 65% of pool surface area for nonres and multifamily, and 60% for single family; or
- A primary heat pump pool heater meeting sizing requirement in new JA15 and minimum efficiency requirement; or
- On-site renewable energy or site recovered energy providing at least 60% of the annual heating energy.

2025 Proposed Requirements

Exceptions to section 110.4(c):

- Portable electric spas compliant with the Appliance Efficiency Regulations.
- Single family buildings with existing heating systems or equipment for pools and/or spas.
- A pool/and or spa that is heated solely by a solar swimming pool or spa heating system.

2025 Proposed Requirements

- Cleanup of Section 150.0(p) to account for federal actions taken on pool pumps.
- Adding requirements for system piping, filters and valves for pools at multifamily buildings.
- New Appendix JA15 with criteria specific to new Section 110.4(c).

Key Assumptions

- Pool heating schedule and frequency per CEC Residential Appliance Survey and National Renewable Energy Laboratory Solar Pool Heating Quantitative Survey
- Baseline heating provided by natural gas heater
- Solar thermal heating provided by unglazed solar collectors with backup heating from natural gas heater

Software Used & Prototypes

- Analysis performed for indoor and outdoor pools and also covered and uncovered pools
- Motel 20,000 gallon and Olympic-size 660,000 gallon pools analyzed
- Analysis performed per enerpool simulation software using CEC 2025 climate files

Incremental Costs – Solar Thermal

- **Material Costs:**
  - Estimated from the California Solar Initiative CSI Commercial Pool Solar Thermal Rebate program's installation cost database
  - Database contains 1,100+ commercial pool solar thermal projects with data on the collector size and total project cost
- **Maintenance Costs:**
  - Routine upkeep: clearing the collector surface, examining for leaks, and preventing foliage obstruction. The tasks could be performed by the property owner
  - Incremental maintenance costs were assumed to be one percent of the initial system cost

Total Incremental Cost – Solar Thermal

- Residential and nonresidential pools 20,000 gallons
    - Incremental Cost of solar collector system: $5,250
    - Maintenance Cost per year: $52.50
- Olympic-sized Pools 660,000 gallons
    - Incremental Cost of solar collector system: $139,214
    - Maintenance Costs per year: $1,392.14

Cost Effectiveness - Solar Thermal

Climate Zone	NR Benefits: LSC Savings + Other PV Savings (2026 PV$/Pool)	NR Costs: Total Incremental PV Costs (2026 PV$/Pool)	NR Benefit-to-Cost Ratio	R Benefits: LSC Savings + Other PV Savings (2026 PV$)	Res Costs: Total Incremental PV Costs (2026 PV$)	Res Benefit-to-Cost Ratio
1	38,284	18,786	2.0	4,692	8,713	(0.5)
2	99,740	18,786	5.3	22,036	8,713	2.5
3	63,681	18,786	3.4	10,707	8,713	1.2
4	125,875	18,786	6.7	25,525	8,713	2.9
5	74,100	18,786	3.9	10,306	8,713	1.2
6	75,320	18,786	4.0	12,547	8,713	1.4
7	78,738	18,786	4.2	11,665	8,713	1.3
8	117,385	18,786	6.2	22,011	8,713	2.5
9	120,703	18,786	6.4	22,093	8,713	2.5
10	123,466	18,786	6.6	28,555	8,713	3.3
11	111,074	18,786	5.9	29,028	8,713	3.3
12	104,567	18,786	5.6	26,181	8,713	3.0
13	118,059	18,786	6.3	32,254	8,713	3.7
14	134,192	18,786	7.1	29,703	8,713	3.4
15	150,548	18,786	8.0	31,713	8,713	3.6
16	102,804	18,786	5.5	12,179	8,713	1.4

Incremental Costs – Heat Pump Pool Heater

- Material Costs
  - Incremental cost represents the addition of a HPPH to the pool heating system.
  - A bank of HPPH creates capacity for Olympic pool
- Maintenance Costs
  - Incremental maintenance costs were assumed to be one percent of the incremental first cost of the HPPH
  - The HPPH was assumed to have a design life of 11 years.

Total Incremental Cost – Heat Pump Pool Heater

- Residential and nonresidential pools 20,000 gallons
  - Incremental Cost of the HPPH: $4,063
  - Maintenance Cost per year: $41
- Olympic-sized Pools 660,000 gallons
  - Incremental Cost of the HPPH: $52,818
  - Maintenance Costs per year: $528

Cost Effectiveness – Heat Pump Pool Heater

Climate Zone	NR Benefits: LSC Savings + Other PV Savings 2026 PV$/Pool	NR Costs: Total Incremental PV Costs 2026 PV$/Pool	NR Benefit-to-Cost Ratio	R Benefits: LSC Savings + Other PV Savings 2026 PV$	R Costs: Total Incremental PV Costs 2026 PV$	R Benefit-to-Cost Ratio
1	89,054	17,416	5.1	38,319	10,982	3.5
2	78,472	17,416	4.5	63,402	10,982	5.8
3	145,811	17,416	8.4	69,401	10,982	6.3
4	63,748	17,416	3.7	46,013	10,982	4.2
5	127,326	17,416	7.3	48,652	10,982	4.4
6	192,883	17,416	11.1	49,295	10,982	4.5
7	202,301	17,416	11.6	34,761	10,982	3.2
8	182,842	17,416	10.5	37,951	10,982	3.5
9	132,699	17,416	7.6	44,100	10,982	4.0
10	128,988	17,416	7.4	58,433	10,982	5.3
11	102,670	17,416	5.9	56,045	10,982	5.1
12	98,988	17,416	5.7	57,292	10,982	5.2
13	116,723	17,416	6.7	64,468	10,982	5.9
14	90,249	17,416	5.2	71,812	10,982	6.5
15	157,971	17,416	9.1	48,143	10,982	4.4
16	40,697	17,416	2.3	29,216	10,982	2.6

Comments

Comments on today's workshop due

September 5, 2023, by 5:00 PM

Submit comments to CEC Docket 22-BSTD-01

https://efiling.energy.ca.gov/Ecomment/Ecomment.aspx?docketnumber=22-BSTD-01

Contact: danny.tam@energy.ca.gov

Thank You!

Appendix

First-Year Electricity Savings

- Based on the analysis of using a gas-fired pool heater baseline, there are no first-year electricity savings

First-Year Natural Gas Savings Per Pool (kBtu/year) – Solar Thermal

Solar Thermal Pool Heater

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8
NR Motel Indoor Pool Uncovered Gas	17,000	69,000	34,000	84,000	42,000	48,000	52,000	88,000
NR Motel Outdoor Pool Covered Gas	19,000	70,000	36,000	88,000	44,000	48,000	52,000	86,000
NR Motel Outdoor Pool Uncovered Gas	20,000	72,000	37,000	93,000	46,000	50,000	54,000	88,000
NR Olympic Indoor Pool Uncovered Gas	490,000	2,000,000	960,000	2,400,000	1,200,000	1,400,000	1,500,000	2,500,000
NR Olympic Outdoor Pool Covered Gas	950,000	2,300,000	1,400,000	3,200,000	1,700,000	1,500,000	1,600,000	2,600,000
NR Olympic Outdoor Pool Uncovered Gas	1,400,000	3,000,000	2,300,000	3,900,000	2,500,000	2,300,000	2,300,000	3,200,000
Residential Outdoor Pool Covered Gas	6,400	44,000	19,000	48,000	18,000	23,000	21,000	39,000
Residential Outdoor Pool Uncovered Gas	6,400	44,000	19,000	52,000	19,000	23,000	22,000	45,000

First-Year Natural Gas Savings per Pool (kBtu/year) – Solar Thermal

Prototype	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NR Motel Indoor Pool Uncovered Gas	84,000	88,000	78,000	75,000	87,000	78,000	110,000	52,000
NR Motel Outdoor Pool Covered Gas	84,000	87,000	79,000	76,000	85,000	86,000	88,000	59,000
NR Motel Outdoor Pool Uncovered Gas	88,000	93,000	87,000	79,000	93,000	110,000	120,000	78,000
NR Olympic Indoor Pool Uncovered Gas	2,400,000	2,500,000	2,300,000	2,200,000	2,500,000	2,300,000	3,200,000	1,500,000
NR Olympic Outdoor Pool Covered Gas	2,700,000	2,800,000	2,700,000	2,400,000	2,600,000	3,500,000	2,800,000	2,700,000
NR Olympic Outdoor Pool Uncovered Gas	3,500,000	3,600,000	3,500,000	3,200,000	3,500,000	4,500,000	4,400,000	3,700,000
Residential Outdoor Pool Covered Gas	39,000	48,000	42,000	48,000	45,000	45,000	29,000	22,000
Residential Outdoor Pool Uncovered Gas	45,000	59,000	62,000	54,000	69,000	63,000	70,000	23,000

30-Year Natural Gas Savings per Pool (2026 PV$) – Solar Thermal

Climate Zone	NR Motel Indoor Pool Uncovered Gas	NR Motel Outdoor Pool Covered Gas	NR Motel Outdoor Pool Uncovered Gas	NR Olympic Indoor Pool Uncovered Gas	NR Olympic Outdoor Pool Covered Gas	NR Olympic Outdoor Pool Uncovered Gas	Residential Outdoor Pool Covered Gas	Residential Outdoor Pool Uncovered Gas
1	8,919	10,153	10,635	254,186	527,143	777,398	1,209	1,205
2	34,947	35,794	37,004	1,000,304	1,216,580	1,642,684	8,241	8,268
3	17,438	18,930	19,660	496,592	791,323	1,266,356	3,563	3,667
4	42,839	45,029	47,991	1,235,879	1,706,417	2,100,552	9,041	9,781
5	22,274	23,352	24,638	636,119	945,277	1,380,443	3,414	3,502
6	25,436	25,679	26,731	726,613	809,476	1,284,602	4,308	4,417
7	27,512	28,029	28,917	785,612	859,792	1,290,280	3,903	4,064
8	45,643	45,225	46,556	1,312,806	1,370,994	1,727,261	7,431	8,377
9	43,961	44,278	46,627	1,264,486	1,446,959	1,916,930	7,330	8,431
10	45,048	45,007	48,539	1,300,441	1,508,489	1,936,807	9,041	11,198
11	38,203	39,023	43,552	1,110,946	1,373,767	1,810,727	7,902	11,589
12	37,388	37,901	39,617	1,079,357	1,260,821	1,679,248	9,067	10,084
13	43,619	43,125	46,522	1,274,819	1,344,934	1,825,778	8,539	13,004
14	39,402	43,697	55,358	1,155,810	1,863,599	2,384,031	8,491	11,817
15	55,158	46,869	60,383	1,637,489	1,511,747	2,403,040	5,383	13,222
16	26,398	30,163	42,167	752,883	1,489,643	1,952,466	4,125	4,272

Long-Term System Cost LSC Savings (2026 PV$) – Solar Thermal

Climate Zone	NR Motel Indoor Pool Uncovered Gas	NR Motel Outdoor Pool Covered Gas	NR Motel Outdoor Pool Uncovered Gas	NR Olympic Indoor Pool Uncovered Gas	NR Olympic Outdoor Pool Covered Gas	NR Olympic Outdoor Pool Uncovered Gas	Residential Outdoor Pool Covered Gas	Residential Outdoor Pool Uncovered Gas
1	8,919	10,153	10,635	254,186	527,143	777,398	1,209	1,205
2	34,947	35,794	37,004	1,000,304	1,216,580	1,642,684	8,241	8,268
3	17,438	18,930	19,660	496,592	791,323	1,266,356	3,563	3,667
4	42,839	45,029	47,991	1,235,879	1,706,417	2,100,552	9,041	9,781
5	22,274	23,352	24,638	636,119	945,277	1,380,443	3,414	3,502
6	25,436	25,679	26,731	726,613	809,476	1,284,602	4,308	4,417
7	27,512	28,029	28,917	785,612	859,792	1,290,280	3,903	4,064
8	45,643	45,225	46,556	1,312,806	1,370,994	1,727,261	7,431	8,377
9	43,961	44,278	46,627	1,264,486	1,446,959	1,916,930	7,330	8,431
10	45,048	45,007	48,539	1,300,441	1,508,489	1,936,807	9,041	11,198
11	38,203	39,023	43,552	1,110,946	1,373,767	1,810,727	7,902	11,589
12	37,388	37,901	39,617	1,079,357	1,260,821	1,679,248	9,067	10,084
13	43,619	43,125	46,522	1,274,819	1,344,934	1,825,778	8,539	13,004
14	39,402	43,697	55,358	1,155,810	1,863,599	2,384,031	8,491	11,817
15	55,158	46,869	60,383	1,637,489	1,511,747	2,403,040	5,383	13,222
16	26,398	30,163	42,167	752,883	1,489,643	1,952,466	4,125	4,272

First-Year Source Energy Savings per Pool (kBtu/year) – Solar Thermal

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8
NR Motel Indoor Pool Uncovered Gas	16,000	62,000	31,000	76,000	38,000	43,000	47,000	79,000
NR Motel Outdoor Pool Covered Gas	18,000	63,000	33,000	79,000	40,000	43,000	47,000	77,000
NR Motel Outdoor Pool Uncovered Gas	18,000	65,000	34,000	84,000	42,000	45,000	48,000	79,000
NR Olympic Indoor Pool Uncovered Gas	450,000	1,800,000	870,000	2,200,000	1,100,000	1,200,000	1,300,000	2,300,000
NR Olympic Outdoor Pool Covered Gas	860,000	2,100,000	1,300,000	2,900,000	1,500,000	1,300,000	1,400,000	2,300,000
NR Olympic Outdoor Pool Uncovered Gas	1,300,000	2,800,000	2,100,000	3,600,000	2,200,000	2,000,000	2,000,000	2,800,000
Residential Outdoor Pool Covered Gas	5,800	40,000	17,000	44,000	16,000	21,000	19,000	36,000
Residential Outdoor Pool Uncovered Gas	5,800	40,000	18,000	47,000	17,000	21,000	19,000	40,000

First-Year Source Energy Savings per Pool (kBtu/year) – Solar Thermal

Prototype	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NR Motel Indoor Pool Uncovered Gas	76,000	79,000	70,000	68,000	79,000	70,000	96,000	47,000
NR Motel Outdoor Pool Covered Gas	76,000	78,000	71,000	68,000	77,000	77,000	79,000	53,000
NR Motel Outdoor Pool Uncovered Gas	79,000	83,000	79,000	71,000	84,000	95,000	100,000	71,000
NR Olympic Indoor Pool Uncovered Gas	2,200,000	2,300,000	2,000,000	2,000,000	2,300,000	2,100,000	2,900,000	1,300,000
NR Olympic Outdoor Pool Covered Gas	2,400,000	2,500,000	2,400,000	2,200,000	2,400,000	3,100,000	2,500,000	2,500,000
NR Olympic Outdoor Pool Uncovered Gas	3,100,000	3,200,000	3,100,000	2,900,000	3,200,000	4,000,000	4,000,000	3,300,000
Residential Outdoor Pool Covered Gas	35,000	43,000	38,000	44,000	41,000	41,000	26,000	20,000
Residential Outdoor Pool Uncovered Gas	40,000	53,000	56,000	49,000	63,000	56,000	63,000	20,000

Long-Term System Cost LSC (2026 $PV) Savings per Pool – Solar Thermal

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8
NR Motel Indoor Pool Uncovered Gas	8,900	35,000	17,000	43,000	22,000	25,000	28,000	46,000
NR Motel Outdoor Pool Covered Gas	10,000	36,000	19,000	45,000	23,000	26,000	28,000	45,000
NR Motel Outdoor Pool Uncovered Gas	11,000	37,000	20,000	48,000	25,000	27,000	29,000	47,000
NR Olympic Indoor Pool Uncovered Gas	250,000	1,000,000	500,000	1,200,000	640,000	730,000	790,000	1,300,000
NR Olympic Outdoor Pool Covered Gas	530,000	1,200,000	790,000	1,700,000	950,000	810,000	860,000	1,400,000
NR Olympic Outdoor Pool Uncovered Gas	780,000	1,600,000	1,300,000	2,100,000	1,400,000	1,300,000	1,300,000	1,700,000
Residential Outdoor Pool Covered Gas	7,300	50,000	22,000	55,000	21,000	26,000	24,000	45,000
Residential Outdoor Pool Uncovered Gas	7,300	50,000	22,000	59,000	21,000	27,000	25,000	51,000

Long-Term System Cost LSC (2026 $PV) Savings per Pool – Solar Thermal

Prototype	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NR Motel Indoor Pool Uncovered Gas	44,000	45,000	38,000	37,000	44,000	39,000	55,000	26,000
NR Motel Outdoor Pool Covered Gas	44,000	45,000	39,000	38,000	43,000	44,000	47,000	30,000
NR Motel Outdoor Pool Uncovered Gas	47,000	49,000	44,000	40,000	47,000	55,000	60,000	42,000
NR Olympic Indoor Pool Uncovered Gas	1,300,000	1,300,000	1,100,000	1,100,000	1,300,000	1,200,000	1,600,000	750,000
NR Olympic Outdoor Pool Covered Gas	1,400,000	1,500,000	1,400,000	1,300,000	1,300,000	1,900,000	1,500,000	1,500,000
NR Olympic Outdoor Pool Uncovered Gas	1,900,000	1,900,000	1,800,000	1,700,000	1,800,000	2,400,000	2,400,000	2,000,000
Residential Outdoor Pool Covered Gas	44,000	55,000	48,000	55,000	52,000	51,000	32,000	25,000
Residential Outdoor Pool Uncovered Gas	51,000	68,000	70,000	61,000	79,000	71,000	80,000	26,000

First-Year Electricity Savings per Pool (kWh/year) – Heat Pump Pool Heater

Heat Pump Pool Heater

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8
NR Motel Indoor Pool Covered Electric	-4,100	-3,700	-5,100	-3,000	-5,000	-6,600	-7,200	-6,900
NR Motel Outdoor Pool Covered Electric	-13,000	-10,000	-17,000	-7,700	-16,000	-19,000	-20,000	-18,000
NR Motel Outdoor Pool Uncovered Electric	-16,000	-13,000	-21,000	-10,000	-20,000	-25,000	-26,000	-23,000
NR Olympic Indoor Pool Covered Electric	-120,000	-110,000	-150,000	-89,000	-150,000	-200,000	-220,000	-210,000
NR Olympic Outdoor Pool Covered Electric	-390,000	-310,000	-500,000	-230,000	-480,000	-580,000	-600,000	-540,000
NR Olympic Outdoor Pool Uncovered Electric	-470,000	-380,000	-600,000	-300,000	-570,000	-700,000	-750,000	-660,000
Residential Outdoor Pool Covered Electric	-4,800	-7,400	-7,200	-4,300	-5,800	-4,700	-3,100	-3,300
Residential Outdoor Pool Uncovered Electric	-7,000	-12,000	-12,000	-8,200	-8,900	-8,200	-5,600	-6,200

First-Year Electricity Savings (kWh/year) – Heat Pump Pool Heater

Prototype	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NR Motel Indoor Pool Covered Electric	-5,200	-5,100	-4,000	-4,100	-4,500	-3,200	-5,200	-1,900
NR Motel Outdoor Pool Covered Electric	-13,000	-13,000	-9,400	-10,000	-9,900	-9,200	-11,000	-4,800
NR Motel Outdoor Pool Uncovered Electric	-17,000	-17,000	-13,000	-14,000	-14,000	-13,000	-16,000	-6,500
NR Olympic Indoor Pool Covered Electric	-160,000	-150,000	-120,000	-120,000	-140,000	-99,000	-160,000	-54,000
NR Olympic Outdoor Pool Covered Electric	-390,000	-380,000	-270,000	-310,000	-290,000	-270,000	-320,000	-140,000
NR Olympic Outdoor Pool Uncovered Electric	-500,000	-480,000	-370,000	-410,000	-410,000	-370,000	-460,000	-190,000
Residential Outdoor Pool Covered Electric	-3,800	-5,100	-4,100	-5,300	-4,700	-5,000	-2,300	-2,700
Residential Outdoor Pool Uncovered Electric	-7,300	-9,600	-9,100	-9,800	-10,000	-12,000	-7,100	-4,800

First-Year Peak Electricity Demand Reductions per Pool (watts) – Heat Pump Pool Heater

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8
NR Motel Indoor Pool Covered Electric	-250	-240	-230	-200	-230	-330	-740	-670
NR Motel Outdoor Pool Covered Electric	-880	-890	-740	-720	-790	-1,000	-2,400	-2,300
NR Motel Outdoor Pool Uncovered Electric	-1,200	-1,200	-1,100	-1,100	-1,100	-1,600	-3,600	-3,400
NR Olympic Indoor Pool Covered Electric	-7,400	-7,200	-6,800	-6,000	-6,900	-10,000	-22,000	-20,000
NR Olympic Outdoor Pool Covered Electric	-30,000	-29,000	-25,000	-24,000	-25,000	-35,000	-83,000	-77,000
NR Olympic Outdoor Pool Uncovered Electric	-37,000	-36,000	-33,000	-31,000	-33,000	-45,000	-100,000	-94,000
Residential Outdoor Pool Covered Electric	-450	-800	-700	-590	-750	-430	-350	-270
Residential Outdoor Pool Uncovered Electric	-620	-1,200	-1,100	-1,000	-1,100	-790	-690	-690

First-Year Peak Electricity Demand Reductions per Pool (watts) – Heat Pump Pool Heater

Prototype	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NR Motel Indoor Pool Covered Electric	-290	-290	-210	-220	-200	-200	-200	-200
NR Motel Outdoor Pool Covered Electric	-870	-920	-560	-680	-480	-640	-420	-690
NR Motel Outdoor Pool Uncovered Electric	-1,300	-1,400	-930	-1,000	-830	-1,100	-890	-1,000
NR Olympic Indoor Pool Covered Electric	-8,600	-8,800	-6,200	-6,600	-5,900	-6,000	-6,300	-5,900
NR Olympic Outdoor Pool Covered Electric	-28,000	-29,000	-17,000	-21,000	-15,000	-22,000	-13,000	-23,000
NR Olympic Outdoor Pool Uncovered Electric	-38,000	-38,000	-27,000	-31,000	-25,000	-31,000	-26,000	-29,000
Residential Outdoor Pool Covered Electric	-320	-250	-330	-500	-240	-480	-69	-400
Residential Outdoor Pool Uncovered Electric	-810	-760	-920	-1,000	-820	-1,100	-660	-600

First-Year Natural Gas Savings per Pool (kBtu/year) – Heat Pump Pool Heater

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8
NR Motel Indoor Pool Covered Electric	73,000	73,000	97,000	61,000	94,000	130,000	140,000	140,000
NR Motel Outdoor Pool Covered Electric	240,000	190,000	320,000	150,000	300,000	370,000	390,000	350,000
NR Motel Outdoor Pool Uncovered Electric	290,000	240,000	400,000	200,000	370,000	470,000	490,000	440,000
NR Olympic Indoor Pool Covered Electric	2,200,000	2,200,000	2,900,000	1,800,000	2,800,000	3,900,000	4,200,000	4,200,000
NR Olympic Outdoor Pool Covered Electric	7,000,000	5,700,000	9,400,000	4,500,000	8,900,000	11,000,000	12,000,000	10,000,000
NR Olympic Outdoor Pool Uncovered Electric	8,300,000	7,100,000	11,000,000	5,900,000	10,000,000	14,000,000	14,000,000	13,000,000
Residential Outdoor Pool Covered Electric	85,000	130,000	140,000	81,000	110,000	93,000	62,000	67,000
Residential Outdoor Pool Uncovered Electric	120,000	210,000	230,000	160,000	160,000	160,000	110,000	120,000

First-Year Natural Gas Savings per Pool (kBtu/year) – Heat Pump Pool Heater

Prototype	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NR Motel Indoor Pool Covered Electric	100,000	100,000	84,000	84,000	95,000	69,000	110,000	38,000
NR Motel Outdoor Pool Covered Electric	260,000	250,000	190,000	200,000	200,000	190,000	230,000	100,000
NR Motel Outdoor Pool Uncovered Electric	340,000	320,000	260,000	270,000	290,000	280,000	330,000	130,000
NR Olympic Indoor Pool Covered Electric	3,200,000	3,200,000	2,500,000	2,500,000	2,800,000	2,100,000	3,400,000	1,100,000
NR Olympic Outdoor Pool Covered Electric	7,700,000	7,400,000	5,500,000	6,000,000	5,900,000	5,600,000	6,700,000	2,900,000
NR Olympic Outdoor Pool Uncovered Electric	9,800,000	9,300,000	7,400,000	7,800,000	8,300,000	7,700,000	9,600,000	3,800,000
Residential Outdoor Pool Covered Electric	76,000	99,000	81,000	100,000	92,000	99,000	48,000	53,000
Residential Outdoor Pool Uncovered Electric	150,000	190,000	180,000	190,000	210,000	240,000	150,000	95,000

Long-Term System Cost LSC Savings per Pool (2026 PV$) – Heat Pump Pool Heater

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8
NR Motel Indoor Pool Covered Electric	15,000	16,000	23,000	13,000	21,000	33,000	35,000	35,000
NR Motel Outdoor Pool Covered Electric	45,000	36,000	72,000	28,000	64,000	93,000	93,000	86,000
NR Motel Outdoor Pool Uncovered Electric	53,000	44,000	90,000	36,000	77,000	120,000	120,000	100,000
NR Olympic Indoor Pool Covered Electric	430,000	480,000	680,000	390,000	630,000	990,000	1,100,000	1,100,000
NR Olympic Outdoor Pool Covered Electric	1,300,000	1,000,000	2,100,000	790,000	1,900,000	2,700,000	2,800,000	2,500,000
NR Olympic Outdoor Pool Uncovered Electric	1,500,000	1,300,000	2,500,000	1,100,000	2,200,000	3,300,000	3,500,000	3,100,000
Residential Outdoor Pool Covered Electric	65,000	100,000	110,000	63,000	79,000	73,000	49,000	53,000
Residential Outdoor Pool Uncovered Electric	97,000	160,000	180,000	120,000	120,000	130,000	90,000	98,000

Long-Term System Cost LSC Savings per Pool (2026 PV$) – Heat Pump Pool Heater

Prototype	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NR Motel Indoor Pool Covered Electric	26,000	26,000	20,000	20,000	24,000	16,000	31,000	8,100
NR Motel Outdoor Pool Covered Electric	61,000	59,000	45,000	44,000	48,000	39,000	65,000	20,000
NR Motel Outdoor Pool Uncovered Electric	77,000	74,000	61,000	57,000	67,000	54,000	92,000	24,000
NR Olympic Indoor Pool Covered Electric	780,000	780,000	610,000	590,000	710,000	480,000	950,000	240,000
NR Olympic Outdoor Pool Covered Electric	1,800,000	1,700,000	1,300,000	1,300,000	1,400,000	1,100,000	1,900,000	530,000
NR Olympic Outdoor Pool Uncovered Electric	2,200,000	2,100,000	1,700,000	1,700,000	2,000,000	1,600,000	2,700,000	710,000
Residential Outdoor Pool Covered Electric	60,000	80,000	66,000	81,000	76,000	78,000	40,000	41,000
Residential Outdoor Pool Uncovered Electric	110,000	150,000	150,000	150,000	170,000	190,000	130,000	75,000

First-Year Source Energy Savings per Pool (kBtu/year) – Heat Pump Pool Heater

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 07	CZ 8
NR Motel Indoor Pool Covered Electric	61,000	61,000	82,000	51,000	79,000	110,000	110,000	110,000
NR Motel Outdoor Pool Covered Electric	190,000	160,000	260,000	120,000	250,000	300,000	300,000	270,000
NR Motel Outdoor Pool Uncovered Electric	230,000	190,000	330,000	170,000	300,000	370,000	380,000	340,000
NR Olympic Indoor Pool Covered Electric	1,800,000	1,800,000	2,400,000	1,500,000	2,400,000	3,200,000	3,400,000	3,400,000
NR Olympic Outdoor Pool Covered Electric	5,700,000	4,600,000	7,700,000	3,700,000	7,300,000	8,800,000	9,000,000	8,000,000
NR Olympic Outdoor Pool Uncovered Electric	6,800,000	5,800,000	9,400,000	4,900,000	8,700,000	11,000,000	11,000,000	9,900,000
Residential Outdoor Pool Covered Electric	70,000	110,000	110,000	67,000	86,000	76,000	51,000	54,000
Residential Outdoor Pool Uncovered Electric	100,000	170,000	190,000	130,000	130,000	130,000	93,000	100,000

First-Year Source Energy Savings per Pool (kBtu/year) – Heat Pump Pool Heater

Prototype	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NR Motel Indoor Pool Covered Electric	87,000	87,000	71,000	70,000	80,000	58,000	93,000	31,000
NR Motel Outdoor Pool Covered Electric	210,000	200,000	150,000	160,000	160,000	160,000	180,000	78,000
NR Motel Outdoor Pool Uncovered Electric	270,000	260,000	210,000	220,000	230,000	220,000	270,000	100,000
NR Olympic Indoor Pool Covered Electric	2,600,000	2,600,000	2,100,000	2,100,000	2,400,000	1,800,000	2,900,000	910,000
NR Olympic Outdoor Pool Covered Electric	6,100,000	5,900,000	4,400,000	4,800,000	4,800,000	4,600,000	5,300,000	2,300,000
NR Olympic Outdoor Pool Uncovered Electric	7,800,000	7,500,000	6,100,000	6,400,000	6,900,000	6,300,000	7,700,000	3,000,000
Residential Outdoor Pool Covered Electric	62,000	82,000	67,000	83,000	77,000	81,000	40,000	43,000
Residential Outdoor Pool Uncovered Electric	120,000	160,000	150,000	160,000	170,000	200,000	130,000	78,000

30-Year Electricity Savings per Pool (2026 PV$) – Heat Pump Pool Heater

Climate Zone	NR Motel Indoor Pool Uncovered Electric	NR Motel Outdoor Pool Covered Electric	NR Motel Outdoor Pool Uncovered Electric	NR Olympic Indoor Pool Uncovered Electric	NR Olympic Outdoor Pool Covered Electric	NR Olympic Outdoor Pool Uncovered Electric	Residential Outdoor Pool Covered Electric	Residential Outdoor Pool Uncovered Electric
1	-19,814	-66,620	-81,805	-584,950	-1,998,914	-2,373,163	-5,083	-7,345
2	-18,273	-54,958	-69,128	-544,666	-1,652,911	-2,031,522	-8,052	-12,585
3	-24,809	-85,606	-110,000	-739,602	-2,554,429	-3,053,894	-7,705	-12,858
4	-15,460	-44,882	-60,622	-462,001	-1,352,166	-1,735,116	-4,793	-9,712
5	-24,809	-85,721	-104,913	-744,887	-2,544,631	-2,974,371	-6,771	-10,285
6	-35,180	-109,696	-140,679	-1,060,705	-3,281,951	-3,969,222	-5,408	-9,550
7	-40,151	-123,414	-154,069	-1,205,717	-3,661,942	-4,428,499	-3,621	-6,665
8	-38,428	-108,088	-137,654	-1,159,360	-3,241,582	-3,967,340	-3,766	-7,245
9	-27,315	-74,981	-98,469	-824,027	-2,236,693	-2,833,784	-4,290	-8,654
10	-27,144	-73,160	-95,413	-818,986	-2,174,838	-2,708,335	-5,458	-10,743
11	-20,716	-50,736	-71,940	-618,743	-1,478,178	-1,999,529	-4,434	-10,136
12	-21,560	-57,900	-78,244	-647,934	-1,718,615	-2,251,202	-5,747	-11,065
13	-22,809	-52,463	-76,641	-687,680	-1,554,356	-2,208,147	-4,790	-10,987
14	-17,172	-52,330	-76,596	-523,287	-1,567,222	-2,088,632	-5,655	-13,547
15	-27,092	-59,523	-89,740	-830,366	-1,772,295	-2,530,460	-2,347	-7,873
16	-9,934	-28,054	-38,346	-289,769	-841,699	-1,084,279	-3,176	-5,466

30-Year Natural Gas Savings per Pool (2026 PV$) – Heat Pump Pool Heater

Climate Zone	NR Motel Indoor Pool Uncovered Electric	NR Motel Outdoor Pool Covered Electric	NR Motel Outdoor Pool Uncovered Electric	NR Olympic Indoor Pool Uncovered Electric	NR Olympic Outdoor Pool Covered Electric	NR Olympic Outdoor Pool Uncovered Electric	Residential Outdoor Pool Covered Electric	Residential Outdoor Pool Uncovered Electric
1	34,470	111,906	135,143	1,018,710	3,290,233	3,912,656	15,912	23,440
2	34,304	90,862	112,941	1,023,575	2,701,231	3,346,569	25,060	39,491
3	47,666	157,341	199,534	1,422,112	4,645,100	5,587,868	25,483	42,455
4	28,681	72,463	96,309	855,845	2,140,443	2,799,290	15,295	29,455
5	45,925	149,491	181,835	1,379,375	4,396,585	5,159,824	19,936	30,865
6	67,894	202,981	256,381	2,048,603	6,015,775	7,291,994	17,519	30,588
7	75,560	216,029	272,430	2,279,670	6,432,086	7,948,419	11,693	21,508
8	73,864	194,457	242,590	2,228,982	5,764,399	7,059,821	12,535	23,475
9	53,036	136,022	175,159	1,600,121	4,024,727	5,066,047	14,225	27,586
10	52,975	132,619	169,576	1,598,936	3,914,429	4,853,595	18,746	35,880
11	41,066	95,789	132,896	1,225,164	2,760,770	3,690,250	15,299	34,518
12	41,091	101,903	135,237	1,233,295	3,003,971	3,911,230	19,100	35,658
13	46,366	100,921	143,725	1,397,608	2,972,521	4,165,570	17,342	39,058
14	32,779	90,937	130,850	999,189	2,663,488	3,639,409	18,639	44,988
15	58,008	124,792	181,555	1,780,576	3,685,102	5,191,653	9,052	29,179
16	17,997	47,647	62,723	526,107	1,373,535	1,794,270	10,049	17,893

30-Year Long-Term System Cost LSC Savings per Pool (2026 PV$) – Heat Pump Pool Heater

Climate Zone	NR Motel Indoor Pool Uncovered Electric	NR Motel Outdoor Pool Covered Electric	NR Motel Outdoor Pool Uncovered Electric	NR Olympic Indoor Pool Uncovered Electric	NR Olympic Outdoor Pool Covered Electric	NR Olympic Outdoor Pool Uncovered Electric	Residential Outdoor Pool Covered Electric	Residential Outdoor Pool Uncovered Electric
1	14,656	45,286	53,338	433,760	1,291,319	1,539,493	10,828	16,095
2	16,031	35,904	43,813	478,910	1,048,320	1,315,047	17,007	26,906
3	22,857	71,735	89,533	682,510	2,090,672	2,533,974	17,778	29,597
4	13,221	27,582	35,687	393,844	788,277	1,064,174	10,502	19,743
5	21,116	63,770	76,921	634,488	1,851,954	2,185,452	13,165	20,580
6	32,714	93,285	115,703	987,898	2,733,824	3,322,771	12,111	21,038
7	35,408	92,615	118,361	1,073,953	2,770,144	3,519,920	8,072	14,842
8	35,436	86,368	104,936	1,069,622	2,522,818	3,092,482	8,768	16,231
9	25,721	61,041	76,691	776,094	1,788,034	2,232,263	9,935	18,933
10	25,831	59,459	74,163	779,950	1,739,591	2,145,260	13,289	25,137
11	20,350	45,053	60,956	606,421	1,282,592	1,690,721	10,865	24,382
12	19,532	44,003	56,994	585,360	1,285,355	1,660,027	13,354	24,594
13	23,557	48,458	67,084	709,928	1,418,166	1,957,423	12,552	28,070
14	15,606	38,607	54,253	475,902	1,096,266	1,550,777	12,984	31,441
15	30,916	65,268	91,815	950,211	1,912,807	2,661,193	6,705	21,307
16	8,062	19,594	24,376	236,338	531,835	709,990	6,874	12,427

15-minute Break

We will resume at 10:30

2025 Energy Code – Pre-Rulemaking

Residential HVAC Performance

Bach Tsan P.E., Senior Mechanical Engineer, Building Standards Branch

August 23, 2023

Agenda Overview

Topics:

1. Residential HVAC System Design
2. Supplemental Heat
3. Defrost Function
4. Crankcase heating
5. Refrigerant Charge Verification
6. Variable Capacity Systems

Agenda

- Baseline Overview
- Existing Code Requirements
- 2025 Proposed Requirements
- Energy Savings Methodology
- Energy Impact Results
- Cost Analysis
- Questions and Comments

Single Family Software Used & Prototypes

- **Software used:** CBECC-Res 2025 RV.

- **Prototypes used:**

  New construction

  1. Single-story, 2,100 ft^2 home — Weighting: 42%
  2. Two-story, 2,700 ft^2 home — Weighting: 56%
  3. Single-story, 500 ft^2, small home — Weighting: 2%

  Alterations

  1. Single-story, 1,665 ft^2 existing home

Multifamily Software Used & Prototypes

- **Software used:** CBECC 2025 RV
- **Prototypes used:**
  New construction & alterations
  1. Low-Rise Garden: 2-story, 8-unit apartment building, 7,320 ft^2
  2. Loaded Corridor: 3-story, 36-unit apartment building, 39,264 ft^2
  3. Mid-Rise Mixed Use: 5-story, 88-unit mixed use bldg., 112,641ft^2
  4. High-Rise Mixed Use: 10-story, 117-unit mixed use bldg., 125,400 ft^2

Design
(Sizing, Equipment Selection, and Ducts/Diffusers)

Measure Overview

Design

Proper design of Residential Systems related to sizing, equipment selection and the air distribution systems and accessories benefits:

- Energy Savings
- Effective Operation
- Improved comfort

Design considerations

- Load calculations assist in systems sizing and equipment selection
- Duct and diffusers address efficiency in delivery of conditioned air

Existing Code Requirements

Design

Section 150.0 – SINGLE-FAMILY RESIDENTIAL BUILDINGS - MANDATORY FEATURES AND DEVICES

- Section 150.0(h)1 - Space-conditioning equipment / Building cooling and heating loads
- Section 150.0(h)2 - Space-conditioning equipment / Design Conditions
- Section 150.0(m) Air-Distribution and Ventilation System Ducts, Plenums, and Fans.
    - Refers to **California Mechanical Code Chapter 6 – Duct Systems**
        - Requires that residential ducts be sized according to ACCA Manual D

Key Assumptions

Design

- Cooling dominated climates (CZs 2-15), applies to alterations only
  - Impacts of cooling undersizing/oversizing not fully considered in CBECC
  - Cooling savings calculated as 7.3% energy penalty for 20% oversizing, based on NIST study (Domanski, Henderson, & Payne, 2014).
- Heating dominated climates (CZ 1, 16), new construction & alterations, single family only
  - Heating savings a result of reduced backup heat operation, calculated as the difference between compressor sized to 90% of the heating load and 100% of the heating load
- All other building characteristics meet 2022 prescriptive requirements.

2025 Proposed Requirements

Design

- The mandatory measure proposed in this section include the following:
  - Require documentation of load calculations and system sizing, even for like-for-like replacements; and
  - Provide details on duct/diffuser design; and
  - Require use of average infiltration assumptions (or blower door test).
  - Allow simplifying assumptions in some load calculations;
    - Minimum heating capacity—not including supplementary heating; and maximum equipment sizing limits (or ensure adequate airflow).

First-Year Energy Savings

Design
Single Family 2,100/2,700 ft^2 Weighted New Construction

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	33	0.008		105
2	N/A	N/A		N/A
3	N/A	N/A		N/A
4	N/A	N/A		N/A
5	N/A	N/A		N/A
6	N/A	N/A		N/A
7	N/A	N/A		N/A
8	N/A	N/A		N/A
9	N/A	N/A		N/A
10	N/A	N/A		N/A
11	N/A	N/A		N/A
12	N/A	N/A		N/A
13	N/A	N/A		N/A
14	N/A	N/A		N/A
15	N/A	N/A		N/A
16	6	0.002		3

First-Year Energy Savings

Design

Single Family 500 ft^2 Small Home New Construction

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	6	0.002		20
2	N/A	N/A		N/A
3	N/A	N/A		N/A
4	N/A	N/A		N/A
5	N/A	N/A		N/A
6	N/A	N/A		N/A
7	N/A	N/A		N/A
8	N/A	N/A		N/A
9	N/A	N/A		N/A
10	N/A	N/A		N/A
11	N/A	N/A		N/A
12	N/A	N/A		N/A
13	N/A	N/A		N/A
14	N/A	N/A		N/A
15	N/A	N/A		N/A
16	15	0.004		45

First-Year Energy Savings

Design

Single Family 1,665 ft^2 Alteration

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	51	0.013		167
2	38	N/A		30
3	8	N/A		7
4	155	N/A		111
5	5	N/A		5
6	53	N/A		34
7	74	N/A		50
8	135	N/A		94
9	127	N/A		94
10	182	N/A		122
11	254	N/A		198
12	112	N/A		102
13	317	N/A		250
14	222	N/A		143
15	652	N/A		447
16	59	0.012		167

First-Year Energy Savings

Design
Multi Family 2 Story Low-Rise Garden Alteration

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	1	0.000		2
3	0	0.000		0
4	10	0.000		11
5	0	0.000		0
6	3	0.000		4
7	6	0.001		8
8	22	0.001		21
9	20	0.001		20
10	29	0.001		26
11	39	0.001		39
12	15	0.001		17
13	47	0.002		50
14	33	0.001		30
15	108	0.004		102
16	N/A	N/A		N/A

First-Year Energy Savings

Design
Multi Family 3 Story Loaded Corridor Alteration

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	5	0.000		5
3	2	0.000		3
4	17	0.000		17
5	2	0.000		3
6	9	0.001		10
7	14	0.001		16
8	33	0.001		31
9	27	0.001		27
10	39	0.001		35
11	50	0.002		48
12	25	0.001		26
13	59	0.002		59
14	46	0.001		39
15	130	0.004		120
16	N/A	N/A		N/A

First-Year Energy Savings

Design
Multi Family 5 Story Mid-Rise Mixed-Use Alteration

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	30	0.000		20
3	14	0.000		9
4	54	0.001		42
5	17	0.000		10
6	37	0.001		32
7	44	0.001		41
8	77	0.002		62
9	70	0.002		57
10	87	0.002		68
11	97	0.002		81
12	64	0.001		52
13	107	0.003		94
14	91	0.002		69
15	198	0.005		167
16	N/A	N/A		N/A

First-Year Energy Savings

Design

Multi Family 10 Story High-Rise Mixed-Use Alteration

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	9	0.000		6
3	3	0.000		2
4	23	0.000		19
5	4	0.000		3
6	12	0.001		11
7	15	0.001		15
8	40	0.001		31
9	36	0.001		30
10	51	0.001		39
11	63	0.001		54
12	30	0.000		26
13	71	0.002		65
14	57	0.001		43
15	149	0.004		124
16	N/A	N/A		N/A

30-Year Energy Cost Savings

Total 30-Year LSC Savings (2026 PV$) Design

Climate Zone	Single Family 2,100/2,700 ft^2 Weighted New Construction	Single Family 500 ft^2 Small Home New Construction	Single Family 1,665 ft^2 Alteration	Low-Rise Garden Multifamily	Loaded Corridor Multifamily	Mid-Rise Mixed Use Multifamily	High-Rise Mixed Use Multifamily
1	$269	$45	$416	N/A	N/A	N/A	N/A
2	N/A	N/A	$30	$8	$28	$138	$42
3	N/A	N/A	$7	$3	$15	$64	$15
4	N/A	N/A	$111	$78	$128	$311	$148
5	N/A	N/A	$5	$2	$14	$74	$18
6	N/A	N/A	$34	$28	$63	$202	$76
7	N/A	N/A	$50	$58	$111	$276	$112
8	N/A	N/A	$94	$147	$216	$430	$240
9	N/A	N/A	$94	$139	$187	$398	$228
10	N/A	N/A	$122	$188	$250	$484	$305
11	N/A	N/A	$198	$268	$339	$568	$398
12	N/A	N/A	$102	$118	$185	$377	$198
13	N/A	N/A	$250	$333	$405	$644	$469
14	N/A	N/A	$143	$215	$288	$510	$340
15	N/A	N/A	$447	$689	$818	$1,144	$904
16	$28	$120	$433	N/A	N/A	N/A	N/A

Cost Effectiveness

Benefit-to-Cost Ratios
Design

Climate Zone	Single Family 2,100/2,700 ft^2 Weighted New Construction	Single Family 500 ft^2 Small Home New Construction	Single Family 1,665 ft^2 Alteration	Low-Rise Garden Multifamily	Loaded Corridor Multifamily	Mid-Rise Mixed Use Multifamily	High-Rise Mixed Use Multifamily
1	infinite	infinite	3.83	N/A	N/A	N/A	N/A
2	N/A	N/A	infinite	infinite	infinite	infinite	infinite
3	N/A	N/A	infinite	infinite	infinite	infinite	infinite
4	N/A	N/A	infinite	infinite	infinite	infinite	infinite
5	N/A	N/A	infinite	infinite	infinite	infinite	infinite
6	N/A	N/A	infinite	infinite	infinite	infinite	infinite
7	N/A	N/A	infinite	infinite	infinite	infinite	infinite
8	N/A	N/A	infinite	infinite	infinite	infinite	infinite
9	N/A	N/A	infinite	infinite	infinite	infinite	infinite
10	N/A	N/A	infinite	infinite	infinite	infinite	infinite
11	N/A	N/A	infinite	infinite	infinite	infinite	infinite
12	N/A	N/A	infinite	infinite	infinite	infinite	infinite
13	N/A	N/A	infinite	infinite	infinite	infinite	infinite
14	N/A	N/A	infinite	infinite	infinite	infinite	infinite
15	N/A	N/A	infinite	infinite	infinite	infinite	infinite
16	infinite	infinite	1.09	N/A	N/A	N/A	N/A

Supplemental Heat

Measure Overview

Supplemental Heating

- Supplemental Heating comes in the form of gas or electric
  - Adds capacity to maintain comfort and satisfaction
- Energy intensive when compared to a heat pump
  - Electric resistance uses approximately 3 times energy
  - Gas furnace heat source results in more green house gas emissions

Existing Code Requirements

Supplemental Heat

SECTION 110.2 - MANDATORY REQUIREMENTS FOR SPACE-CONDITIONING EQUIPMENT

Section 110.2(b) - Controls for Heat Pumps with Supplementary Electric Resistance Heaters

Exception 1 to Section 110.2(b): Controls may allow supplemental Heater operation during:

- Defrost: and
- Transient periods such as start-ups

Key Assumptions

Supplemental Heat

- Standard Design: Supplemental heating allowed to operate as needed.
- Proposed Design: Supplemental heating allowed to operate only when outdoor air temperatures ≤ 35°F.
- Supplemental heating evaluated as electric resistance.
- Both fixed and setback thermostat setpoints analysis. Results presented as an average of the two.
- All other building characteristics meet 2022 prescriptive requirements.

2025 Proposed Requirements

Supplemental Heat

The mandatory measure proposed in this section include the following for all climate zones except 15 :

- Install and field verify controls that lock out supplementary heating above a certain outdoor temperature:
  - Both electric resistance strip heating and furnaces in dual fuel systems; and
  - Lock out at outdoor air temperatures above 35°F
- Impose strip heating capacity limits
  - Limit is based on the greater of either:
    - Difference between the heating capacity at the design temperature and the heating design load, <u>or</u>
    - 2.7 kw per nominal ton, whichever is greater.
- Controls are HERS verified

First-Year Energy Savings

Supplemental Heating
Single Family 2,100/2,700 ft^2 Weighted New Construction

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	424	0.061		1,025
2	241	0.047		696
3	135	0.035		448
4	175	0.028		463
5	138	0.034		431
6	36	0.009		134
7	31	0.005		100
8	38	0.010		138
9	54	0.016		200
10	54	0.018		192
11	157	0.036		486
12	190	0.042		562
13	109	0.031		364
14	224	0.054		693
15	N/A	N/A		N/A
16	303	0.054		789

First-Year Energy Savings

Supplemental Heating
Single Family 500 ft^2 Small Home New Construction

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	N/A	N/A		N/A
3	N/A	N/A		N/A
4	N/A	N/A		N/A
5	N/A	N/A		N/A
6	N/A	N/A		N/A
7	N/A	N/A		N/A
8	N/A	N/A		N/A
9	N/A	N/A		N/A
10	N/A	N/A		N/A
11	N/A	N/A		N/A
12	N/A	N/A		N/A
13	N/A	N/A		N/A
14	N/A	N/A		N/A
15	N/A	N/A		N/A
16	N/A	N/A		N/A

First-Year Energy Savings

Supplementary Heating
Single Family 1,665 ft^2 Alteration

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	376	0.053		856
2	137	0.026		370
3	129	0.026		366
4	91	0.015		230
5	140	0.027		372
6	32	0.008		116
7	27	0.005		90
8	56	0.016		189
9	62	0.019		209
10	55	0.020		179
11	103	0.020		287
12	122	0.024		329
13	85	0.020		256
14	155	0.035		454
15	N/A	N/A		N/A
16	245	0.041		626

30-Year Energy Cost Savings

Total 30-Year LSC Savings (2026 PV$)
Supplementary Heating

Climate Zone	Single Family 2,100/2,700 ft^2 Weighted New Construction	Single Family 500 ft^2 Small Home New Construction	Single Family 1,665 ft^2 Alteration	Low-Rise Garden Multifamily	Loaded Corridor Multifamily	Mid-Rise Mixed Use Multifamily	High-Rise Mixed Use Multifamily
1	$3,061	N/A	$2,648	N/A	N/A	N/A	N/A
2	$1,853	N/A	$1,023	N/A	N/A	N/A	N/A
3	$1,096	N/A	$978	N/A	N/A	N/A	N/A
4	$1,294	N/A	$662	N/A	N/A	N/A	N/A
5	$1,099	N/A	$1,038	N/A	N/A	N/A	N/A
6	$289	N/A	$253	N/A	N/A	N/A	N/A
7	$215	N/A	$191	N/A	N/A	N/A	N/A
8	$299	N/A	$440	N/A	N/A	N/A	N/A
9	$435	N/A	$491	N/A	N/A	N/A	N/A
10	$436	N/A	$441	N/A	N/A	N/A	N/A
11	$1,229	N/A	$777	N/A	N/A	N/A	N/A
12	$1,475	N/A	$915	N/A	N/A	N/A	N/A
13	$880	N/A	$658	N/A	N/A	N/A	N/A
14	$1,700	N/A	$1,156	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	$2,186	N/A	$1,744	N/A	N/A	N/A	N/A

Cost Effectiveness

Benefit-to-Cost Ratios
Supplementary Heating

Climate Zone	Single Family 2,100/2,700 ft^2 Weighted New Construction	Single Family 500 ft^2 Small Home New Construction	Single Family 1,665 ft^2 Alteration	Low-Rise Garden Multifamily	Loaded Corridor Multifamily	Mid-Rise Mixed Use Multifamily	High-Rise Mixed Use Multifamily
1	20.41	N/A	17.65	N/A	N/A	N/A	N/A
2	12.35	N/A	6.82	N/A	N/A	N/A	N/A
3	7.31	N/A	6.52	N/A	N/A	N/A	N/A
4	8.63	N/A	4.41	N/A	N/A	N/A	N/A
5	7.33	N/A	6.92	N/A	N/A	N/A	N/A
6	1.93	N/A	1.68	N/A	N/A	N/A	N/A
7	1.43	N/A	1.27	N/A	N/A	N/A	N/A
8	2.00	N/A	2.94	N/A	N/A	N/A	N/A
9	2.90	N/A	3.27	N/A	N/A	N/A	N/A
10	2.91	N/A	2.94	N/A	N/A	N/A	N/A
11	8.19	N/A	5.18	N/A	N/A	N/A	N/A
12	9.84	N/A	6.10	N/A	N/A	N/A	N/A
13	5.87	N/A	4.39	N/A	N/A	N/A	N/A
14	11.34	N/A	7.71	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	14.57	N/A	11.63	N/A	N/A	N/A	N/A

Defrost Controls

Measure Overview

Defrost

- Defrost operation in a heat pump
  - Removes ice from outdoor coils
  - Defrost cycle “reverses”; utilizes indoor space conditions to warm up outdoor coil
  - Recovery required to reheat indoor space

Existing Code Requirements

Defrost

Section 150.0 – MANDATORY FEATURES AND DEVICES (h) Space-conditioning equipment.

Section 110.2(b) - Controls for Heat Pumps with Supplementary Electric Resistance Heaters Exception 1 to Section 110.2(b)A

Key Assumptions

Defrost

- Modeled to achieve a 25% reduction in defrost energy as a result of increasing delay time from 45min (30min to 60min is typical) to 90min.
    - Standard Design: CBECC's current assumptions for defrost, capacity at 35°F is degraded by 10%.
    - Proposed Design: Capacity at 35°F is degraded by 7.5%.
- All other building characteristics meet 2022 prescriptive requirements.

2025 Proposed Requirements

Defrost

The mandatory measure proposed in this section include the following:

- This measure requires the installer to set the defrost delay timer—if it exists—to a value of no less than 90 minutes.
  - This would be required for all climate zones, but for
  - Homes less than 500 square feet it would be required only for climate zones 1-4, 11-14, and 16.
- Requires the manufacturer to provide simple instructions for how to configure this timer. Proper settings are required to be HERS verified.

First-Year Energy Savings

Defrost
Single Family 2,100/2,700 ft^2 Weighted New Construction

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	147	0.040		482
2	100	0.028		339
3	36	0.015		143
4	84	0.026		279
5	41	0.018		143
6	3	0.001		24
7	3	0.000		10
8	8	0.003		49
9	16	0.007		73
10	19	0.010		73
11	80	0.023		279
12	83	0.028		279
13	61	0.022		220
14	92	0.037		328
15	6	0.004		24
16	142	0.039		401

First-Year Energy Savings

Defrost

Single Family 500 ft^2 Small Home New Construction

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	21	0.006		70
2	8	0.003		25
3	3	0.001		15
4	8	0.003		30
5	N/A	N/A		N/A
6	N/A	N/A		N/A
7	N/A	N/A		N/A
8	N/A	N/A		N/A
9	N/A	N/A		N/A
10	N/A	N/A		N/A
11	6	0.002		25
12	7	0.003		25
13	6	0.003		20
14	9	0.004		35
15	N/A	N/A		N/A
16	14	0.005		40

First-Year Energy Savings

Defrost

Single Family 1,665 ft^2 Alteration

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	253	0.068		783
2	156	0.047		516
3	70	0.027		266
4	143	0.047		466
5	87	0.036		300
6	4	0.002		17
7	5	0.000		17
8	24	0.010		100
9	41	0.017		166
10	47	0.027		183
11	165	0.046		566
12	167	0.055		566
13	124	0.044		433
14	204	0.080		699
15	18	0.011		83
16	288	0.079		799

First-Year Energy Savings

Defrost
Multi Family 2 Story Low-Rise Garden

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	14	0.004		45
3	9	0.003		34
4	24	0.007		75
5	11	0.004		38
6	N/A	N/A		N/A
7	N/A	N/A		N/A
8	N/A	N/A		N/A
9	N/A	N/A		N/A
10	N/A	N/A		N/A
11	11	0.004		41
12	12	0.005		43
13	8	0.003		30
14	12	0.005		44
15	N/A	N/A		N/A
16	N/A	N/A		N/A

First-Year Energy Savings

Defrost
Multi Family 3 Story Loaded Corridor

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	16	0.005		53
3	8	0.003		33
4	24	0.007		77
5	10	0.004		37
6	N/A	N/A		N/A
7	N/A	N/A		N/A
8	N/A	N/A		N/A
9	N/A	N/A		N/A
10	N/A	N/A		N/A
11	14	0.005		50
12	14	0.006		50
13	10	0.004		37
14	15	0.006		53
15	N/A	N/A		N/A
16	N/A	N/A		N/A

First-Year Energy Savings

Defrost
Multi Family 5 Story Mid-Rise Mixed Use

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	11	0.003		30
3	7	0.003		23
4	17	0.006		47
5	8	0.004		25
6	N/A	N/A		N/A
7	N/A	N/A		N/A
8	N/A	N/A		N/A
9	N/A	N/A		N/A
10	N/A	N/A		N/A
11	11	0.004		33
12	10	0.004		30
13	8	0.003		23
14	12	0.005		34
15	N/A	N/A		N/A
16	N/A	N/A		N/A

First-Year Energy Savings

Defrost
Multi Family 10 Story High-Rise Mixed Use

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	12	0.004		39
3	8	0.003		29
4	19	0.006		58
5	10	0.004		32
6	N/A	N/A		N/A
7	N/A	N/A		N/A
8	N/A	N/A		N/A
9	N/A	N/A		N/A
10	N/A	N/A		N/A
11	13	0.005		45
12	12	0.005		41
13	10	0.004		31
14	14	0.006		47
15	N/A	N/A		N/A
16	N/A	N/A		N/A

30-Year Energy Cost Savings

Total 30-Year LSC Savings (2026 PV$)
Defrost

Climate Zone	Single Family 2,100/2,700 ft^2 Weighted New Construction	Single Family 500 ft^2 Small Home New Construction	Single Family 1,665 ft^2 Alteration	Low-Rise Garden Multifamily	Loaded Corridor Multifamily	Mid-Rise Mixed Use Multifamily	High-Rise Mixed Use Multifamily
1	$1,215	$170	$2,048	N/A	N/A	N/A	N/A
2	$820	$65	$1,265	$111	$129	$72	$91
3	$325	$25	$616	$75	$74	$52	$63
4	$667	$60	$1,149	$185	$188	$113	$139
5	$359	N/A	$716	$88	$87	$58	$74
6	$24	N/A	$33	N/A	N/A	N/A	N/A
7	$24	N/A	$33	N/A	N/A	N/A	N/A
8	$49	N/A	$216	N/A	N/A	N/A	N/A
9	$147	N/A	$366	N/A	N/A	N/A	N/A
10	$171	N/A	$416	N/A	N/A	N/A	N/A
11	$646	$55	$1,315	$92	$113	$73	$101
12	$681	$60	$1,349	$101	$117	$70	$95
13	$513	$50	$1,016	$71	$87	$54	$74
14	$768	$75	$1,665	$102	$122	$78	$109
15	$63	N/A	$183	N/A	N/A	N/A	N/A
16	$1,138	$115	$2,298	N/A	N/A	N/A	N/A

Cost Effectiveness

Benefit-to-Cost Ratios
Defrost

Climate Zone	Single Family 2,100/2,700 ft^2 Weighted New Construction	Single Family 500 ft^2 Small Home New Construction	Single Family 1,665 ft^2 Alteration	Low-Rise Garden Multifamily	Loaded Corridor Multifamily	Mid-Rise Mixed Use Multifamily	High-Rise Mixed Use Multifamily
1	55.21	7.73	93.09	N/A	N/A	N/A	N/A
2	37.28	2.95	57.52	5.03	5.84	3.26	4.15
3	14.75	1.14	28.00	3.43	3.37	2.37	2.88
4	30.30	2.73	52.22	8.42	8.54	5.14	6.33
5	16.34	N/A	32.54	3.99	3.96	2.62	3.35
6	1.11	N/A	1.51	N/A	N/A	N/A	N/A
7	1.11	N/A	1.51	N/A	N/A	N/A	N/A
8	2.22	N/A	9.84	N/A	N/A	N/A	N/A
9	6.66	N/A	16.65	N/A	N/A	N/A	N/A
10	7.77	N/A	18.92	N/A	N/A	N/A	N/A
11	29.35	2.50	59.79	4.20	5.14	3.34	4.60
12	30.93	2.73	61.30	4.57	5.32	3.19	4.30
13	23.32	2.27	46.17	3.21	3.96	2.44	3.34
14	34.90	3.41	75.68	4.66	5.55	3.54	4.96
15	2.86	N/A	8.32	N/A	N/A	N/A	N/A
16	51.72	5.23	104.44	N/A	N/A	N/A	N/A

Crankcase Heating

Measure Overview

Crankcase Heat

- Common in heat pumps and air conditioners
- Maintenance and Operation
  - Designed to keep compressor warmer thank outdoor coils and casing
  - Keeps refrigerant migration into compressor and mixing with oil
  - Typically, a heating element

Existing Code Requirements

Crankcase Heating

- No requirements related to Crankcase Heating (CCH) is covered in the Energy Code
- Existing federal regulations regulates operation when compressor is not operating

Key Assumptions

Crankcase Heating

- Standard Design: On continuously, no control
- Proposed Design: Off when the compressor is in operation or when the outdoor air temperature >71°F
- Crankcase heater sized to:
  - Heat pumps: 33W for ≤ 3-ton, 11W/ton >3-ton
  - Air conditioners: 30W for ≤ 3-ton, 10W/ton >3-ton
- Results presented are weighted average for heat pumps and air conditioners.
- All other building characteristics meet 2022 prescriptive requirements.

2025 Proposed Requirements

Crankcase Heating

The prescriptive measure proposed in this section include two alternatives for heat pumps and ACs:

- Controlled by an Occupant Controlled Smart Thermostat compliant with Section 110.12(a)

OR

- Crankcase heating power limited.
  - Installer discloses there is no crankcase heater; or
  - Uses “Better Control” and include both:
    - States that CCH may not run continuously when the compressor is operating; and
    - Includes either thermostatic control (disabling CCH above outdoor temperature no higher than 71°F or differential temperature between crankcase and evaporator or condenser) or Positive Temperature Coefficient Control.

First-Year Energy Savings

Crankcase Heating
Single Family 2,100/2,700 ft^2 Weighted New Construction

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	46	0.010		129
2	63	0.005		78
3	26	0.004		41
4	82	0.007		112
5	33	0.003		33
6	45	0.004		46
7	49	0.004		47
8	82	0.005		80
9	86	0.006		105
10	99	0.006		95
11	121	0.010		151
12	82	0.007		90
13	123	0.012		143
14	119	0.010		150
15	249	0.014		280
16	75	0.010		144

First-Year Energy Savings

Crankcase Heating

Single Family 500 ft^2 Small Home New Construction

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	21	0.005		59
2	46	0.002		38
3	17	0.001		19
4	69	0.003		67
5	24	0.001		19
6	42	0.003		31
7	47	0.004		45
8	82	0.004		75
9	84	0.004		75
10	94	0.005		85
11	99	0.006		103
12	69	0.004		63
13	107	0.008		118
14	105	0.006		112
15	172	0.009		189
16	53	0.004		75

First-Year Energy Savings

Crankcase Heating
Single Family 1,665 ft² Alteration

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	266	0.035		501
2	558	0.063		941
3	432	0.050		741
4	542	0.061		918
5	454	0.052		772
6	458	0.052		772
7	453	0.051		757
8	529	0.059		872
9	539	0.061		903
10	613	0.069		1,026
11	673	0.076		1,126
12	572	0.065		964
13	633	0.071		1,053
14	578	0.065		965
15	888	0.097		1,459
16	469	0.054		807

First-Year Energy Savings

Crankcase Heating
Multi Family 2 Story Low-Rise Garden

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	17	0.001		22
3	7	0.001		14
4	33	0.003		46
5	10	0.001		16
6	18	0.002		29
7	21	0.002		33
8	44	0.003		63
9	49	0.003		70
10	35	0.002		48
11	39	0.003		49
12	25	0.002		34
13	39	0.003		50
14	39	0.003		50
15	87	0.006		120
16	16	0.001		22

First-Year Energy Savings

Crankcase Heating
Multi Family 3 Story Loaded Corridor

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	37	0.002		46
3	16	0.002		28
4	59	0.005		78
5	22	0.002		33
6	31	0.003		46
7	36	0.003		55
8	59	0.004		81
9	62	0.004		84
10	76	0.005		101
11	85	0.006		105
12	61	0.004		77
13	94	0.006		115
14	90	0.006		111
15	165	0.010		228
16	31	0.002		41

First-Year Energy Savings

Crankcase Heating
Multi Family 5 Story Mid-Rise Mixed Use

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	40	0.002		35
3	14	0.002		18
4	66	0.005		67
5	22	0.002		24
6	41	0.004		48
7	47	0.004		56
8	82	0.006		87
9	82	0.005		87
10	91	0.006		95
11	95	0.006		89
12	66	0.004		63
13	105	0.006		100
14	100	0.006		93
15	166	0.010		184
16	36	0.003		35

First-Year Energy Savings

Crankcase Heating
Multi Family 10 Story High-Rise Mixed Use

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	N/A	N/A		N/A
2	37	0.002		40
3	16	0.002		25
4	61	0.005		72
5	22	0.002		30
6	33	0.003		45
7	36	0.003		49
8	72	0.005		89
9	75	0.005		92
10	77	0.005		93
11	83	0.005		92
12	60	0.004		68
13	86	0.005		95
14	89	0.006		99
15	167	0.011		211
16	33	0.003		38

30-Year Energy Cost Savings

Total 30-Year LSC Savings (2026 PV$)
Crankcase Heating

Climate Zone	Single Family 2,100/2,700 ft^2 Weighted New Construction	Single Family 500 ft^2 Small Home New Construction	Single Family 1,665 ft^2 Alteration	Low-Rise Garden Multifamily	Loaded Corridor Multifamily	Mid-Rise Mixed Use Multifamily	High-Rise Mixed Use Multifamily
1	$374	$162	$1,825	N/A	N/A	N/A	N/A
2	$388	$249	$3,738	$104	$226	$190	$202
3	$178	$102	$2,895	$48	$107	$75	$97
4	$565	$456	$3,625	$222	$389	$350	$365
5	$193	$132	$3,033	$65	$143	$113	$131
6	$299	$268	$3,084	$123	$204	$218	$198
7	$346	$338	$3,040	$142	$250	$257	$224
8	$512	$511	$3,554	$292	$387	$424	$427
9	$566	$535	$3,612	$321	$401	$424	$442
10	$640	$595	$4,117	$228	$490	$471	$455
11	$806	$647	$4,514	$252	$551	$489	$488
12	$557	$462	$3,844	$169	$404	$349	$361
13	$827	$706	$4,236	$257	$607	$541	$504
14	$783	$674	$3,877	$252	$580	$510	$522
15	$1,577	$1,085	$5,929	$559	$1,060	$856	$981
16	$525	$330	$3,174	$100	$194	$182	$190

Cost Effectiveness

Benefit-to-Cost Ratios
Crankcase Heating

Climate Zone	Single Family 2,100/2,700 ft² Weighted New Construction	Single Family 500 ft² Small Home New Construction	Single Family 1,665 ft² Alteration	Low-Rise Garden Multifamily	Loaded Corridor Multifamily	Mid-Rise Mixed Use Multifamily	High-Rise Mixed Use Multifamily
1	5.75	2.50	28.07	0.57	0.70	0.14	0.30
2	5.97	3.83	57.51	1.60	3.48	2.92	3.10
3	2.74	1.57	44.54	0.75	1.64	1.16	1.49
4	8.69	7.01	55.77	3.42	5.98	5.38	5.62
5	2.97	2.03	46.66	1.00	2.21	1.73	2.01
6	4.60	4.12	47.45	1.89	3.14	3.36	3.04
7	5.32	5.20	46.76	2.19	3.85	3.96	3.45
8	7.87	7.85	54.67	4.49	5.95	6.53	6.57
9	8.71	8.23	55.56	4.93	6.17	6.52	6.80
10	9.84	9.15	63.33	3.51	7.54	7.24	6.99
11	12.40	9.95	69.45	3.88	8.48	7.52	7.50
12	8.56	7.11	59.14	2.60	6.22	5.37	5.55
13	12.72	10.86	65.17	3.95	9.34	8.32	7.76
14	12.05	10.37	59.64	3.88	8.93	7.84	8.03
15	24.26	16.68	91.21	8.59	16.31	13.16	15.08
16	8.08	5.08	48.83	1.54	2.98	2.80	2.92

Refrigerant Charge Verification

Measure Overview

Refrigerant Charge Verification

- Refrigerant charge verification
  - Crucial to operation of heat pump systems
  - Longer lifespan detection of leaks
  - Minimizes efficiency degradation
  - Effects heating and cooling performance

Existing Code Requirements
Refrigerant Charge Verification

Section 150.1 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR SINGLE FAMILY RESIDENTIAL BUILDINGS

- Section 150.1(c)7ii Prescriptive standards/component packages for refrigerant charge fault indicator display in JA6

Table 150.1-A

CZ:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
AC and HP	NR	REQ	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR

- Reference Residential Appendix Section RA3.2.2 Standard Charge Verification Procedure - describe the required instrumentation, calibration, diagnostic measurements, and calculations

Key Assumptions
Refrigerant Charge Verification

- Standard Design:
  - No charge verification
  - EER degraded by 10%
  - HSPF degraded by 10%
- Proposed Design:
  - Charge verification
  - EER degraded by 4%
  - HSPF degraded by 6%
- Add heating impact of refrigerant charge to software
  - Studies have shown the impact of correct charge is not as impactful for heating as for cooling.
- All other building characteristics meet 2022 prescriptive requirements.

2025 Proposed Requirements

Refrigerant Charge Verification

- The prescriptive measure proposed in this section include:
  - Heat Pumps in CZ 1-5 and 8-16:
    - Refrigerant charge verification is proposed to be required for heat pumps.
    - It would not be required for ADUs.

    Exception: Pre-charged systems that have a line set length within 5′ and a coil size within 10 percent of the manufacturer's defaults.
    - Systems for which charge cannot be adjusted may not use compression or flare fittings
  - Remove any mention of the FID approach from Title 24, Part 6
- Shift focus from charge testing to verified weigh-in
- Adds more rigor to the weigh-in method
- Provides an option that would allow HERS Raters to verify weigh-in remotely

First-Year Energy Savings

Refrigerant Charge Verification
Single Family 2,100/2,700 ft^2 Weighted New Construction

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	125	0.028		335
2	N/A	N/A		N/A
3	43	0.018		157
4	82	0.024		244
5	36	0.014		133
6	N/A	N/A		N/A
7	N/A	N/A		N/A
8	N/A	N/A		N/A
9	N/A	N/A		N/A
10	N/A	N/A		N/A
11	N/A	N/A		N/A
12	N/A	N/A		N/A
13	N/A	N/A		N/A
14	N/A	N/A		N/A
15	N/A	N/A		N/A
16	142	0.032		377

First-Year Energy Savings

Refrigerant Charge Verification
Single Family 1,665 ft^2 Alteration

Climate Zone	First-year Electricity Savings Per Unit (kWh)	First-Year Peak Demand Reduction Per Unit (kW)	First-Year Natural Gas Savings Per Unit (kBtu)	First-Year Source Energy Savings Per Unit (kBtu)
1	209	0.047		566
2	N/A	N/A		N/A
3	97	0.034		300
4	281	0.043		466
5	83	0.028		250
6	73	0.007		117
7	93	0.004		83
8	N/A	N/A		N/A
9	N/A	N/A		N/A
10	N/A	N/A		N/A
11	N/A	N/A		N/A
12	N/A	N/A		N/A
13	N/A	N/A		N/A
14	N/A	N/A		N/A
15	N/A	N/A		N/A
16	306	0.063		749

30-Year Energy Cost Savings

Total 30-Year LSC Savings (2026 PV$)
Refrigerant Charge Verification

Climate Zone	Single Family 2,100/2,700 ft^2 Weighted New Construction	Single Family 500 ft^2 Small Home New Construction	Single Family 1,665 ft^2 Alteration	Low-Rise Garden Multifamily	Loaded Corridor Multifamily	Mid-Rise Mixed Use Multifamily	High-Rise Mixed Use Multifamily
1	$981	N/A	$1,598	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	$412	N/A	$816	N/A	N/A	N/A	N/A
4	$656	N/A	$1,881	N/A	N/A	N/A	N/A
5	$311	N/A	$649	N/A	N/A	N/A	N/A
6	N/A	N/A	$450	N/A	N/A	N/A	N/A
7	N/A	N/A	$566	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	$1,127	N/A	$2,298	N/A	N/A	N/A	N/A

Cost Effectiveness

Benefit-to-Cost Ratios
Refrigerant Charge Verification

Climate Zone	Single Family 2,100/2,700 ft^2 Weighted New Construction	Single Family 500 ft^2 Small Home New Construction	Single Family 1,665 ft^2 Alteration	Low-Rise Garden Multifamily	Loaded Corridor Multifamily	Mid-Rise Mixed Use Multifamily	High-Rise Mixed Use Multifamily
1	3.24	N/A	5.28	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	1.36	N/A	2.69	N/A	N/A	N/A	N/A
4	2.17	N/A	6.21	N/A	N/A	N/A	N/A
5	1.03	N/A	2.14	N/A	N/A	N/A	N/A
6	N/A	N/A	1.48	N/A	N/A	N/A	N/A
7	N/A	N/A	1.87	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	3.72	N/A	7.59	N/A	N/A	N/A	N/A

Variable Capacity Systems

Measure Overview

Variable Capacity Systems

- Variable capacity (VC) heat pumps and air conditioners
  - Ability to deliver capacity to match building loads by:
    - Changing the speed of the compressor
    - Modulating ancillary components like fans and expansion valves
  - Two speed and Variable Speed Compressors
  - Can provide improved system efficiency
  - Reduction in sound levels

Existing Code Requirements

Variable Capacity Systems

Section 150.0(m)13C – Single Family Residential Mandatory Features and Devices

- Requires zonally controlled systems to deliver through the air handler fan in every zonal control mode 350 cfm per ton of nominal cooling capacity.

Reference Residential Appendix RA3.3 – Airflow rates and fan efficacy field verification and diagnostic testing

Key Assumptions
Variable Capacity Systems

- All building characteristics meet 2022 prescriptive requirements
- Systems are modeled using the “VCHP-Detailed” option (only available for cold-climate heat pumps that are NEEP listed) but is not reflected in standard CBECC-Res modeling of Variable Capacity Multispeed Systems (VCMS)

2025 Proposed Requirements

Variable Capacity Systems

- Change to compliance software
  - Account for reduced distribution efficiency while operating at lower speeds and airflows
- The mandatory measures proposed in this section for Variable Capacity/Zoned Systems include the following:
  - Modify fan efficacy test procedure; Airflow and efficacy testing must be done with only a single zone calling
  - *Sum* of airflows measured at all air handlers must be at least 350 cfm per ton of nominal compressor capacity.
  - For non-zonally controlled VCMS systems with attic ducts, performance (airflow, distribution efficiency, and duct loss) would be calculated by compliance software as a function of instantaneous building load
- There are no energy savings associated with this measure

Questions

- [Any questions for the stakeholders that you might have… requests for input]

Comments

Comments on today's workshop due

September 5, 2023, by 5:00 PM

Submit comments to CEC Docket 22-BSTD-01

https://efiling.energy.ca.gov/Ecomment/Ecomment.aspx?docketnumber=22-BSTD-01

Contact: Bach.Tsan@energy.ca.gov

Thank You!

2025 Pre-rulemaking Workshop

Multifamily Domestic Hot Water

Danny Tam, Mechanical Engineer, Building Standards Branch

August 23, 2023

California Plumbing Code Appendix M

Existing Code Requirements

2022 Title 24 Part 6 Section 170.2(d)

- Current practice is to use California Plumbing Code (CPC) Appendix A pipe sizing
- California Building Standards Commission approved final adoption of UPC Appendix M, available as a voluntary option in the CPC effective July 1, 2024.
  - More compatible with modern efficient fixtures. Results in smaller pipe size

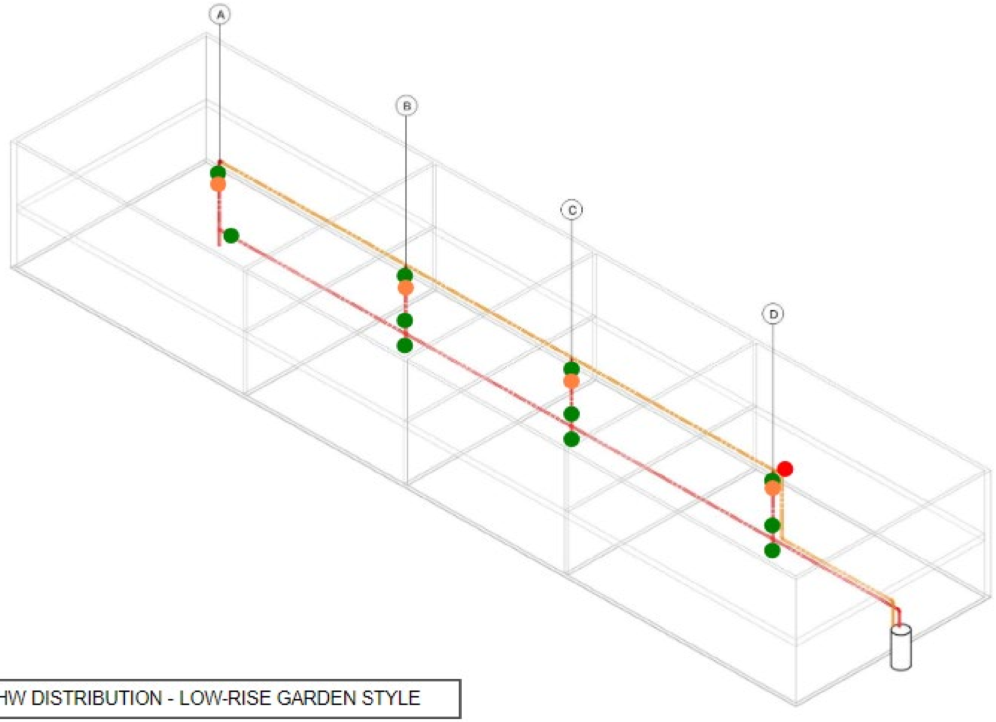
2025 Proposed Requirements

2025 Title 24 Part 6, Section 170.2(d)

- New prescriptive requirement for the use of CPC Appendix M for sizing of domestic hot water distribution systems serving multiple dwelling units
- Remove CPC Appendix M compliance credit added in 2022 California Building Energy Code Compliance (CBECC) software
- No additional field verification or acceptance tests

Key Assumptions

- Utilized basis of design developed from the 2022 CASE cycle for the hot water distribution system using CPC Appendix A and M for the four prototype buildings
- Modeled both gas and heat pump water heating plants for the four prototype buildings



DHW DISTRIBUTION - LOW-RISE GARDEN STYLE

Incremental First Cost – Heat Pump Water Heater Scenario

MF Building Type	HPWH-AppM Base Case	HPWH-AppM Proposed Case	HPWH-AppM Total Incremental Cost Savings	HPWH-AppM Average Incremental Cost Savings per Dwelling Unit
Low-Rise Garden	$33,682	$30,511	-$3,172	-$396
Low-Rise Loaded Corridor	$89,481	$68,673	-$20,808	-$578
Mid-Rise Mixed Use	$211,739	$154,810	-$56,930	-$647
High-Rise Mixed Use	$243,546	$190,251	-$53,294	-$456

Incremental First Cost – Gas Water Heater Scenario

MF Building Type	Gas-AppM Base Case	Gas-AppM Proposed Case	Gas-AppM Total Incremental Cost Savings	Gas-AppM Average Incremental Cost Savings per Dwelling Unit
Low-Rise Garden	$34,936	$33,427	-$1,510	-$189
Low-Rise Loaded Corridor	$95,051	$74,044	-$21,007	-$584
Mid-Rise Mixed Use	$240,630	$174,346	-$66,284	-$753
High-Rise Mixed Use	$308,021	$247,179	-$60,841	-$520

Total Incremental Cost

- Proposed case (CPC Appendix M) minus base case (CPC Appendix A)
- Material savings and installation savings due to reduction in pipe diameter
- The incremental measure cost is negative

Cost Effectiveness – Heat Pump Water Heater Scenario

Climate Zone	Benefits: LSC Savings + Other PV Cost Savings (2026 PV$/dwelling unit)	Costs: Total Incremental PV Costs (2026 PV$/dwelling unit)	B/C Ratio
1	$1,410	$0	Infinite
2	$1,408	$0	Infinite
3	$1,402	$0	Infinite
4	$1,408	$0	Infinite
5	$1,464	$0	Infinite
6	$1,357	$0	Infinite
7	$1,349	$0	Infinite
8	$1,329	$0	Infinite
9	$1,328	$0	Infinite
10	$1,342	$0	Infinite
11	$1,355	$0	Infinite
12	$1,376	$0	Infinite
13	$1,368	$0	Infinite
14	$1,332	$0	Infinite
15	$1,285	$0	Infinite
16	$1,365	$0	Infinite
Total	$1,358	$0	Infinite

Cost Effectiveness – Gas Water Heater Scenario

30-Year Cost Effectiveness Summary Per Dwelling Unit - New Construction – Additions - Gas-AppM

Climate Zone	Benefits: LSC Savings + Other PV Cost Savings (2026 PV$/dwelling unit)	Costs: Total Incremental PV Costs (2026 PV$/dwelling unit)	B/C Ratio
1	$1,544	$0	Infinite
2	$1,544	$0	Infinite
3	$1,546	$0	Infinite
4	$1,554	$0	Infinite
5	$1,603	$0	Infinite
6	$1,514	$0	Infinite
7	$1,522	$0	Infinite
8	$1,490	$0	Infinite
9	$1,488	$0	Infinite
10	$1,503	$0	Infinite
11	$1,513	$0	Infinite
12	$1,537	$0	Infinite
13	$1,531	$0	Infinite
14	$1,487	$0	Infinite
15	$1,451	$0	Infinite
16	$1,507	$0	Infinite
Total	$1,515	$0	Infinite

Pipe Insulation Enhancement

Existing Code Requirements

2022 Title 24 Section 160.4(f)

MANDATORY REQUIREMENTS FOR WATER HEATING SYSTEMS

(f) Insulation for piping and tanks

1. Piping for multifamily domestic hot water systems shall be insulated to meet the requirements of Table 160.4-A

TABLE 160.4-A PIPE INSULATION THICKNESS – Multifamily Domestic Hot Water

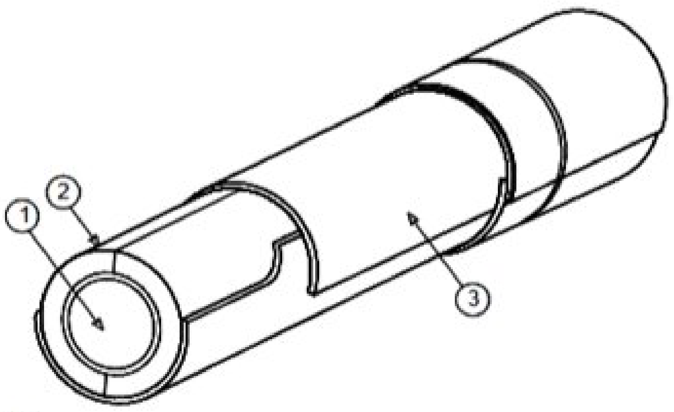
Fluid Operating Temperature Range (°F)	Insulation Conductivity			Nominal Pipe Diameter (in inches)				
	Conductivity (in Btu·in/h·ft^2· °F)	Mean Rating Temperature (°F)		< 1	1 to <1.5	1.5 to < 4	4 to < 8	8 and larger
Multifamily Domestic Hot Water Systems				Minimum Pipe Insulation Required (Thickness in inches or R-value)				
105-140[1]	0.22-0.28	100	Inches	1.0	1.5	2.0	2.0	2.0
			R-value	R 7.7	R 12.5	R 16	R 12.5	R 11

1. Multifamily and hotel/motel domestic hot water systems with water temperature above 140°F shall use the row in Table 120.3-A for the applicable water temperature.

2025 Proposed Requirements

2025 Title 24 Part 6, Section 160.4

- <u>All</u> piping, appurtenances, and pipe hangers for multifamily domestic hot water systems shall be insulated, insulation on the piping and appurtenances shall be continuous.
- Central water heater and recirculation system piping insulation quality shall be field verified by a HERS rater.



1. PIPE
2. FIBERGLASS INSULATION WITH ALL SERVICE JACKET.
3. WHERE PIPING IS NOT CONCEALED IN WALL OR CEILING SPACES, PROVIDE PVC JACKETING ON PIPING INDOORS & ALUMINUM JACKETING ON PIPING OUTDOORS. SILICONE CAULK PVC JACKETING SEAMS, JOINTS & ENDS WATERTIGHT WITH APPROVED ADHESIVE. INSIDE BUILDINGS LOCATE JACKET SEAMS IN LEAST VISIBLE LOCATION. OUTSIDE, WHERE EXPOSED TO WEATHER, LOCATE JACKET SEAMS ON BOTTOM OF PIPING.

INSULATION THICKNESS (1)

SERVICE	TEMPERATURE RANGE	NOMINAL PIPE DIAMETER (in inches)				
		< 1	1 to < 1.5	1.5	2 to <4	4 to < 8
HOT WATER	141F - 200F	1.5	1.5	2.0	2.0	2.0
COLD WATER	FREEZE PROTECTION	3/4	3/4	3/4	3/4	3/4

NOTES:
1. REFERENCE CALIFORNIA ENERGY CODE, TABLE 120.3-A & CALIFORNIA PLUMBING CODE SECTION 609.11.
2. INSULATE ALL HOT WATER SYSTEMS AS INDICATED.
3. COLD WATER IS ONLY INSULATED OUTSIDE THE BUILDING, WHERE EXPOSED TO EXTERIOR AMBIENT CONDITIONS, FOR FREEZE PROTECTION.

Illustration from Advanced Build Energy Program Plan Review Sketches Form Multifamily Building in Santa Rosa.

Software Used & Prototypes

- The Statewide CASE Team used a recirculation heat loss spreadsheet calculator and a heating plant pipe heat loss spreadsheet calculator to assess the energy impact of the proposed code change.
- The spreadsheet calculator includes features to handle detailed recirculation piping designs, insulation conditions, and recirculation flow controls.
- In comparison, CBECC uses a simple recirculation model with six pipe sections to streamline code compliance, but they are not capable of assessing the energy impact of complicated recirculation system designs found in real buildings.

Total Incremental Cost – Heat Pump Water Heater Scenario

Total Incremental Cost by Prototype HP Heating Plant

MF Building Type	Language Cleanup	Pipe Insulation Verification	Total Incremental Cost	Average Incremental Cost per Dwelling Unit
Low-Rise Garden	$831	$847	$1,678	$210
Low-Rise Loaded Corridor	$2,306	$3,712	$6,018	$167
Mid-Rise Mixed Use	$5,580	$10,278	$15,858	$180
High-Rise Mixed Use	$5,865	$11,303	$17,168	$147

Total Incremental Cost Gas Water Heater Scenario

Total Incremental Cost by Prototype Gas Heating Plant

MF Building Type	Language Cleanup	Pipe Insulation Verification	Total Incremental Cost	Average Incremental Cost per Dwelling Unit
Low-Rise Garden	$808	$847	$1,655	$207
Low-Rise Loaded Corridor	$2,277	$3,712	$5,989	$166
Mid-Rise Mixed Use	$5,609	$10,278	$15,887	$181
High-Rise Mixed Use	$4,125	$11,303	$15,428	$132

Cost Effectiveness – Heat Pump Water Heater Scenario

30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – HPWH-Pipe Insulation

Climate Zone	Benefits: LSC Savings + Other PV Cost Savings (2026 PV$/dwelling unit)	Costs: Total Incremental PV Costs (2026 PV$/dwelling unit)	B/C Ratio
1	$1,292	$304	4
2	$1,205	$380	3
3	$1,212	$348	3
4	$1,189	$379	3
5	$1,252	$374	3
6	$1,184	$307	4
7	$1,153	$307	4
8	$1,157	$305	4
9	$1,163	$304	4
10	$1,169	$306	4
11	$1,183	$310	4
12	$1,184	$316	4
13	$1,175	$314	4
14	$1,182	$302	4
15	$1,113	$302	4
16	$1,220	$310	4
Total	$1,176	$320	4

Cost Effectiveness – Gas Water Heater Scenario

30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Gas-Pipe Insulation

Climate Zone	Benefits: LSC Savings + Other PV Cost Savings (2026 PV$/dwelling unit)	Costs: Total Incremental PV Costs (2026 PV$/dwelling unit)	B/C Ratio
1	$1,754	$303	6
2	$1,687	$379	4
3	$1,693	$346	5
4	$1,679	$378	4
5	$1,725	$373	5
6	$1,673	$305	5
7	$1,662	$306	5
8	$1,655	$303	5
9	$1,832	$302	6
10	$1,664	$304	5
11	$1,675	$308	5
12	$1,848	$314	6
13	$1,669	$312	5
14	$1,675	$301	6
15	$1,795	$301	6
16	$1,697	$309	5
Total	$1,722	$318	5

Thermostatic Balancing Valves

Existing Code Requirements

- There are no specific requirements for balancing valves

2025 Proposed Requirements

Title 24, Part 6 Section 170.1(d)k

- New compliance option
  - Applies to new constructed buildings, additions, and alterations
  - Applies to central hot water systems with more than one riser
- For a compliance credit, the project shall include:
  - Thermal balancing valves set to a maximum temperature set point of 120°F at the last branch from each riser; and
  - A variable speed pump with differential pressure control; and
  - Hot water return piping total developed length (TDL) that does not exceed 160 feet

Software Used & Prototypes

- The Statewide CASE Team used a recirculation heat loss spreadsheet calculator and a heating plant pipe heat loss spreadsheet calculator to assess the energy impact of the proposed code change.
- Since this proposal is limited to DHW distribution systems with shorter recirculation return pipes, the Mid-Rise Mixed Use and High-Rise Mixed Use prototype buildings do not meet the recirculation return pipe length criteria.

Total Incremental Cost

MF Building Type	Base (First and Replacement Cost)	Proposed (First and Replacement Cost)	Total 30-Year Incremental Cost
Low-Rise Garden Style	$5,195	$4,600	($595)
Low-Rise Loaded Corridor	$10,342	$9,737	($605)

Cost Effectiveness – Heat Pump Water Heater Scenario – Newly Constructed and Addition

Climate Zone	Benefits: LSC Savings + Other PV Cost Savings (2026 PV$/dwelling unit)	Costs: Total Incremental PV Costs (2026 PV$/dwelling unit)	B/C Ratio
1	$130	$0	Infinite
2	$130	$0	Infinite
3	$125	$0	Infinite
4	$128	$0	Infinite
5	$133	$0	Infinite
6	$117	$0	Infinite
7	$113	$0	Infinite
8	$115	$0	Infinite
9	$114	$0	Infinite
10	$116	$0	Infinite
11	$118	$0	Infinite
12	$122	$0	Infinite
13	$117	$0	Infinite
14	$118	$0	Infinite
15	$124	$0	Infinite
16	$123	$0	Infinite

Cost Effectiveness – Heat Pump Water Heater Scenario - Alteration

Climate Zone	Benefits: LSC Savings + Other PV Cost Savings (2026 PV$/dwelling unit)	Costs: Total Incremental PV Costs (2026 PV$/dwelling unit)	B/C Ratio
1	$139	$0	Infinite
2	$138	$0	Infinite
3	$133	$0	Infinite
4	$135	$0	Infinite
5	$142	$0	Infinite
6	$126	$0	Infinite
7	$122	$0	Infinite
8	$123	$0	Infinite
9	$119	$0	Infinite
10	$124	$0	Infinite
11	$127	$0	Infinite
12	$131	$0	Infinite
13	$125	$0	Infinite
14	$126	$0	Infinite
15	$133	$0	Infinite
16	$132	$0	Infinite

Cost Effectiveness – Gas Water Heater Scenario – Newly Constructed and Addition

Climate Zone	Benefits: LSC Savings + Other PV Cost Savings (2026 PV$/dwelling unit)	Costs: Total Incremental PV Costs (2026 PV$/dwelling unit)	B/C Ratio
1	$91	$0	Infinite
2	$93	$0	Infinite
3	$88	$0	Infinite
4	$91	$0	Infinite
5	$94	$0	Infinite
6	$82	$0	Infinite
7	$80	$0	Infinite
8	$80	$0	Infinite
9	$82	$0	Infinite
10	$81	$0	Infinite
11	$83	$0	Infinite
12	$85	$0	Infinite
13	$82	$0	Infinite
14	$83	$0	Infinite
15	$88	$0	Infinite
16	$86	$0	Infinite

Cost Effectiveness – Gas Water Heater Scenario – Alteration

Climate Zone	Benefits: LSC Savings + Other PV Cost Savings (2026 PV$/dwelling unit)	Costs: Total Incremental PV Costs (2026 PV$/dwelling unit)	B/C Ratio
1	$94	$0	Infinite
2	$95	$0	Infinite
3	$91	$0	Infinite
4	$93	$0	Infinite
5	$97	$0	Infinite
6	$85	$0	Infinite
7	$83	$0	Infinite
8	$83	$0	Infinite
9	$84	$0	Infinite
10	$84	$0	Infinite
11	$86	$0	Infinite
12	$88	$0	Infinite
13	$85	$0	Infinite
14	$86	$0	Infinite
15	$91	$0	Infinite
16	$89	$0	Infinite

Master Mixing Valves

Existing Code Requirements

- The California Plumbing and Energy Codes do not require the use of master mixing valves (MMV) for centralized domestic hot water (DHW) distribution systems with recirculation
- Compared to systems with MMV, no MMW result in higher energy use from increased pipe heat loss from higher temperature recirculation loops
- MMV results energy savings at the heating plant by diverting most of the recirculation loop return water back to the mixing valve versus going back to the storage tank to maximize water temperature stratification in the tank

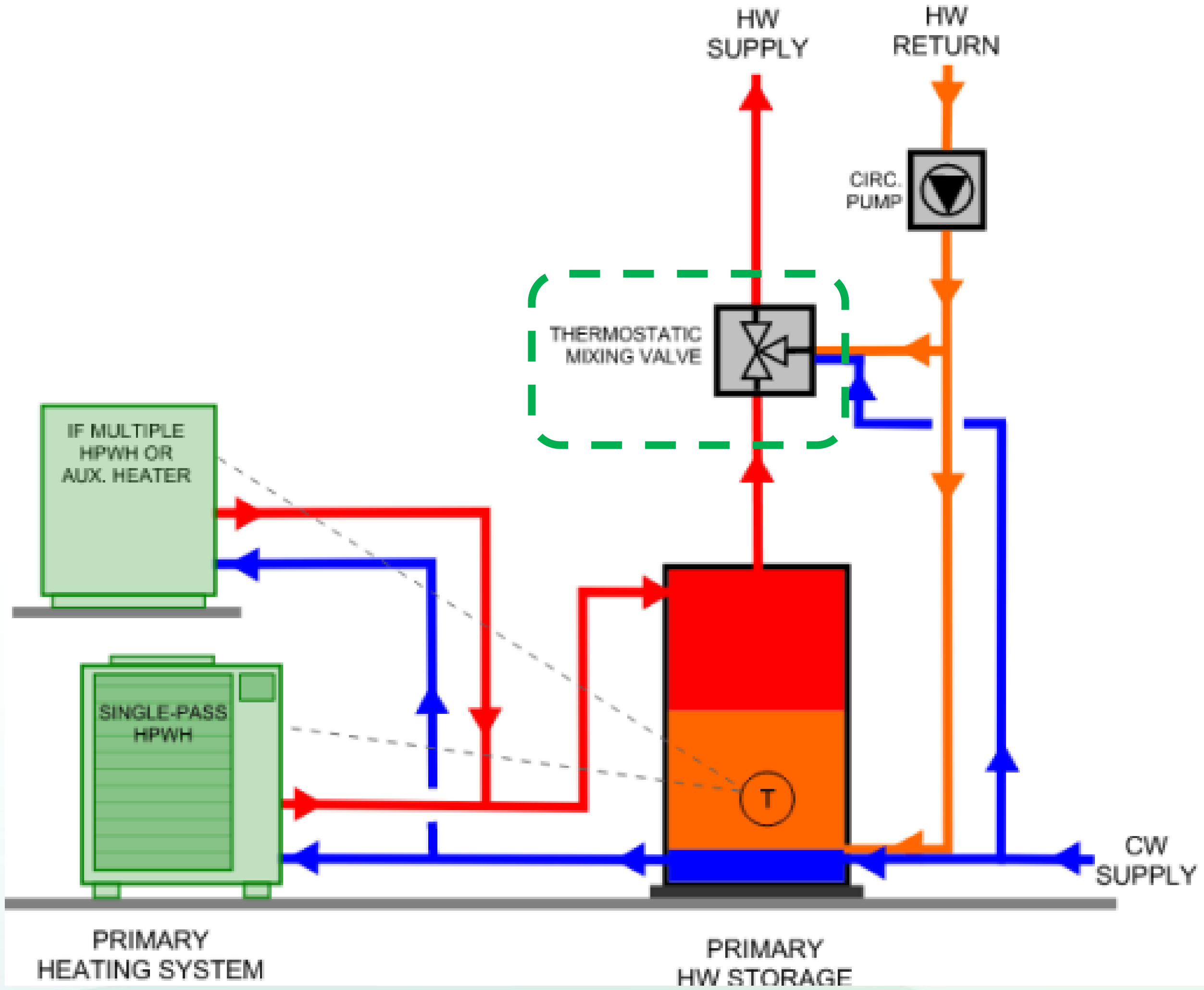


Photo Credit NEEA. 2/2023. https://neea.org/img/documents/Advanced-Water-Heating-Specification.pdf

2025 Proposed Code Change

- New prescriptive requirement for multifamily central DHW system for a mechanical or digital thermostatic MMV at the centralized hot water system outlet pipe to the distribution system with continuous recirculation.
- New Reference Appendix Section RA4.4.20, requirements for how the MMV would be installed and commissioned
- Performance approach: The standard design would be mechanical MMV
  - If no MMV is specified, there will be an energy penalty
  - If a digital MMV is specified, there will be an energy credit

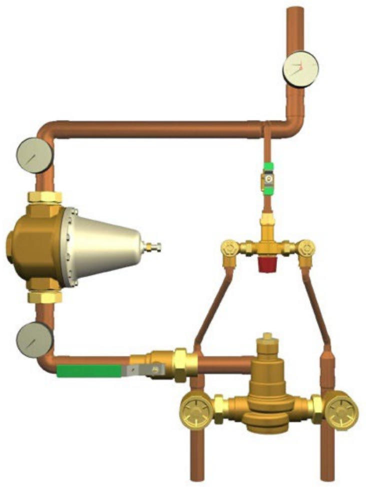


Photo Credit: Powers

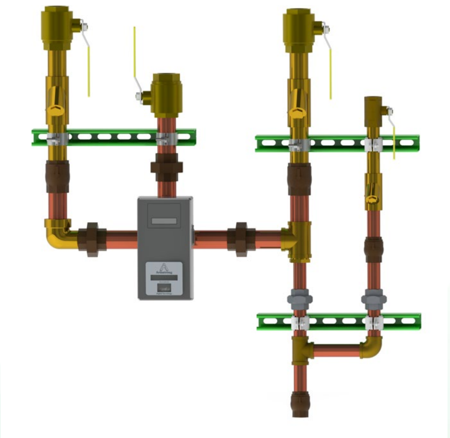


Photo Credit: Armstrong

Key Assumptions

Existing Design

- No MMV

Proposed Design

- Adds MMV inputs to CBECC
  - 10.5% energy savings for HPWH systems
  - 3.0% energy savings for gas HW systems

Software Used & Prototypes

- The Statewide CASE Team developed energy savings for this measure on a per-dwelling unit basis from results from lab testing at PG&E ATS.
- The Statewide CASE Team used the lab testing results to estimate heating plant energy saving percentages for the various configurations and extrapolated the energy savings for all prototypes and other heating plant types.

Total Incremental Costs

Total Incremental Costs for Base Case vs Proposed Case

MF Building Type	Incremental First Costs	Incremental Maintenance Costs	Incremental Replacement Costs	Total 30-Year Incremental Cost
Low-Rise Garden Style	$3,064	$1,794	$2,810	$7,668
Low-Rise Loaded Corridor	$3,183	$1,794	$2,906	$7,883
Mid-Rise Mixed Use	$6,640	$1,794	$6,031	$14,465
High-Rise Mixed Use	$6,912	$1,794	$6,050	$14,756

Assumptions:

The Statewide CASE Team determined that the average inspection to take 1 hour per year as part of a larger annual maintenance program over the life of the unit.

Cost Effectiveness – Heat Pump Water Heater Scenario

30-Year Cost-Effectiveness Summary Per Dwelling Units – New Construction/Additions – Prescriptive HPWH- Master Mixing Valve

Climate Zone	Benefits: LSCLSC Savings + Other PV Cost Savings (2026 PV$/dwelling unit)	Costs: Total Incremental PV Costs (2026 PV$/dwelling unit)	B/C Ratio
1	$3,400	$155	22
2	$3,068	$170	18
3	$3,066	$167	18
4	$3,172	$173	18
5	$2,957	$176	17
6	$2,448	$160	15
7	$2,792	$163	17
8	$2,801	$158	18
9	$2,740	$157	17
10	$2,858	$159	18
11	$3,367	$160	21
12	$3,149	$164	19
13	$3,294	$164	20
14	$3,007	$154	19
15	$2,954	$154	19
16	$3,245	$156	21

Cost Effectiveness – Gas Water Heater Scenario

30-Year Cost-Effectiveness Summary Per Dwelling Units – New Construction/Additions – Prescriptive Gas Master Mixing Valve

Climate Zone	Benefits: LSCLSC Savings + Other PV Cost Savings (2026 PV$/dwelling unit)	Costs: Total Incremental PV Costs (2026 PV$/dwelling unit)	B/C Ratio
1	$1,768	$143	12
2	$1,632	$157	10
3	$1,597	$154	10
4	$1,551	$159	10
5	$1,593	$162	10
6	$1,451	$147	10
7	$1,420	$150	9
8	$1,403	$145	10
9	$1,417	$144	10
10	$1,339	$146	9
11	$1,409	$147	10
12	$1,477	$152	10
13	$1,384	$151	9
14	$1,415	$142	10
15	$1,135	$142	8
16	$1,458	$149	10

Central Heat Pump Water Heater Clean-up

Existing Code Requirements

Title 24, Part 6 Section 170.2(d)2

- Allows both single-pass and multi-pass primary equipment
- Requires recirculation loop decoupled from primary HPWH systems
- Plumbing configurations to ensure stratification in primary tanks
- Control requirements to achieve minimal efficiency
- Requires heat pump compressor cut-off to be 40°F or lower
- Design documentation of specified operating conditions of the system according to Joint Appendix 14.4
- **Performance Requirements: Joint Appendix 14**
  - Qualification requirements for a performance pathway for central HPWH
  - Includes product performance testing requirements, as well as design documentation requirements

2025 Proposed Requirements

Title 24, Part 6 Section 170.2(d)2

- Updates primary prescriptive requirement to ensure system efficiency and operation reliability
  - Use of single-pass primary HPWH only
  - Remove requirement on multiple primary storage tanks plumbing to be in-series or in-parallel depending on the primary HPWH type
  - Clean-up recirculation loop system requirement language for clarity and simplification
- New alternative prescriptive pathways for system that meets NEEA Advanced Water Heater Commercial Spec Tier 2 or higher

2025 Proposed Requirements

System Configurations	Details	Prescriptive Compliance Pathway	Prescriptive Compliance Pathway	Prescriptive Compliance Pathway
		2022	**2025 Primary path**	**2025 Alternative path**
Single-Pass Primary	with HW Circulation Returned to Primary Storage	No	No	NEEA AWHS Commercial HPWH **Tier 2** or higher
Single-Pass Primary	with Series Temperature Maintenance Tank System (Swing Tank)	Yes	Yes	NEEA AWHS Commercial HPWH **Tier 2** or higher
Single-Pass Primary	with Parallel Temperature Maintenance Tank System with multi-pass HPWH	Yes	Yes	NEEA AWHS Commercial HPWH **Tier 2** or higher
Multi-Pass Primary	with HW Circulation Returned to Primary Storage	No	No	NEEA AWHS Commercial HPWH **Tier 2** or higher
Multi-Pass Primary	with Series or Parallel Temperature Maintenance Tank System (Swing Tank)	Yes	No	NEEA AWHS Commercial HPWH **Tier 2** or higher

Individual Heat Pump Water Heater Ventilation

Existing Code Requirements

- There are no existing individual HPWH ventilation code requirements.

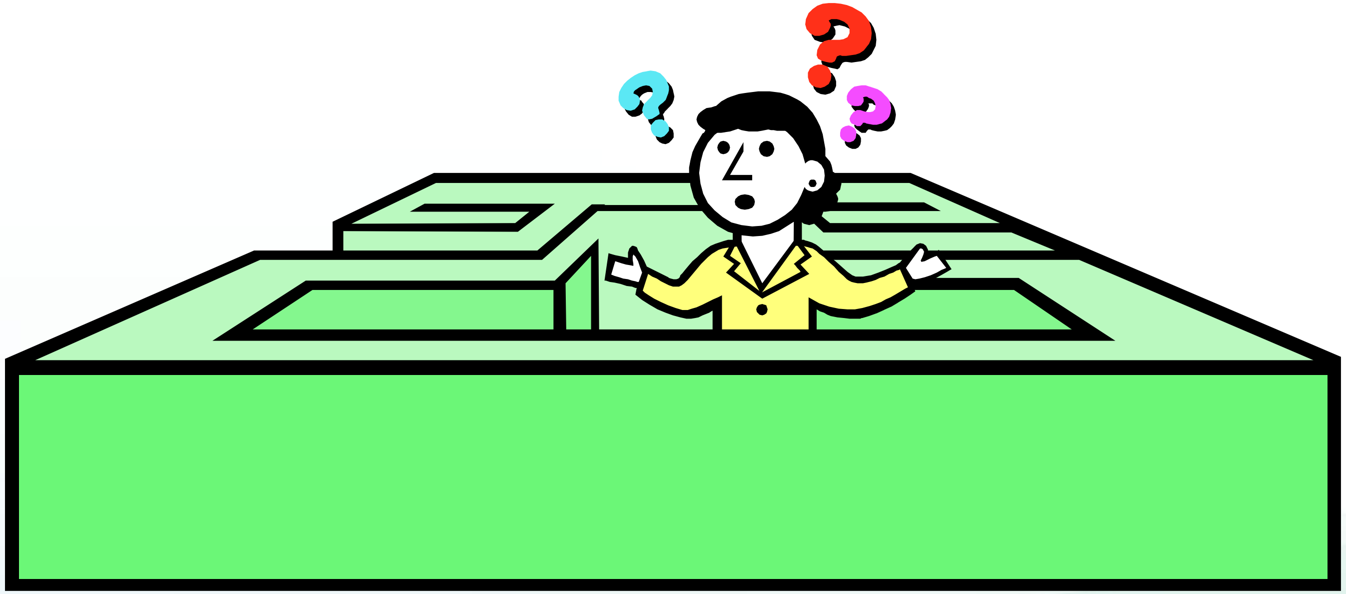
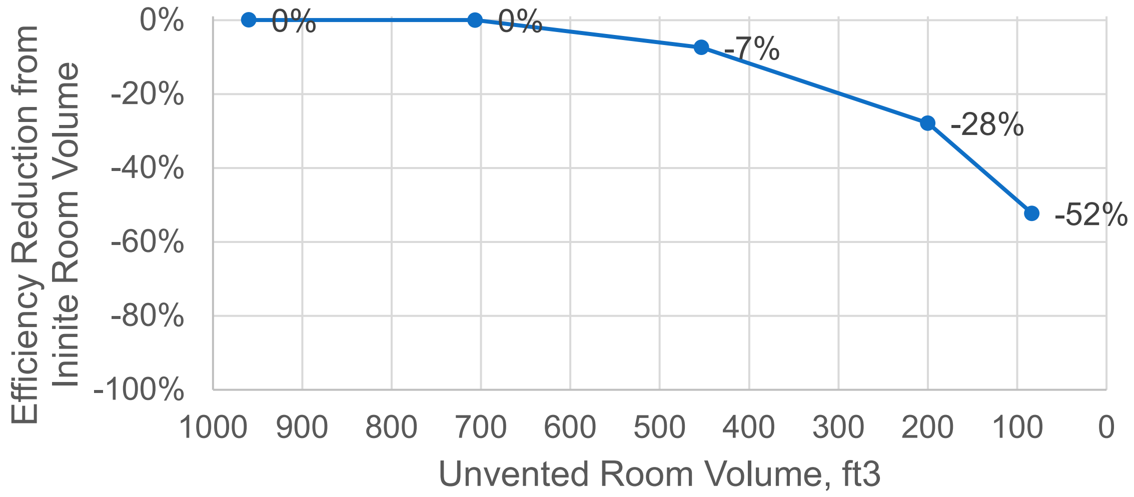
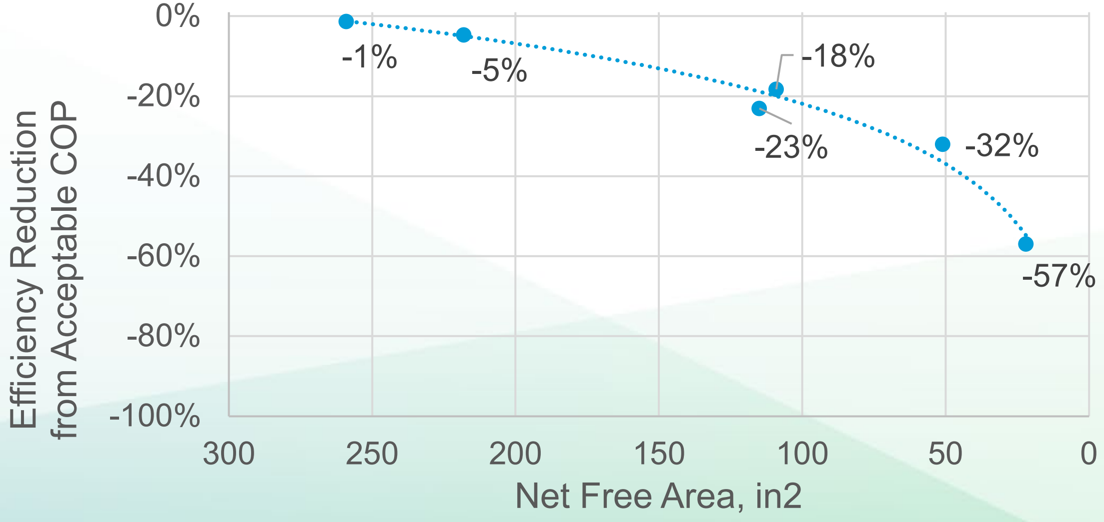


Image credit: Microsoft Clipart

Existing Market Condition

- HPWH performance is heavily dependent on install location air volume and ventilation.
- Performance ceases to be “acceptable” in unvented rooms smaller than 450 ft^3, which is in line with manufacturer installation manuals.
- Despite guidance, most designs and installs do not provide adequate ventilation.
- A majority of HPWH installs are likely not operating at acceptable efficiency levels.





Measure Scope

This proposed code change involves:

- **Section 110.3** Mandatory ventilation air requirements for consumer-sized integrated heat pump water heaters (HPWHs) in all occupancies.
- Consumer Integrated HPWHs defined as in federal code (CFR 430):
  - ≤ 120-gallon storage volume.
  - Electrical input < 24 amps at < 250 volts.
- **Applies to single family and multifamily**

This proposed code change does not involve:

- Commercial integrated HPWHs.
- Split system HPWHs.
- Requiring HPWHs.

Image credits (L to R): Bradford-White, A. O. Smith, Rheem

2025 Proposed Requirements

Must provide ventilation for a HPWH via one of four methods:

1) Large unvented room/closet.
   - Larger of 100 ft^3 room volume / kBtu/h of compressor input capacity, or manufacturer specified requirements.
2) Small vented room/closet.
   - Larger of 20 ft^3 room volume / kBtu/h of compressor capacity, or manufacturer specified requirements; and
   - Larger of 125 in^2 net free area (NFA) plus 25 in^2 per kBtu/h of compressor capacity, or manufacturer specified requirements.

2025 Proposed Requirements - Cont

3) Directly ducted to the HPWH inlet or outlet in any size room/closet.
   - Exhaust duct must be insulated, all ducts sealed using mastic, etc.
4) Ventilation methods approved by the HPWH manufacturer. A letter from the manufacturer must be included with plans submitted to the building department.

- HPWHs must be installed with backup heat if unconditioned air is used for ventilation and the compressor cutout temperature is above the Winter Median of Extremes in Joint Appendix 2.2, Table 2-3.

Software Used & Prototypes

Existing Design

- CBECC results adjusted to reflect poor ventilation using temperature bin model developed from laboratory test results

Proposed Design

- Existing CBECC HPWH model

Incremental Costs

- For the purpose of the analysis, incremental costs are the costs of including ventilation vs. not including ventilation.
- Incremental costs depend on the ventilation method applied.
- For the purpose of calculating cost effectiveness, the Statewide CASE Team assumed the most likely applied ventilation method: grilles.
- The result was a statewide average incremental first cost of $179.29 and maintenance and replacement costs of $0, per dwelling unit.

Total Incremental Costs

Incremental First Cost

Item	Cost
Equipment	$76.55
Installation	$102.74
Commissioning	$0.00
Other	$0.00
Total	**$179.29***

Maintenance Cost

Item	Cost
Equipment Replacement	$0.00
Annual Maintenance	$0.00
Total	**$0.00**

Total incremental cost over 30-year period of analysis: $179.29*

*Average for all climate zones and prototypes.

Cost Effectiveness – Exterior Closets

New Construction and Additions

Climate Zone	Benefits LSC Savings + Other PV Savings (2026 PV$)	Costs Total Incremental PV Costs (2026 PV$)	Benefit-to-Cost Ratio
1	$7,942	$169	46.95
2	$6,381	$205	31.12
3	$6,772	$191	35.48
4	$5,936	$206	28.89
5	$7,129	$205	34.81
6	$5,709	$172	33.16
7	$5,503	$174	31.70
8	$5,080	$171	29.78
9	$5,072	$170	29.87
10	$5,262	$171	30.70
11	$5,103	$173	29.44
12	$5,699	$178	32.11
13	$5,028	$177	28.48
14	$4,863	$168	28.91
15	$3,851	$168	22.90
16	$5,043	$172	29.31

Alterations

Climate Zone	Benefits LSC Savings + Other PV Savings (2026 PV$)	Costs Total Incremental PV Costs[b] (2026 PV$)	Benefit-to-Cost Ratio
1	$7,095	$169	41.95
2	$5,735	$205	27.97
3	$6,279	$191	32.89
4	$5,342	$206	25.99
5	$6,340	$205	30.96
6	$5,149	$172	29.91
7	$5,119	$174	29.49
8	$4,663	$171	27.34
9	$4,651	$170	27.39
10	$4,621	$171	26.96
11	$4,593	$173	26.50
12	$5,102	$178	28.74
13	$4,588	$177	25.99
14	$4,304	$168	25.59
15	$3,511	$168	20.87
16	$4,705	$172	27.34

Cost Effectiveness – Interior Closets

New Construction and Additions

Climate Zone	Benefits LSC Savings + Other PV Savings (2026 PV$)	Costs Total Incremental PV Costs (2026 PV$)	Benefit-to-Cost Ratio
1	$6,479.87	$169.15	38.31
2	$5,712.06	$205.05	27.86
3	$5,411.00	$190.88	28.35
4	$5,160.55	$205.50	25.11
5	$5,745.67	$204.80	28.06
6	$4,925.34	$172.18	28.61
7	$4,763.81	$173.60	27.44
8	$4,626.05	$170.58	27.12
9	$4,646.67	$169.78	27.37
10	$4,872.42	$171.38	28.43
11	$5,213.58	$173.33	30.08
12	$5,379.04	$177.50	30.30
13	$5,049.98	$176.53	28.61
14	$5,094.83	$168.18	30.29
15	$3,938.54	$168.18	23.42
16	$6,578.02	$172.08	38.23

Alterations

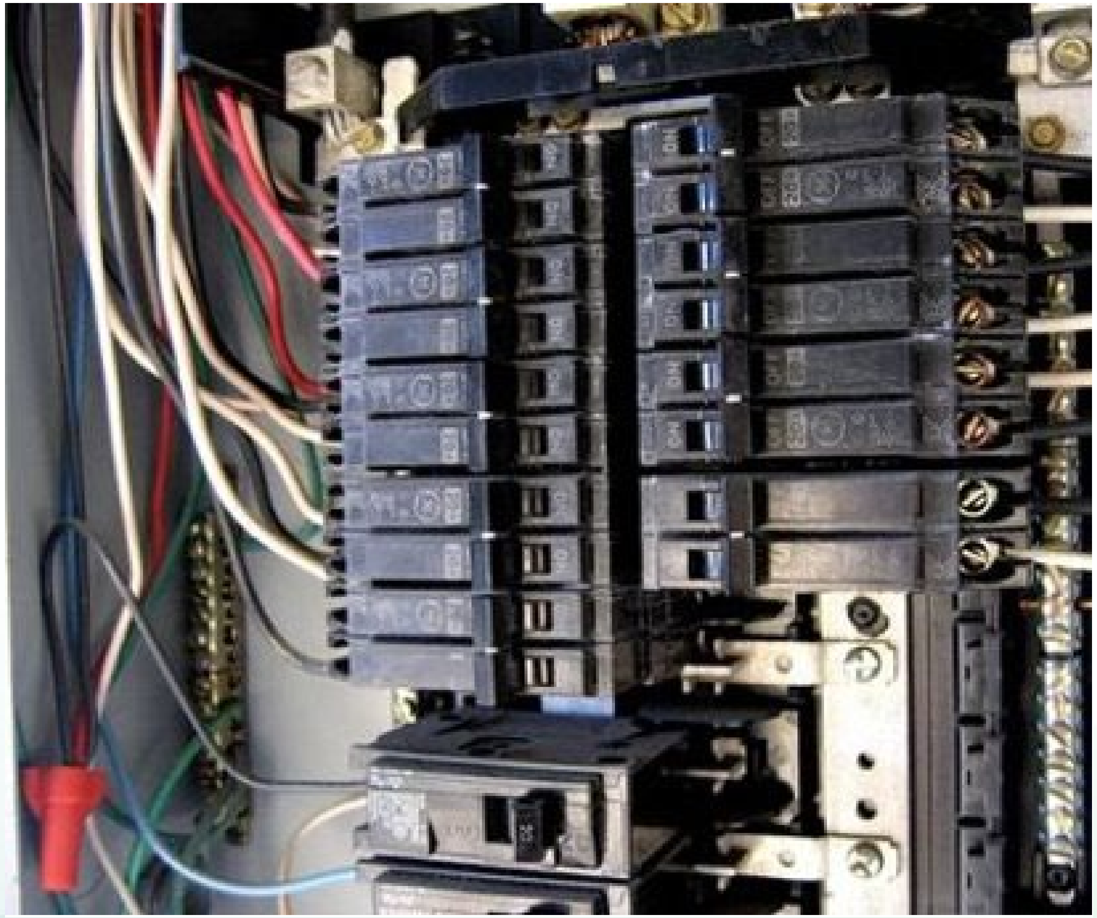
Climate Zone	Benefits LSC Savings + Other PV Savings (2026 PV$)	Costs Total Incremental PV Costs (2026 PV$)	Benefit-to-Cost Ratio
1	$6,261.21	$169.15	37.02
2	$5,502.12	$205.05	26.83
3	$5,289.56	$190.88	27.71
4	$4,984.94	$205.50	24.26
5	$5,565.78	$204.80	27.18
6	$4,778.22	$172.18	27.75
7	$4,657.16	$173.60	26.83
8	$4,515.27	$170.58	26.47
9	$4,538.18	$169.78	26.73
10	$4,702.96	$171.38	27.44
11	$5,090.24	$173.33	29.37
12	$5,199.31	$177.50	29.29
13	$4,968.43	$176.53	28.15
14	$4,922.41	$168.18	29.27
15	$3,887.24	$168.18	23.11
16	$6,507.68	$172.08	37.82

Electric Ready – Individual Water Heating System

Existing Code Requirements

2022 Title 24 Part 6, Section 160.4(a)

- A reserved additional single pole circuit breaker space for future 240 volt use
- Dedicated 125 volt, 20 amp receptacle
- Condensate drainage
- Feeder: 120/240 volt, 3 conductor, 10 AWG copper branch circuit to future location

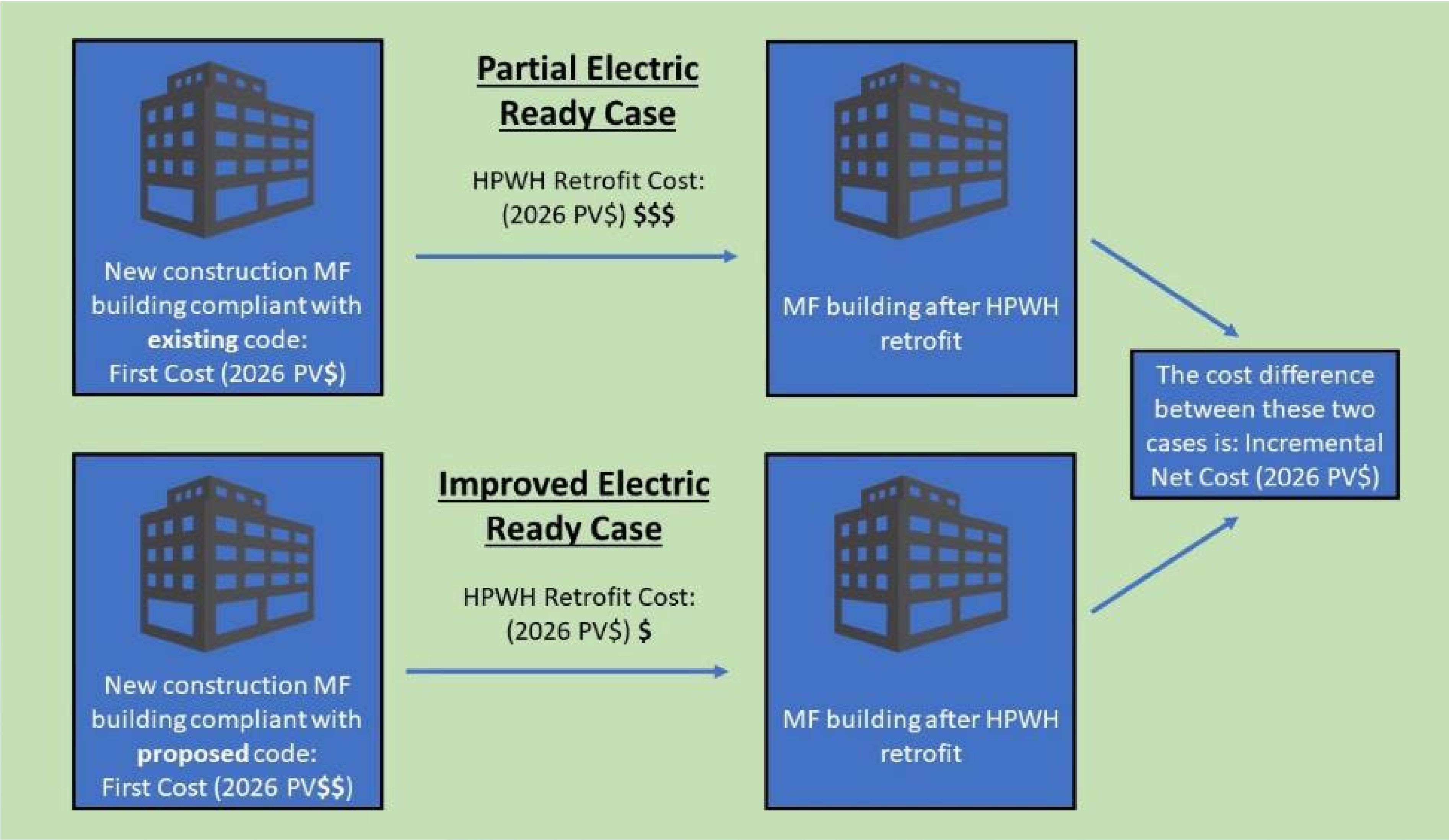


2025 Proposed Requirements

2025 Title 24 Part 6, Section 160.9(d)

- Change conductor requirement from 10 AWG copper branch circuit to 30 amps minimum
- Entire building electrical system must be sized following 160.9 (f) to meet future load
- Minimum space: 39”x39”x96” (W,L,H)
- Ventilation – Meet one of the following:
    - Installed in space with minimum volume of 700 cu. ft.; or
    - Installed in a smaller space and vented via permanent openings with a total of 250 sq. in. NFA so that the combined volume connected via permanent openings is 700 cu. ft. or larger; or
    - Installed with two 8” capped ducts, venting to exterior

Electric Ready Measure Cost Evaluation Methodology



Incremental First Costs

Water Heating Closet Augmentation and Door Ventilation Costs Per Dwelling Unit

Climate Zone	Incremental First Cost (2026 PV$)
1	$188
2	$228
3	$213
4	$229
5	$228
6	$192
7	$193
8	$190
9	$189
10	$191
11	$193
12	$198
13	$196
14	$187
15	$187
16	$192

Incremental Retrofit Costs

Water Heating Closet Augmentation and Door Ventilation Costs Per Dwelling Unit

Climate Zone	Incremental Retrofit Cost	Incremental Retrofit Cost (2026 PV$)
1	-$833	-$461
2	-$1,050	-$581
3	-$969	-$536
4	-$1,048	-$580
5	-$1,032	-$571
6	-$838	-$464
7	-$841	-$466
8	-$833	-$461
9	-$830	-$460
10	-$835	-$463
11	-$849	-$470
12	-$864	-$478
13	-$856	-$474
14	-$825	-$457
15	-$825	-$457
16	-$848	-$469

Total Incremental Net Cost and Cost Effectiveness

Water Heating Closet Augmentation and Door Ventilation Costs Per Dwelling Unit

Climate Zone	Incremental Net Cost (2026 PV$)	Cost Effective?
1	-$273	Yes
2	-$353	Yes
3	-$324	Yes
4	-$351	Yes
5	-$343	Yes
6	-$272	Yes
7	-$273	Yes
8	-$271	Yes
9	-$271	Yes
10	-$272	Yes
11	-$277	Yes
12	-$281	Yes
13	-$277	Yes
14	-$269	Yes
15	-$269	Yes
16	-$278	Yes

Electric Ready – Central Domestic Hot Water System

Existing Code Requirements

- There are no existing code requirements for central hot water systems to be electric ready
- Central water heating is the only major building service that does not currently require electric readiness

2025 Proposed Requirements

2025 Title 24 Part 6 Proposed Requirements

Provide the following to ensure the building can accommodate a future central HPWH system:

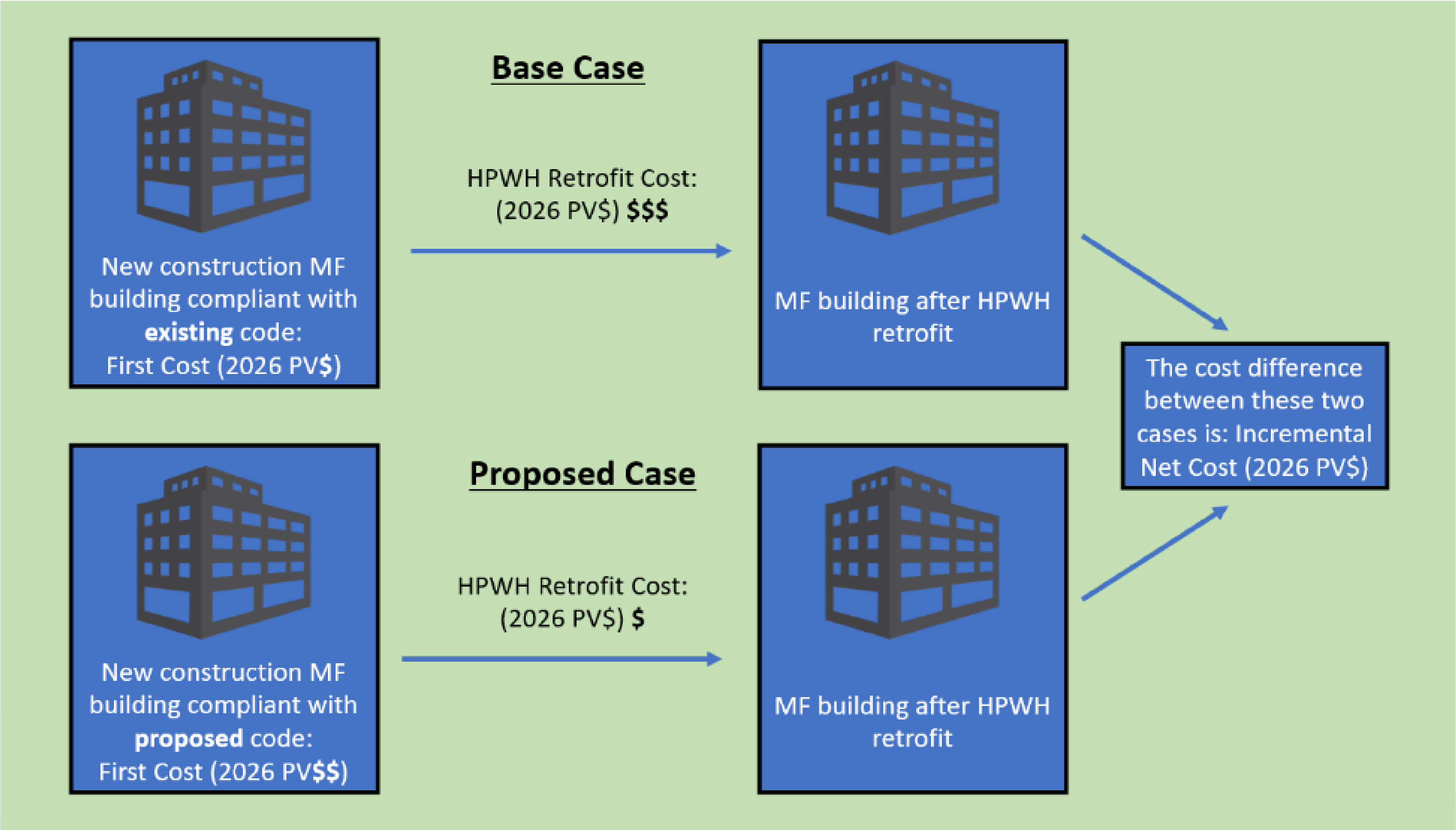
- Electrical
  - The entire building electrical system upstream of the future water heater panel must be sized to meet the future load
- Condensate drainage piping installed
- Reserve space for the heat pump and temperature maintenance tank
- Ventilation
  - Install louver or duct penetrations through the building envelope, or
  - Reserve space for the future heat pump outdoors

2025 Proposed Requirements

There are two pathways to comply with the proposed requirements:

- Designer provides a design for a future central HPWH.
- Prescribed sizing factors in JA15.

Electric Ready Measure Cost Evaluation Methodology



Incremental First Costs

Incremental First Building Main Service Cost

Building Type	Cost Component	Base Case (Not Electric Ready)[a] Cost at Time of Construction (2026 PV$)	Proposed Case (Electric Ready)[b] Cost at Time of Construction (2026 PV$)
Low-Rise Garden Style	Building Main Service	$21,612	$21,612
Low-Rise Garden Style	Total Incremental First Costs	NA	$ -
Low-Rise Loaded Corridor	Building Main Service	$61,389	$61,389
Low-Rise Loaded Corridor	Total Incremental First Costs	NA	$ -
Mid-Rise Mixed Use	Building Main Service	$102,316	$102,316
Mid-Rise Mixed Use	Total Incremental First Costs	NA	$ -
High-Rise Mixed Use	Building Main Service	$102,316	$102,316
High-Rise Mixed Use	Total Incremental First Costs	NA	$ -

Total Incremental Net Cost and Cost Effectiveness

Central Electric Ready

Building Prototype	Incremental Net Cost (2026 PV$)	Cost Effective?
Low-Rise Garden Style	$0	YES
Low-Rise Loaded Corridor	$0	YES
Mid-Rise Mixed Use	$0	YES
High-Rise Mixed Use	$0	YES

- $0 savings is considered cost effective.
  - Had main service upgrades been required, there would have been a nonzero savings.

Building Level Electric Ready

Building Level Electric Ready Cleanup

- Improves the language of Title 24, Part 6, Section 160.9 to align with standard practice
- Explicitly requires that electrical system upstream of the dwelling unit, be sized to meet the demands of future electrification
- Reduces potentially significant technical and financial barriers to future electrification
- Already standard practice

Example: Low Rise Loaded Corridor: In-unit water heater, in-unit dryer, Range

Serving	No Building Level Electrification Planning	With Building Level Electrification Planning	Gap in existing code
Studio Units	100A Panel 1 1/4" Conduit, #2AWG Feeder	150A Panel 1 1/4" Conduit, #1/O Feeder	Dwelling unit main panel Feeders serving dwelling unit main panel
1-BR Units	100A Panel 1 1/4" Conduit, #2AWG Feeder	150A Panel 1 1/4" Conduit, #1/O Feeder	Dwelling unit main panel Feeders serving dwelling unit main panel
2-BR Units	100A Panel 1 1/4" Conduit, #2AWG Feeder	150A Panel 1 1/4" Conduit, #1/O Feeder	Dwelling unit main panel Feeders serving dwelling unit main panel
3-BR Units	100A Panel 1 1/4" Conduit, #2AWG Feeder	175A Panel 1 1/2" Conduit, #2/O Feeder	Dwelling unit main panel Conduit serving dwelling unit main panel Feeders serving dwelling unit main panel
Floor Level Distribution	600 Amps	1000 Amps	Floor level distribution boards, No impact to floor level transformers
Building Main Service	817 Amps, (1000A Switchboard)	1236 Amps, (1600A Switchboard)	Switchboard, Main service conduit

Existing Code Requirements

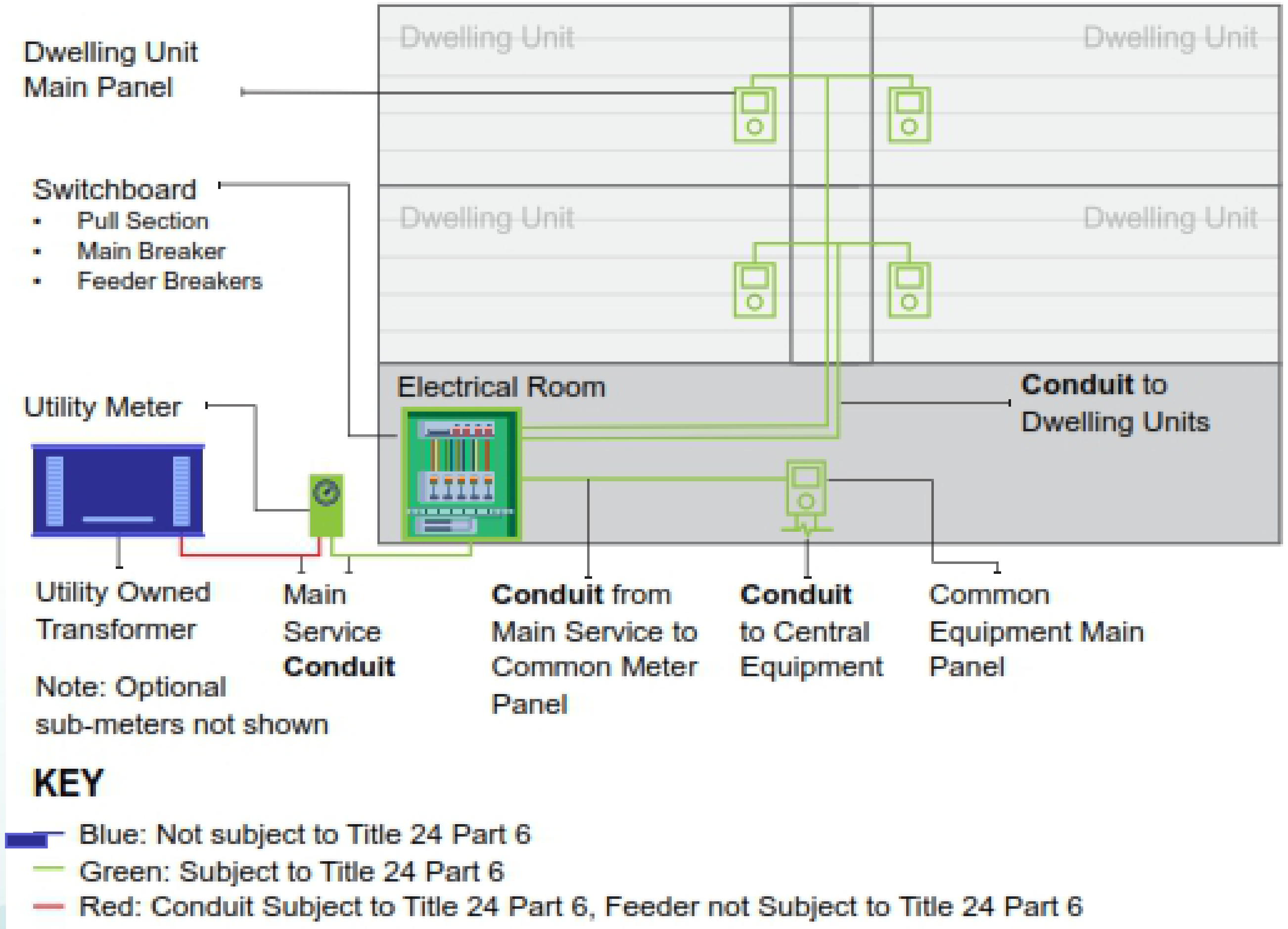
2022 Title 24, Part 6 Section 160.9

Electric Ready Requirements	Dedicated Branch Circuit Requirements	Breaker Requirements	Building Electrical System Requirements
Heat Pump Space Heater	240 volts, Rated at 30 amps (min)	Reserved space for future double pole circuit breaker	No
Electric Cooktop	240 volts, Rated at 50 amps (min)	Reserved space for future double pole circuit breaker	No
Electric Clothes Dryer (Individual)	240 volts, Rated at 30 amps (min)	Reserved space for future double pole circuit breaker	No
Electric Clothes Dryer (Central)	208/240 volts, 24 amp capacity	Busbars and panels shall be sized for the future load	Required to be sized for future electric load to the point where the conductors serving the building connect to the utility distribution system

Proposed Code Requirements

- Add a mandatory requirement that the entire building electrical system to be sized for electric ready equipment
- All existing and proposed electric ready requirements would reference Section 160.9(f)

Typical Low Rise Electrical System



Comments

Comments on today's workshop due

September 5, 2023, by 5:00 PM

Submit comments to CEC Docket 22-BSTD-01

https://efiling.energy.ca.gov/Ecomment/Ecomment.aspx?docketnumber=22-BSTD-01

Contact: danny.tam@energy.ca.gov

Appendix

California Plumbing Code Appendix M

Software Used & Prototypes

- The Statewide CASE Team used a recirculation heat loss spreadsheet calculator and a heating plant pipe heat loss spreadsheet calculator to assess the energy impact of the proposed code change.
- The former is for assessing pipe heat loss of recirculation-based hot water distribution systems, and the latter is for assessing pipe heat loss of water heating plants.
- The recirculation heat loss spreadsheet calculator used pipe heat loss calculation methods defined in the existing 2022 ACM Reference Manual.
- The spreadsheet calculator includes features to handle detailed recirculation piping designs, insulation conditions, and recirculation flow controls.
- In comparison, CBECC uses a simple recirculation model with six pipe sections to streamline code compliance, but they are not capable of assessing the energy impact of complicated recirculation system designs found in real buildings.

First Costs – HPWH Scenario

Material and Labor Costs (HPWH Plant)

MF Building Type	Case	Pipe and Insulation Material Cost	Appurtenances Material Cost	Labor Hours	Labor Rate	Total
Low-Rise Garden Style	Base Case	$9,518	$9,465	155	$95	$33,710
Low-Rise Garden Style	Proposed Case	$8,485	$9,181	136	$95	$30,578
Low-Rise Loaded Corridor	Base Case	$32,558	$20,325	388	$95	$89,778
Low-Rise Loaded Corridor	Proposed Case	$24,183	$13,135	329	$95	$68,601
Mid-Rise Mixed Use	Base Case	$88,006	$43,460	859	$95	$213,025
Mid-Rise Mixed Use	Proposed Case	$60,702	$24,962	728	$95	$154,788
High-Rise Mixed Use	Base Case	$95,791	$61,720	927	$95	$245,603
High-Rise Mixed Use	Proposed Case	$69,783	$46,504	789	$95	$191,238

First Costs – Gas scenario

Material and Labor Costs (Gas Plant)

MF Building Type	Case	Pipe and Insulation Material Cost	Appurtenances Material Cost	Labor Hours	Labor Rate	Total
Low-Rise Garden Style	Base Case	$9,535	$10,625	156	$95	$35,008
Low-Rise Garden Style	Proposed Case	$8,495	$10,365	154	$95	$33,456
Low-Rise Loaded Corridor	Base Case	$32,906	$25,930	387	$95	$95,611
Low-Rise Loaded Corridor	Proposed Case	$24,549	$16,600	346	$95	$74,050
Mid-Rise Mixed Use	Base Case	$89,335	$71,085	870	$95	$243,104
Mid-Rise Mixed Use	Proposed Case	$61,909	$41,440	754	$95	$174,954
High-Rise Mixed Use	Base Case	$98,055	$125,530	940	$95	$312,864
High-Rise Mixed Use	Proposed Case	$73,131	$97,890	834	$95	$250,294

First-Year Electricity Savings – CPC Appendix M

First Year Electricity Savings (kWh) Per Dwelling Unit by Climate Zone (CZ) – HPWH-AppM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	67	61	61	61	65	60	59	58	58	59	60	60	60	60	55	62
Loaded Corridor	116	109	109	108	113	107	105	105	106	106	107	107	107	107	102	110
Mid-Rise Mixed Use	137	126	127	124	132	123	121	120	121	122	124	124	123	123	115	127
High-Rise Mixed Use	88	81	82	81	85	80	78	78	78	79	80	80	80	80	75	82

First-Year Peak Electricity Demand Reductions – CPC Appendix M

First Year Peak Demand Reduction (kW) Per Dwelling Unit by Climate Zone (CZ) – HPWH-AppM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	8	7	7	7	8	7	7	7	7	7	7	7	7	7	7	7
Loaded Corridor	13	13	13	13	13	13	13	13	13	13	13	13	13	13	12	13
Mid-Rise Mixed Use	16	15	15	15	16	15	14	14	14	14	15	15	15	15	14	15
High-Rise Mixed Use	10	10	10	10	10	9	9	9	9	9	9	9	9	9	9	10

First-Year Natural Gas Savings – CPC Appendix M

First Year Natural Gas Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) – Gas-AppM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	287	261	262	259	276	255	250	248	249	252	257	255	255	256	235	264
Loaded Corridor	829	799	802	795	816	791	785	784	785	788	793	794	791	792	769	802
Mid-Rise Mixed Use	753	706	711	701	733	695	685	683	686	689	698	698	694	697	661	712
High-Rise Mixed Use	648	620	623	617	636	614	608	607	608	610	616	616	613	615	594	624

Long-Term System Cost (LSC) Savings – CPC Appendix M - HPWH

LSC Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) – HPWH-AppM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	456	415	416	408	437	405	393	393	395	399	405	405	401	405	374	422
Loaded Corridor	778	735	738	727	759	725	707	711	713	717	724	724	720	724	688	743
Mid-Rise Mixed Use	924	850	857	838	890	832	809	810	815	820	832	833	825	831	774	862
High-Rise Mixed Use	593	550	554	542	573	539	525	526	529	532	539	540	535	538	505	557

Long-Term System Cost (LSC) Savings – CPC Appendix M - Gas

LSC Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) – Gas-AppM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	343	312	313	309	330	305	300	297	298	302	307	306	304	306	281	317
Loaded Corridor	987	953	956	949	972	945	939	936	938	941	947	947	943	947	918	958
Mid-Rise Mixed Use	899	843	849	837	875	831	821	816	820	824	834	834	829	833	790	851
High-Rise Mixed Use	773	740	743	736	758	733	728	724	726	729	734	734	731	734	709	745

First-Year Source Energy Savings – CPC Appendix M

First Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) – HPWH-AppM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	119	108	108	107	114	105	103	103	104	104	106	107	105	106	99	109
Loaded Corridor	198	190	191	189	194	188	184	185	186	187	189	189	188	189	180	191
Mid-Rise Mixed Use	240	220	222	218	231	216	212	211	212	213	217	217	215	216	202	223
High-Rise Mixed Use	154	142	143	141	149	140	137	137	137	138	140	140	139	140	131	144

First-Year Source Energy Savings – CPC Appendix M

First Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate– Zone (CZ) - Gas-AppM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	260	237	237	234	250	230	224	224	224	227	233	231	230	230	211	238
Loaded Corridor	751	723	726	720	739	712	704	705	707	709	718	718	716	713	692	722
Mid-Rise Mixed Use	682	640	644	635	663	625	614	614	617	620	632	632	628	627	595	641
High-Rise Mixed Use	586	562	564	559	576	552	545	546	547	549	557	557	555	553	534	561

30-Year Electricity Savings – CPC Appendix M

Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions – Low-Rise Garden Prototype – HPWH-AppM

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$456	$0	$456
2	$415	$0	$415
3	$416	$0	$416
4	$408	$0	$408
5	$437	$0	$437
6	$405	$0	$405
7	$393	$0	$393
8	$393	$0	$393
9	$395	$0	$395
10	$399	$0	$399
11	$405	$0	$405
12	$405	$0	$405
13	$401	$0	$401
14	$405	$0	$405
15	$374	$0	$374
16	$422	$0	$422

LSC Savings – CPC Appendix M

Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions – Loaded Corridor Prototype – HPWH-AppM

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$778	$0	$778
2	$735	$0	$735
3	$738	$0	$738
4	$727	$0	$727
5	$759	$0	$759
6	$725	$0	$725
7	$707	$0	$707
8	$711	$0	$711
9	$713	$0	$713
10	$717	$0	$717
11	$724	$0	$724
12	$724	$0	$724
13	$720	$0	$720
14	$724	$0	$724
15	$688	$0	$688
16	$743	$0	$743

LSC Savings

Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions – Mid-Rise Mixed Use Prototype – HPWH-AppM

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$924	$0	$924
2	$850	$0	$850
3	$857	$0	$857
4	$838	$0	$838
5	$890	$0	$890
6	$832	$0	$832
7	$809	$0	$809
8	$810	$0	$810
9	$815	$0	$815
10	$820	$0	$820
11	$832	$0	$832
12	$833	$0	$833
13	$825	$0	$825
14	$831	$0	$831
15	$774	$0	$774
16	$862	$0	$862

LSC Savings

Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions – High-Rise Mixed Use Prototype – HPWH-AppM

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$593	$0	$593
2	$550	$0	$550
3	$554	$0	$554
4	$542	$0	$542
5	$573	$0	$573
6	$539	$0	$539
7	$525	$0	$525
8	$526	$0	$526
9	$529	$0	$529
10	$532	$0	$532
11	$539	$0	$539
12	$540	$0	$540
13	$535	$0	$535
14	$538	$0	$538
15	$505	$0	$505
16	$557	$0	$557

LSC Savings

2026 Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions – Low-Rise Garden Prototype – Gas-AppM

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$0	$343	$343
2	$0	$312	$312
3	$0	$313	$313
4	$0	$309	$309
5	$0	$330	$330
6	$0	$305	$305
7	$0	$300	$300
8	$0	$297	$297
9	$0	$298	$298
10	$0	$302	$302
11	$0	$307	$307
12	$0	$306	$306
13	$0	$304	$304
14	$0	$306	$306
15	$0	$281	$281
16	$0	$317	$317

30-Year Natural Gas Savings

2026 Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions – Loaded Corridor Prototype – Gas-AppM

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$0	$987	$987
2	$0	$953	$953
3	$0	$956	$956
4	$0	$949	$949
5	$0	$972	$972
6	$0	$945	$945
7	$0	$939	$939
8	$0	$936	$936
9	$0	$938	$938
10	$0	$941	$941
11	$0	$947	$947
12	$0	$947	$947
13	$0	$943	$943
14	$0	$947	$947
15	$0	$918	$918
16	$0	$958	$958

LSC Savings

2026 Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions – Mid-Rise Mixed Use Prototype – Gas-AppM

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
01	$0	$899	$899
02	$0	$843	$843
03	$0	$849	$849
04	$0	$837	$837
05	$0	$875	$875
06	$0	$831	$831
07	$0	$821	$821
08	$0	$816	$816
09	$0	$820	$820
10	$0	$824	$824
11	$0	$834	$834
12	$0	$834	$834
13	$0	$829	$829
14	$0	$833	$833
15	$0	$790	$790
16	$0	$851	$851

LSC Savings

2026 Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions – High-Rise Mixed Use Prototype – Gas-AppM

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
01	$0	$773	$773
02	$0	$740	$740
03	$0	$743	$743
04	$0	$736	$736
05	$0	$758	$758
06	$0	$733	$733
07	$0	$728	$728
08	$0	$724	$724
09	$0	$726	$726
10	$0	$729	$729
11	$0	$734	$734
12	$0	$734	$734
13	$0	$731	$731
14	$0	$734	$734
15	$0	$709	$709
16	$0	$745	$745

Pipe Insulation Enhancement

Key Assumptions

- Utilized basis of design developed from the 2022 CASE cycle for the hot water distribution system using CPC Appendix A
- Developed a BOD for the Domestic Hot Water heating plant that included various appurtenances
- For distribution systems, the proposed case will have the same effect as reducing uninsulated pipes by 15% of the total recirculation pipe surface area
- For heating plants, the proposed case will reduce uninsulated pipes to 15% of straight pipes and 30% of appurtenance surface areas
- Modeled pipe heat losses and calculated DHW system energy use based on gas and heat pump heating plants for the four prototype buildings

	Base Case	Proposed Case
% of pipes not insulated (Distribution system)	Low-Rise Garden: 52% Loaded Corridor: 43% Mid-Rise Mixed Use: 38.5% High-Rise Mixed Use: 43%	Low-Rise Garden: 37% Loaded Corridor: 28% Mid-Rise Mixed Use: 23.5% High-Rise Mixed Use: 28%
% of pipes not insulated (Water heating plant)	Straight pipes: 30% Appurtenances: 100%	Straight pipes: 15% Appurtenances: 30%
Key Assumption - Pipe sizing method for distribution system and water heating plant	For base case and proposed case: CPC Appendix A	For base case and proposed case: CPC Appendix A
Key Assumption - Balancing valve configurations	For base case and proposed case: Manual balancing valves set to have 0.5 GPM recirculation flow per riser	For base case and proposed case: Manual balancing valves set to have 0.5 GPM recirculation flow per riser
Key Assumption - Recirculation flow controls	For base case and proposed case: None	For base case and proposed case: None

Incremental First Costs HPWH

Proposed Case Incremental Cost Per Prototype (HPWH Plant)

MF Building Type	Baseline	Proposed	Total Incremental Cost	Average Incremental Cost per Dwelling Unit
Low-Rise Garden	$9,070	$10,113	$1,043	$130
Low-Rise Loaded Corridor	$24,070	$27,236	$3,166	$88
Mid-Rise Mixed Use	$57,544	$65,494	$7,950	$90
High-Rise Mixed Use	$62,017	$70,518	$8,501	$73

Incremental First Costs Gas

Proposed Case Incremental Cost Per Prototype (Gas Plant)

MF Building Type	Baseline	Proposed	Total Incremental Cost	Average Incremental Cost per Dwelling Unit
Low-Rise Garden	$8,823	$9,843	$1,020	$127
Low-Rise Loaded Corridor	$23,544	$26,681	$3,137	$87
Mid-Rise Mixed Use	$57,848	$65,827	$7,979	$91
High-Rise Mixed Use	$62,427	$70,966	$8,539	$73

First-Year Electricity Savings – Pipe Insulation Enhancement

First Year Electricity Savings (kWh) Per Dwelling Unit – HPWH-Pipe Insulation

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	256	242	244	241	250	239	236	235	236	237	240	240	239	239	229	244
Loaded Corridor	184	171	172	170	178	168	166	165	166	167	169	169	168	169	159	173
Mid-Rise Mixed Use	192	178	180	177	186	175	172	171	172	173	176	176	175	175	165	180
High-Rise Mixed Use	177	166	167	164	172	163	160	160	160	161	164	164	163	163	154	167

First-Year Peak Electricity Demand Reductions – Pipe Insulation Enhancement

First Year Peak Demand Reduction (kW) Per Dwelling Unit – HPWH-Pipe Insulation

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	30	28	28	28	29	28	28	28	28	28	28	28	28	28	28	29
Loaded Corridor	21	20	20	20	21	20	20	20	20	20	20	20	20	20	20	20
Mid-Rise Mixed Use	23	21	21	21	22	21	20	20	20	20	21	21	21	21	19	21
High-Rise Mixed Use	21	19	20	19	20	19	19	19	19	19	19	19	19	19	18	20

First-Year Natural Gas Savings

First Year Natural Gas Savings (kBtu) Per Dwelling Unit – Gas-Pipe Insulation

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	2,406	2,348	2,354	2,342	2,381	2,334	2,322	2,319	2,322	2,327	2,338	2,338	2,333	2,336	2,291	2,355
Loaded Corridor	1,448	1,396	1,401	1,390	1,426	1,383	1,372	1,370	1,373	1,377	1,387	1,387	1,382	1,385	1,345	1,402
Mid-Rise Mixed Use	1,427	1,367	1,373	1,360	1,401	1,352	1,340	1,337	1,591	1,345	1,356	1,607	1,351	1,354	1,559	1,374
High-Rise Mixed Use	1,622	1,573	1,577	1,567	1,601	1,560	1,550	1,548	1,551	1,554	1,564	1,564	1,559	1,562	1,524	1,579

First-Year Long-Term System Cost (LSC) Savings

First Year LSC Savings (2026 PV$) Per Dwelling Unit – HPWH-Pipe Insulation

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	1,728	1,636	1,644	1,620	1,686	1,615	1,581	1,587	1,596	1,599	1,613	1,617	1,603	1,612	1,547	1,654
Loaded Corridor	1,233	1,160	1,165	1,145	1,200	1,141	1,111	1,118	1,122	1,128	1,140	1,141	1,134	1,139	1,078	1,173
Mid-Rise Mixed Use	1,301	1,206	1,215	1,190	1,258	1,183	1,152	1,155	1,160	1,167	1,183	1,184	1,173	1,181	1,107	1,222
High-Rise Mixed Use	1,198	1,119	1,126	1,106	1,162	1,101	1,074	1,077	1,082	1,087	1,100	1,101	1,092	1,099	1,037	1,133

First-Year Long-Term System Cost (LSC) Savings

First Year LSC Savings (2026 PV$) Per Dwelling Unit – Gas-Pipe Insulation

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	2,868	2,798	2,805	2,791	2,838	2,785	2,776	2,767	2,772	2,776	2,786	2,787	2,780	2,787	2,734	2,810
Loaded Corridor	1,724	1,665	1,671	1,658	1,699	1,652	1,642	1,636	1,639	1,644	1,654	1,655	1,649	1,654	1,605	1,674
Mid-Rise Mixed Use	1,702	1,630	1,637	1,622	1,671	1,615	1,603	1,596	1,899	1,606	1,618	1,916	1,611	1,617	1,861	1,641
High-Rise Mixed Use	1,934	1,875	1,880	1,868	1,908	1,863	1,854	1,847	1,851	1,855	1,864	1,864	1,859	1,865	1,819	1,884

First-Year Source Energy Savings

First Year Source Energy Savings (kBtu) Per Dwelling Unit – HPWH-Pipe Insulation

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	445	421	423	418	435	415	410	409	414	412	417	420	415	416	402	424
Loaded Corridor	314	300	301	298	308	297	291	292	293	295	298	298	297	298	282	302
Mid-Rise Mixed Use	337	312	314	309	326	306	301	300	301	303	308	308	306	307	288	315
High-Rise Mixed Use	310	289	291	287	301	284	280	279	280	282	285	286	284	285	269	292

First-Year Source Energy Savings

First Year Source Energy Savings (kBtu) Per Dwelling Unit – Gas-Pipe Insulation

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	2179	2126	2131	2120	2156	2100	2081	2086	2089	2093	2117	2117	2112	2101	2061	2119
Loaded Corridor	1311	1264	1268	1259	1291	1244	1230	1232	1235	1239	1256	1256	1251	1246	1210	1262
Mid-Rise Mixed Use	1292	1238	1243	1232	1268	1217	1201	1202	1431	1210	1228	1455	1223	1218	1402	1236
High-Rise Mixed Use	1469	1424	1428	1419	1449	1404	1390	1392	1395	1398	1416	1416	1412	1405	1371	1420

30-Year Electricity Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction and Additions– Low-Rise Garden Prototype – HPWH-Pipe Insulation

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$1,728	$0	$1,728
2	$1,636	$0	$1,636
3	$1,644	$0	$1,644
4	$1,620	$0	$1,620
5	$1,686	$0	$1,686
6	$1,615	$0	$1,615
7	$1,581	$0	$1,581
8	$1,587	$0	$1,587
9	$1,596	$0	$1,596
10	$1,599	$0	$1,599
11	$1,613	$0	$1,613
12	$1,617	$0	$1,617
13	$1,603	$0	$1,603
14	$1,612	$0	$1,612
15	$1,547	$0	$1,547
16	$1,654	$0	$1,654

30-Year Electricity Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction and Additions– Loaded Corridor Prototype – HPWH-Pipe Insulation

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$1,233	$0	$1,233
2	$1,160	$0	$1,160
3	$1,165	$0	$1,165
4	$1,145	$0	$1,145
5	$1,200	$0	$1,200
6	$1,141	$0	$1,141
7	$1,111	$0	$1,111
8	$1,118	$0	$1,118
9	$1,122	$0	$1,122
0	$1,128	$0	$1,128
11	$1,140	$0	$1,140
12	$1,141	$0	$1,141
13	$1,134	$0	$1,134
14	$1,139	$0	$1,139
15	$1,078	$0	$1,078
16	$1,173	$0	$1,173

30-Year Electricity Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction and Additions– Mid-Rise Mixed Use Prototype – HPWH-Pipe Insulation

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
01	$1,301	$0	$1,301
02	$1,206	$0	$1,206
03	$1,215	$0	$1,215
04	$1,190	$0	$1,190
05	$1,258	$0	$1,258
06	$1,183	$0	$1,183
07	$1,152	$0	$1,152
08	$1,155	$0	$1,155
09	$1,160	$0	$1,160
10	$1,167	$0	$1,167
11	$1,183	$0	$1,183
12	$1,184	$0	$1,184
13	$1,173	$0	$1,173
14	$1,181	$0	$1,181
15	$1,107	$0	$1,107
16	$1,222	$0	$1,222

30-Year Electricity Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction and Additions– High-Rise Mixed Use Prototype – HPWH-Pipe Insulation

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$1,198	$0	$1,198
2	$1,119	$0	$1,119
3	$1,126	$0	$1,126
4	$1,106	$0	$1,106
5	$1,162	$0	$1,162
6	$1,101	$0	$1,101
7	$1,074	$0	$1,074
8	$1,077	$0	$1,077
9	$1,082	$0	$1,082
10	$1,087	$0	$1,087
11	$1,100	$0	$1,100
12	$1,101	$0	$1,101
13	$1,092	$0	$1,092
14	$1,099	$0	$1,099
15	$1,037	$0	$1,037
16	$1,133	$0	$1,133

30-Year Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction and Additions– Low-Rise Garden Prototype – Gas-Pipe Insulation

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$0	$2,868	$2,868
2	$0	$2,798	$2,798
3	$0	$2,805	$2,805
4	$0	$2,791	$2,791
5	$0	$2,838	$2,838
6	$0	$2,785	$2,785
7	$0	$2,776	$2,776
8	$0	$2,767	$2,767
9	$0	$2,772	$2,772
10	$0	$2,776	$2,776
11	$0	$2,786	$2,786
12	$0	$2,787	$2,787
13	$0	$2,780	$2,780
14	$0	$2,787	$2,787
15	$0	$2,734	$2,734
16	$0	$2,810	$2,810

30-Year Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction and Additions– Loaded Corridor Prototype – Gas-Pipe Insulation

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$0	$1,724	$1,724
2	$0	$1,665	$1,665
3	$0	$1,671	$1,671
4	$0	$1,658	$1,658
5	$0	$1,699	$1,699
6	$0	$1,652	$1,652
7	$0	$1,642	$1,642
8	$0	$1,636	$1,636
9	$0	$1,639	$1,639
10	$0	$1,644	$1,644
11	$0	$1,654	$1,654
12	$0	$1,655	$1,655
13	$0	$1,649	$1,649
14	$0	$1,654	$1,654
15	$0	$1,605	$1,605
16	$0	$1,674	$1,674

30-Year Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction and Additions– Mid-Rise Mixed Use Prototype – Gas-Pipe Insulation

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$0	$1,702	$1,702
2	$0	$1,630	$1,630
3	$0	$1,637	$1,637
4	$0	$1,622	$1,622
5	$0	$1,671	$1,671
6	$0	$1,615	$1,615
7	$0	$1,603	$1,603
8	$0	$1,596	$1,596
9	$0	$1,899	$1,899
10	$0	$1,606	$1,606
11	$0	$1,618	$1,618
12	$0	$1,916	$1,916
13	$0	$1,611	$1,611
14	$0	$1,617	$1,617
15	$0	$1,861	$1,861
16	$0	$1,641	$1,641

30-Year Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction and Additions– High-Rise Mixed Use Prototype – Gas-Pipe Insulation

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$0	$1,934	$1,934
2	$0	$1,875	$1,875
3	$0	$1,880	$1,880
4	$0	$1,868	$1,868
5	$0	$1,908	$1,908
6	$0	$1,863	$1,863
7	$0	$1,854	$1,854
8	$0	$1,847	$1,847
9	$0	$1,851	$1,851
10	$0	$1,855	$1,855
11	$0	$1,864	$1,864
12	$0	$1,864	$1,864
13	$0	$1,859	$1,859
14	$0	$1,865	$1,865
15	$0	$1,819	$1,819
16	$0	$1,884	$1,884

First Costs HPWH

Material and Labor Costs for Proposed Case (HPWH Plant)

MF Building Type	Insulation Material Cost	Labor Hours	Labor Rate	Total
Low-Rise Garden Style	$4,324	58	$100	$10,113
Low-Rise Loaded Corridor	$12,274	150	$100	$27,236
Mid-Rise Mixed Use	$30,545	349	$100	$65,494
High-Rise Mixed Use	$32,662	379	$100	$70,518

First Costs Gas

Material and Labor Costs for Proposed Case (Gas Plant)

MF Building Type	Insulation Material Cost	Labor Hours	Labor Rate	Total
Low-Rise Garden Style	$4,252	56	$100	$9,843
Low-Rise Loaded Corridor	$12,155	145	$100	$26,681
Mid-Rise Mixed Use	$30,711	351	$100	$65,827
High-Rise Mixed Use	$32,885	381	$100	$70,966

Thermostatic Balancing Valves

Key Assumptions for Assessing Energy Impact of Automatic Balancing Valves

Category	Description
Balancing valve configurations, base case and proposed case	Base Case: Manual balancing valves set to have 0.5 GPM recirculation flow per riser Proposed Case: With automatic balancing valves, recirculation flows through risers are adjusted so that water temperature at balancing valves are close to the setpoint.
Pipe sizing method for distribution system, both cases	CPC Appendix A
% of pipes not insulated (Distribution system), both cases	Low-Rise Garden: 52%, Loaded Corridor: 43%
Recirculation flow controls, both cases	None

- Simplifying (conservative) assumptions:
  - Ignoring savings due to increased plant efficiency and improved balance, as compared to poor manual balancing.
  - Only quantify the energy savings potential due to reducing the riser flow rate at each riser to what is necessary to maintain a specified temperature at the automatic balancing valve to achieve the desired energy savings and cost-effectiveness results.
- Proposed design, simplifications due to modeling limitations
  - Applied minimum flow rate to all risers, which results in a conservative estimate of minimum flow rate at each TBV.
  - Minimum flow rates as floor values into the recirculation heat loss spreadsheet calculator.
  - Calculate heat loss based the floor minimum flow rate or the flow needed to meet temperature set point, which results in a conservative estimate of energy savings.

First-Year Electricity Savings

First Year Electricity Savings (kWh) Per Dwelling U–it by Climate Zone (CZ) - HPWH-Balance-valve-temp-120

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	48	44	44	43	46	42	42	41	34	42	43	45	42	43	44	44
Loaded Corridor	12	11	11	11	12	11	11	11	12	11	11	12	11	11	12	11

First-Year Peak Electricity Demand Reductions

First Year Peak Demand Reduction (kW) Per Dwelling Unit - HPWH-Balance-valve-temp-120

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	6	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5
Loaded Corridor	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

First-Year Natural Gas Savings

First Year Natural Gas Savings (kBtu) Per Dwelling Unit - Gas-Balance-valve-temp-120

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	204	186	187	184	196	181	177	177	144	179	182	192	181	182	188	188
Loaded Corridor	53	48	49	48	51	47	46	46	50	46	47	49	47	47	52	49

First-Year Long-Term System Cost (LSC) Savings

First Year LSC Savings (kBtu) Per Dwelling Unit - HPWH-Balance-valve-temp-120

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	324	295	294	290	310	288	279	279	226	283	288	301	285	287	292	300
Loaded Corridor	83	77	77	75	80	75	73	73	79	74	75	78	74	75	82	78

First-Year Long-Term System Cost (LSC) Savings

First Year LSC Savings (kBtu) Per Dwelling Unit - Gas-Balance-valve-temp-120

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	244	222	222	220	234	217	213	211	171	214	218	227	216	218	223	225
Loaded Corridor	63	58	58	57	61	56	55	55	60	56	57	59	56	57	62	58

First-Year Source Energy Savings

First Year Source Energy Savings (kBtu) Per Dwelling Unit - HPWH-Balance-valve-temp-120

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	84	77	73	76	81	75	73	73	56	74	75	75	75	75	72	78
Loaded Corridor	21	20	19	20	21	20	19	19	20	20	20	20	20	20	21	20

First-Year Source Energy Savings

First Year Source Energy Savings (kBtu) Per Dwelling Unit - Gas-Balance-valve-temp-120

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	185	168	170	166	177	163	159	159	129	161	165	173	164	164	169	169
Loaded Corridor	48	44	44	43	46	42	41	41	45	42	43	45	43	42	47	44

30-Year Electricity Savings

2026 Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions —Low-Rise Garden Prototype - HPWH-Balance-valve-temp-120

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	324	0	324
2	295	0	295
3	294	0	294
4	290	0	290
5	310	0	310
6	288	0	288
7	279	0	279
8	279	0	279
9	226	0	226
10	283	0	283
11	288	0	288
12	301	0	301
13	285	0	285
14	287	0	287
15	292	0	292
16	300	0	300

30-Year Electricity Savings

2026 Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions —Loaded Corridor Prototype - HPWH-Balance-valve-temp-120

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	83	0	83
2	77	0	77
3	77	0	77
4	75	0	75
5	80	0	80
6	75	0	75
7	73	0	73
8	73	0	73
9	79	0	79
10	74	0	74
11	75	0	75
12	78	0	78
13	74	0	74
14	75	0	75
15	82	0	82
16	78	0	78

30-Year Natural Gas Savings

2026 Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions — Low-Rise Garden Prototype - Gas-Balance-valve-temp-120

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	0	244	244
2	0	222	222
3	0	222	222
4	0	220	220
5	0	234	234
6	0	217	217
7	0	213	213
8	0	211	211
9	0	171	171
10	0	214	214
11	0	218	218
12	0	227	227
13	0	216	216
14	0	218	218
15	0	223	223
16	0	225	225

30-Year Natural Gas Savings

2026 Present Value LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions — Loaded Corridor Prototype - Gas-Balance-valve-temp-120

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	0	63	63
2	0	58	58
3	0	58	58
4	0	57	57
5	0	61	61
6	0	56	56
7	0	55	55
8	0	55	55
9	0	60	60
10	0	56	56
11	0	57	57
12	0	59	59
13	0	56	56
14	0	57	57
15	0	62	62
16	0	58	58

First Costs

Material and Labor Costs for Base Case

MF Building Type	Average Material Cost	Material Labor Hours	Labor Rate	Total Cost
Low-Rise Garden Style	$1,010	15.01	$100	$2,511
Low-Rise Loaded Corridor	$2,743	24.02	$100	$5,146

Material and Labor Costs for Proposed Case-TBV

MF Building Type	Average Material Cost	Material Labor Hours	Labor Rate	Total Cost
Low-Rise Garden Style	$1,179	11.01	$100	$2,281
Low-Rise Loaded Corridor	$2,907	20.02	$100	$4,909

Replacement Material and Labor Costs for Base Case

MF Building Type	Average Material Cost	Material Labor Hours	Labor Rate	Total Cost
Low-Rise Garden Style	$808	18.76	$100	$2,684
Low-Rise Loaded Corridor	$2,194	30.02	$100	$5,196

Replacement Material and Labor Costs for Proposed Case

MF Building Type	Average Material Cost	Material Labor Hours	Labor Rate	Total Cost
Low-Rise Garden Style	$943	13.76	$100	$2,319
Low-Rise Loaded Corridor	$2,326	25.02	$100	$4,828

Incremental First Cost per Dwelling

Incremental Costs for Base Case vs Proposed Case- TBV

MF Building Type	Base Case	Proposed Case- TBV	Incremental First Cost	Average Incremental First Cost per Dwelling Unit
Low-Rise Garden Style	$2,511	$2,281	-$230	-$29
Low-Rise Loaded Corridor	$5,146	$4,909	-$237	-$7

Incremental Replacement Costs for Base Case vs Proposed Case

MF Building Type	Base Case	Proposed Case- TBV	Incremental First Cost	Average Incremental First Cost per Dwelling Unit
Low-Rise Garden Style	$2,684	$2,319	-$365	-$46
Low-Rise Loaded Corridor	$5,196	$4,828	-$368	-$10

Master Mixing Valves

Lab Testing of MMVs

Heat pump DHW systems with continuous recirculation were tested in the laboratory to mimic real world operation in multifamily buildings.

24-hour testing was conducted

- With no MMV
- With mechanical MMV
- With digital MMV

Testing was limited, but useful.

Test matrix shows the various heating plant designs

- 2022 Preliminary results show a heating plant average electricity savings of 10.5% from using a mechanical or digital MMV versus No MMV
- 2023 testing emphasized minimizing temperature drop through distribution loop and holding a minimum 120°F return temperature
  - 2°F drop for digital valve
  - 5°F drop for mechanical valve

	ENERGY SAVINGS	ENERGY SAVINGS	ENERGY SAVINGS
Heating Plant Design	No MMV to Mechanical MMV	No MMV to Digital MMV	Mechanical MMV to Digital MMV
Single Pass HP with Series Electric Resistance Heater*	*5.4%	6.5%	*1.0%
Single Pass HP with Parallel Multi Pass HP/Tank*	*6.5%	7.5%	*1.0%
Single Pass HP Return to Primary*	9.2%	8.5%	-0.6%
Single Pass HP Return to Primary**	13.5%	18.0%	3.9%
Multi Pass HP Return to Primary*	*12.0%	14.3%	*2.0%

*2022 Testing: 120°F supply and 110°F return temperatures, loop heat loss at 100 watts/dwelling unit
**2023 Testing: Targeted 2°F drop and 120°F return temperature at 50 watts/dwelling unit
**Not tested, but estimated in red

First-Year Electricity Savings

First Year Electricity Savings (kWh) Per Dwelling Unit by Climate Zone (CZ), Prescriptive HPWH Master Mixing Valve

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	140	129	126	122	126	113	112	109	110	109	114	120	111	116	91	141
Loaded Corridor	118	107	104	101	104	92	91	88	89	88	93	99	90	94	70	118
Mid-Rise Mixed Use	148	132	129	125	130	114	112	109	110	108	115	122	111	118	85	167
High-Rise Mixed Use	110	98	95	92	96	83	81	78	79	78	84	90	81	87	60	128

First-Year Peak Electricity Demand Reductions

First Year Peak Demand Reduction (kW) Per Dwelling Unit by Climate Zone (CZ), Prescriptive HPWH - Master Mixing Valve

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	55	52	54	60	51	42	41	43	46	47	54	53	52	55	46	43
Loaded Corridor	57	56	56	63	54	46	45	48	50	51	59	58	57	61	51	48
Mid-Rise Mixed Use	70	72	72	79	71	62	62	66	68	69	76	75	75	77	68	75
High-Rise Mixed Use	56	59	59	66	58	49	49	52	55	56	64	61	61	65	56	60

First-Year Natural Gas Savings

First Year Natural Gas Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ), Prescriptive Gas - Master Mixing Valve

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	1,004	862	846	782	836	733	738	695	694	679	730	785	707	695	496	909
Loaded Corridor	1116	1,044	1,028	963	1,020	961	912	921	923	752	768	825	786	763	658	907
Mid-Rise Mixed Use	1,411	1,310	1,293	1,251	1,300	1,181	1,167	1,139	1,149	1,132	1,166	1,230	1,139	1,177	930	1378
High-Rise Mixed Use	1,078	997	984	950	989	894	883	860	868	854	882	933	860	891	692	1052

First-Year Long-Term System Cost (LSC) Savings

First Year LSC Savings (2026 PV$) Per Dwelling Unit by Climate Zone (CZ), Prescriptive HPWH - Master Mixing Valve

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	2,483	2,234	2,206	2,295	2,103	1,620	1,944	1,747	1,722	1,759	2,153	2,100	2,017	1,952	1,573	1,927
Loaded Corridor	2,419	2,225	2,150	2,316	2,059	1,637	1,958	1,815	1,764	1,828	2,245	2,185	2,112	2,063	1,745	1,986
Mid-Rise Mixed Use	4,056	3,616	3,674	3,728	3,553	2,968	3,342	3,441	3,367	3,521	4,093	3,782	4,056	3,611	3,685	4,074
High-Rise Mixed Use	3,188	3,078	2,917	3,204	2,826	2,545	2,751	2,873	2,875	3,006	3,496	3,172	3,456	3,203	3,653	3,210

First-Year Long-Term System Cost (LSC) Savings

First Year LSC Savings (2026 PV$) Per Dwelling Unit by Climate Zone (CZ), Prescriptive Gas - Master Mixing Valve

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	1,260	1,084	1,063	986	1,049	920	929	876	875	857	925	992	896	881	631	1,815
Loaded Corridor	1,764	1,679	1,657	1,582	1,646	1,577	1,521	1,530	1,533	1,326	1,351	1,418	1,373	1,344	1,215	2,215
Mid-Rise Mixed Use	1,840	1,679	1,634	1,604	1,634	1,447	1,427	1,399	1,420	1,404	1,502	1,571	1,451	1,516	1,147	2,011
High-Rise Mixed Use	1,388	1,235	1,213	1,178	1,217	1,094	1,081	1,052	1,064	1,048	1,097	1,156	1,066	1,108	852	1,650

First-Year Source Energy Savings

First Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ), Prescriptive HPWH - Master Mixing Valve

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	243	229	220	220	221	196	194	193	196	195	211	217	204	216	169	251
Loaded Corridor	196	182	174	174	175	152	150	149	152	150	166	171	159	170	127	202
Mid-Rise Mixed Use	230	210	203	201	203	178	175	172	175	173	190	198	183	198	143	289
High-Rise Mixed Use	170	154	148	145	147	127	125	122	125	123	139	144	132	147	100	221

First-Year Source Energy Savings

First Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ), Prescriptive Gas - Master Mixing Valve

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Loaded Corridor	954	819	804	743	795	692	694	657	656	642	694	746	671	656	469	858
Low-Rise Garden	1,030	964	949	890	942	882	834	845	847	690	709	762	726	700	604	833
Mid-Rise Mixed Use	1,300	1,207	1,192	1,154	1,198	1,083	1,066	1,044	1,053	1,038	1,077	1,134	1,051	1,080	854	1,263
High-Rise Mixed Use	984	910	898	867	903	811	798	781	788	775	806	852	786	808	629	954

30-Year Electricity Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction and Additions – Low-Rise Garden Prototype - Prescriptive HPWH - Master Mixing Valve

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	2483	0	2483
2	2234	0	2234
3	2206	0	2206
4	2295	0	2295
5	2103	0	2103
6	1620	0	1620
7	1944	0	1944
8	1747	0	1747
9	1722	0	1722
10	1759	0	1759
11	2153	0	2153
12	2100	0	2100
13	2017	0	2017
14	1952	0	1952
15	1573	0	1573
16	1927	0	1927

30-Year Electricity Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction and Additions – Loaded Corridor Prototype - Prescriptive HPWH - Master Mixing Valve

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	2419	0	2419
2	2225	0	2225
3	2150	0	2150
4	2316	0	2316
5	2059	0	2059
6	1637	0	1637
7	1958	0	1958
8	1815	0	1815
9	1764	0	1764
10	1828	0	1828
11	2245	0	2245
12	2185	0	2185
13	2112	0	2112
14	2063	0	2063
15	1745	0	1745
16	1986	0	1986

30-Year Electricity Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction and Additions – Mid-Rise Mixed Use Prototype - Prescriptive HPWH - Master Mixing Valve

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	4056	0	4056
2	3616	0	3616
3	3674	0	3674
4	3728	0	3728
5	3553	0	3553
6	2968	0	2968
7	3342	0	3342
8	3441	0	3441
9	3367	0	3367
10	3521	0	3521
11	4093	0	4093
12	3782	0	3782
13	4056	0	4056
14	3611	0	3611
15	3685	0	3685
16	4074	0	4074

30-Year Electricity Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction and Additions – High-Rise Mixed Use Prototype - Prescriptive HPWH - Master Mixing Valve

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	3188	0	3188
2	3078	0	3078
3	2917	0	2917
4	3204	0	3204
5	2826	0	2826
6	2545	0	2545
7	2751	0	2751
8	2873	0	2873
9	2875	0	2875
10	3006	0	3006
11	3496	0	3496
12	3172	0	3172
13	3456	0	3456
14	3203	0	3203
15	3653	0	3653
16	3210	0	3210

30-Year Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction and Additions – Low-Rise Garden Prototype - Prescriptive Gas - Master Mixing Valve

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	0	1260	1260
2	0	1084	1084
3	0	1063	1063
4	0	986	986
5	0	1049	1049
6	0	920	920
7	0	929	929
8	0	876	876
9	0	875	875
10	0	857	857
11	0	925	925
12	0	992	992
13	0	896	896
14	0	881	881
15	0	631	631
16	0	1815	1815

30-Year Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction and Additions – Loaded Corridor Prototype - Prescriptive Gas - Master Mixing Valve

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	0	1764	1764
2	0	1679	1679
3	0	1657	1657
4	0	1582	1582
5	0	1646	1646
6	0	1577	1577
7	0	1521	1521
8	0	1530	1530
9	0	1533	1533
10	0	1326	1326
11	0	1351	1351
12	0	1418	1418
13	0	1373	1373
14	0	1344	1344
15	0	1215	1215
16	0	2215	2215

30-Year Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction and Additions – Mid-Rise Mixed Use Prototype - Prescriptive Gas - Master Mixing Valve

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	0	1840	1840
2	0	1679	1679
3	0	1634	1634
4	0	1604	1604
5	0	1634	1634
6	0	1447	1447
7	0	1427	1427
8	0	1399	1399
9	0	1420	1420
10	0	1404	1404
11	0	1502	1502
12	0	1571	1571
13	0	1451	1451
14	0	1516	1516
15	0	1147	1147
16	0	2011	2011

30-Year Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction and Additions – High-Rise Mixed Use Prototype - Prescriptive Gas - Master Mixing Valve

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	0	1388	1388
2	0	1235	1235
3	0	1213	1213
4	0	1178	1178
5	0	1217	1217
6	0	1094	1094
7	0	1081	1081
8	0	1052	1052
9	0	1064	1064
10	0	1048	1048
11	0	1097	1097
12	0	1156	1156
13	0	1066	1066
14	0	1108	1108
15	0	852	852
16	0	1650	1650

First Costs

For the proposed prescriptive measure, the base case for first cost and incremental cost analysis for buildings with centralized distribution systems is no MMV, and the proposed case is Digital MMV.

MMV Digital Valve Material and Labor Costs for Proposed Case (CZ Average)

MF Building Type	Material	Labor Hours	Labor Rate	Total
Low-Rise Garden Style	$2,263	8	$100	$3,064
Low-Rise Loaded Corridor	$2,383	8	$100	$3,183
Mid-Rise Mixed Use	$5,038	16	$100	$6,640
High-Rise Mixed Use	$5,311	16	$100	$6,912

Incremental First Costs

Incremental First Costs for Base Case vs Proposed Case – Prescriptive HPWH - Master Mixing Valve and Gas – Master Mixing Valve

MF Building Type	Base Case	Proposed Case	Incremental First Cost	Average Incremental Cost Per Dwelling Unit
Low-Rise Garden Style	$0	$3,064	$3,064	$383
Low-Rise Loaded Corridor	$0	$3,183	$3,183	$88
Mid-Rise Mixed Use	$0	$6,640	$6,640	$75
High-Rise Mixed Use	$0	$6,912	$6,912	$59

Incremental Maintenance Costs

Digital or Mechanical MMV 2026 PV$ Incremental Maintenance Costs Over the Buildings Analysis Period (30 Years)

MF Building Type	Base Case Maintenance Material Cost	Base Case Maintenance Labor Cost	Proposed Maintenance Material Cost	Proposed Maintenance Labor Cost	Incremental Maintenance Cost
Low-Rise Garden Style	$0	$0	$0	$1,794	$1,794
Low-Rise Loaded Corridor	$0	$0	$0	$1,794	$1,794
Mid-Rise Mixed Use	$0	$0	$0	$1,794	$1,794
High-Rise Mixed Use	$0	$0	$0	$1,794	$1,794

Incremental Replacement Costs

Incremental Replacement Costs for Base Case vs Proposed Case

MF Building Type	Base Case	Proposed Case	Total Incremental Replacement Cost	Average Incremental Cost per Dwelling Unit
Low-Rise Garden Style	$0	$2,810	$2,810	$351
Low-Rise Loaded Corridor	$0	$2,906	$2,906	$81
Mid-Rise Mixed Use	$0	$6,031	$6,031	$69
High-Rise Mixed Use	$0	$6,050	$6,050	$52

Central Heat Pump Water Heater Clean-up

Key Assumptions

The Statewide CASE Team used assumptions for DHW Standard Design based on the 2022 Title 24, Part 6 Nonresidential and Multifamily ACM Reference Manual with the following assumptions:

- The standard design has a HPWH_SPST configuration.
- The primary single-pass heat pump is a generic heat pump based on the R-134 refrigerant operating cycle.
- The secondary tank volume is 80 if there are up to 48 dwelling units or 120 if there are more than 48 dwelling units.
- Both the primary and secondary storage tanks have insulation R-values of 16 (°F ft2 hr/Btu) insulation.
- The locations of the standard design storage tanks and heat pumps are the same as proposed design.
- The temperature setpoints are 140°F for primary single-pass HPWH and 136°F for secondary water heater.
- Thermostatic mixing valve outlet: 125°F.
- The efficiency and standby losses match the appropriate minimum federal requirements.

Key Assumptions

The basis of design assumes the following:

- On average, the studio units have 1 occupant, the one-bedroom units have 1.5 occupants, the two-bedroom units have 2.5 occupants, and the three-bedroom units have 3.5 occupants.
- The average maximum hot water demand is 22 gallons per person per day delivered at 120°F at the fixtures. This hot water demand assumption is based on practical experience and is between the low and medium guidelines in the ASHRAE HVAC Applications Handbook, Chapter 50 Service Water Heating (Table 7 – Hot Water Demand and Use Guidelines for Apartment Buildings 2019).
- The recirculation loop heat loss is assumed as 100 W/Apartment.
- The design air temperature for the HPWH is assumed to be 30°F.
- The Auqastat Fraction of the HPWH is assumed to be 30 percent.
- The design cold water temperature is assumed as 60°F.
- The HPWH compressor is assumed to run 16 hours per day.

Key Assumptions

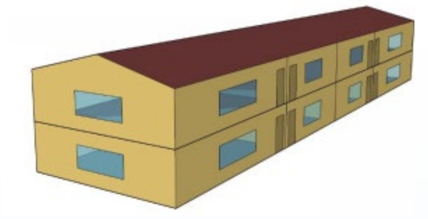
Assumptions for Standard and Proposed Designs

Central HPWH system components	Standard Design	Proposed Design-1	Proposed Design-2	Proposed Design-3	Proposed Design-4 (Only applicable for 4-story and higher)
	HPWH Base	**HPWH_SPST**	**HPWH_SPRetP**	**HPWH_MPRetP**	**HPWH_SPwMPTM**
Primary HPWH type	Single-pass	Single-pass	Single-pass	Multi-pass	Single-pass
Primary system refrigerant, 3-story and lower	R-410a	R-744	R-410a	R-410a	N/A
Primary system refrigerant, 4-story and higher	R-134a	R-744	R-134a	R-134a	R-744
Primary to TMS configuration	In series	In series	N/A	N/A	In parallel
TMS heater	Electric Resistant Water Heater	Electric Resistant Water Heater	N/A	N/A	Split HP with Storage Tank

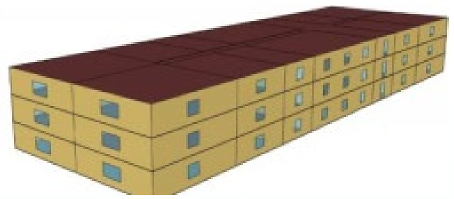
Software Used & Prototypes

Modeled in CBECC 2025 software

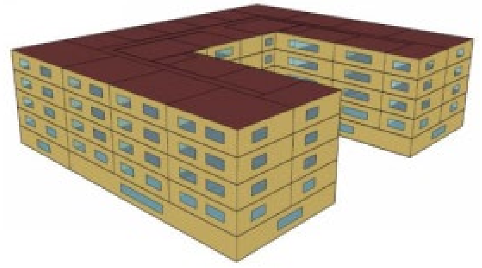
Four multifamily prototypes



Low-Rise Garden Style
2 Story



Low-Rise Loaded Corridor
3 Story



Mid-Rise Mixed-Use
5 Story

High-Rise Mixed-Use
10 Story

First Costs

Install Cost for Baseline and Proposed Central HPWH Designs for Low-Rise Garden

Cost	HPWH Base	HPWH_SPST	HPWH_SPRetP	HPWH_MPRetP
Equipment Total	$58,089	$35,221	$57,024	$98,535
Labor Total	$8,365	$8,365	$8,335	$10,533
Total	$66,454	$43,586	$65,359	$109,068

Install Cost for Baseline and Proposed Central HPWH Designs for Loaded Corridor

Cost	HPWH Base	HPWH_SPST	HPWH_SPRetP	HPWH_MPRetP
Equipment Total	$148,654	$82,352	$105,894	$273,205
Labor Total	$13,113	$16,713	$8,985	$18,405
Total	$161,766	$99,065	$114,879	$291,610

Install Cost for Baseline and Proposed Central HPWH Designs for Mid-Rise Mixed Use

Cost	HPWH Base	HPWH_SPST	HPWH_SPRetP	HPWH_MPRetP	HPWH_SPwMPTM
Equipment Total	$362,880	$139,985	$206,682	$316,960	$362,880
Labor Total	$31,783	$21,493	$16,138	$19,628	$31,783
Total	$394,663	$161,477	$222,820	$336,588	$394,663

Install Cost for Baseline and Proposed Central HPWH Designs for High-Rise Mixed Use

Cost	HPWH Base	HPWH_SPST	HPWH_SPRetP	HPWH_MPRetP	HPWH_SPwMPTM
Equipment total	$422,589	$160,707	$300,631	$328,040	$304,901
Labor total	$36,205	$24,090	$20,238	$24,088	$28,985
Total	$458,794	$184,797	$320,868	$352,128	$333,886

First Incremental Cost

Install Incremental First Cost for Central HPWH Designs for Low-Rise Garden

Cost	HPWH_SPST	HPWH_SPRetP	HPWH_MPRetP
Equipment Total	($22,868)	($1,065)	$40,446
Labor Total	$0	($30)	$2,168
Total	($22,868)	($1,095)	$42,614

Install Incremental First Cost for Central HPWH Designs for Loaded Corridor

Cost	HPWH_SPST	HPWH_SPRetP	HPWH_MPRetP
Equipment Total	($66,302)	($42,760)	$124,551
Labor Total	$3,600	($4,128)	$5,292
Total	($62,701)	($46,887)	$129,844

Install Incremental First Cost for Central HPWH Designs for Mid-Rise Mixed Use

Cost	HPWH_SPST	HPWH_SPRetP	HPWH_MPRetP	HPWH_SPwMPTM
Equipment Total	($222,895)	($156,198)	($45,920)	$0
Labor Total	($10,290)	($15,645)	($12,155)	$0
Total	($233,186)	($171,843)	($58,075)	$0

Install Incremental First Cost for Central HPWH Designs for High-Rise Mixed Use

Cost	HPWH_SPST	HPWH_SPRetP	HPWH_MPRetP	HPWH_SPwMPTM
Equipment Total	($261,882)	($121,958)	($94,549)	($117,688)
Labor Total	($12,115)	($15,967)	($12,117)	($7,220)
Total	($273,997)	($137,926)	($106,666)	($124,908)

Incremental Replacement and Maintenance Cost

Replacement and Maintenance Cost for Central DWH Designs for Low-Rise Garden

Cost	Year	HPWH SPST - Proposed	HPWH SPRetP	HPWH MPRetP
Heat Pump Water Heaters	15	($20,260)	$0	$39,141

Replacement and Maintenance Cost for Central DWH Designs for Loaded Corridor

Cost	Year	HPWH SPST - Proposed	HPWH SPRetP	HPWH MPRetP
Heat Pump Water Heaters	15	($65,235)	($37,408)	$117,424

Replacement and Maintenance Cost for Central DWH Designs for Mid-Rise Mixed Use

Cost	Year	HPWH_ SPST - Proposed	HPWH_ SPRetP	HPWH_ MPRetP	HPWH_ SPwMPTM
Heat Pump Water Heaters	15	($217,921)	($113,956)	($15,575)	($245,956)

Replacement and Maintenance Cost for Central DWH Designs for High-Rise Mixed Use

Cost	Year	HPWH SPST - Proposed	HPWH SPRetP	HPWH MPRetP	HPWH SPwMPTM
Water Heaters, Primary Storage Tank	15	($257,062)	($73,080)	($54,716)	($257,062)

Total Incremental Cost

Total Incremental Costs for all Prototypes

Prototype	HPWH SPST	HPWH SPRetP	HPWH MPRetP	HPWH SPwMPTM
Low-Rise Garden	($43,128)	($1,095)	$81,755	N/A
Loaded Corridor	($127,936)	($84,295)	$247,268	N/A
Mid-Rise Mixed Use	($451,107)	($285,799)	($73,650)	($245,956)
High-Rise Mixed Use	($491,918)	($251,882)	($122,241)	($370,864)

First-Year Electricity Savings

First Year Electricity Savings (kWh) Per Dwelling Unit by Climate Zone (CZ) - Central – HPWH_SPST

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	417	386	382	359	384	339	335	314	317	306	316	348	301	313	207	407
Loaded Corridor	412	362	354	330	358	298	291	271	275	264	281	316	267	287	162	388
Mid-Rise Mixed Use	492	440	432	402	437	376	367	344	350	337	348	388	328	362	204	674
High-Rise Mixed Use	433	373	355	336	358	301	293	276	281	270	296	327	272	312	166	591

First-Year Peak Electricity Demand Reductions

First Year Peak Demand Reduction (kW) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_SPST

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	(2)	0	6	1	7	11	11	12	12	7	(1)	4	1	(2)	5	(2)
Loaded Corridor	26	31	32	36	31	34	35	36	33	34	31	32	34	31	37	29
Mid-Rise Mixed Use	7	13	13	15	14	23	24	20	21	20	14	15	18	15	31	25
High-Rise Mixed Use	7	8	9	3	10	14	15	15	16	16	10	7	10	12	18	23

First-Year Natural Gas Savings

First Year Natural Gas Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_SPST

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(34)
Loaded Corridor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(5)
Mid-Rise Mixed Use	(2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(8)
High-Rise Mixed Use	(2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(4)

First-Year Long-Term System Cost (LSC) Savings

LSC Savings Cost Savings (2026 PV$) Per Dwelling Unit by Climate Zone (CZ)- Central - HPWH_SPST

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	2808	2660	2601	2372	2626	2286	2368	2138	2129	2067	2098	2341	2005	2070	1463	2715
Loaded Corridor	2872	2604	2498	2203	2459	2027	2044	1832	1858	1795	1882	2093	1795	1959	1168	2701
Mid-Rise Mixed Use	3280	3013	2922	2580	2923	2479	2500	2231	2265	2176	2204	2510	2084	2336	1385	4686
High-Rise Mixed Use	2812	2467	2361	2062	2355	1933	1983	1742	1772	1694	1803	2016	1650	1963	1048	4053

First-Year Source Energy Savings

First Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_SPST

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	572	597	589	582	597	574	573	566	561	557	558	580	541	550	475	554
Loaded Corridor	759	692	666	652	673	554	542	526	539	526	586	629	557	602	383	716
Mid-Rise Mixed Use	830	791	765	734	772	688	664	641	652	636	662	708	626	720	458	1375
High-Rise Mixed Use	717	631	617	563	618	527	513	487	497	480	551	577	500	593	339	1166

First-Year Electricity Savings

First Year Electricity Savings (kWh) Per Dwelling Unit by Climate Zone (CZ) - Central – HPWH_SPRetP

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	67	76	79	79	77	91	93	95	93	94	90	84	93	87	117	77
Loaded Corridor	9	13	15	16	14	20	21	21	21	21	20	17	21	19	32	10
Mid-Rise Mixed Use	12	14	16	17	16	18	19	19	19	20	18	17	20	15	27	3
High-Rise Mixed Use	0	3	6	3	5	6	6	7	6	7	5	5	6	1	9	(7)

First-Year Peak Electricity Demand Reductions

First Year Peak Demand Reduction (kW) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_SPRetP

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	6	5	9	7	8	9	11	9	9	8	6	7	8	6	13	4
Loaded Corridor	5	5	6	8	7	7	7	9	7	8	5	6	8	5	9	3
Mid-Rise Mixed Use	0	4	4	3	4	4	4	4	5	5	4	6	6	(1)	7	(2)
High-Rise Mixed Use	(4)	(4)	(3)	(5)	(1)	(3)	(3)	(4)	(3)	(2)	(8)	(4)	(6)	(8)	(1)	(7)

First-Year Natural Gas Savings

First Year Natural Gas Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_SPRetP

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(70)
Loaded Corridor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Mid-Rise Mixed Use	(0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
High-Rise Mixed Use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(0)

First-Year Long-Term System Cost (LSC) Savings

LSC Savings Cost Savings (2026 PV$) Per Dwelling Unit by Climate Zone (CZ)-Central - HPWH_SPRetP

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	491	549	602	548	568	666	687	684	665	671	611	593	636	616	839	487
Loaded Corridor	82	116	127	121	111	159	146	173	173	176	144	123	166	151	243	87
Mid-Rise Mixed Use	64	103	123	94	91	136	106	143	147	148	104	116	125	78	197	15
High-Rise Mixed Use	(16)	(3)	1	(12)	26	21	(21)	26	34	32	(8)	14	18	(25)	56	(88)

First-Year Source Energy Savings

First Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_ SPRetP

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	171	187	201	189	193	221	229	224	219	221	206	196	212	198	258	130
Loaded Corridor	58	62	65	67	63	74	73	74	74	74	71	68	72	68	88	54
Mid-Rise Mixed Use	28	44	57	46	57	58	56	56	56	57	42	45	53	23	70	12
High-Rise Mixed Use	(9)	(3)	10	(4)	8	12	14	14	15	15	(5)	5	12	(22)	23	(31)

First-Year Electricity Savings

First Year Electricity Savings (kWh) Per Dwelling Unit by Climate Zone (CZ) - Central – HPWH_MPRetP

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	(295)	(245)	(232)	(219)	(235)	(175)	(168)	(156)	(164)	(156)	(180)	(206)	(165)	(188)	(93)	(284)
Loaded Corridor	(332)	(286)	(274)	(262)	(277)	(223)	(218)	(207)	(214)	(207)	(229)	(251)	(217)	(236)	(156)	(328)
Mid-Rise Mixed Use	(213)	(185)	(181)	(170)	(183)	(152)	(148)	(141)	(142)	(138)	(148)	(165)	(142)	(150)	(90)	(173)
High-Rise Mixed Use	(174)	(152)	(149)	(142)	(151)	(128)	(126)	(120)	(122)	(119)	(125)	(137)	(120)	(125)	(83)	(134)

First-Year Peak Electricity Demand Reductions

First Year Peak Demand Reduction (kW) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_MPRetP

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	(295)	(245)	(232)	(219)	(235)	(175)	(168)	(156)	(164)	(156)	(180)	(206)	(165)	(188)	(93)	(284)
Loaded Corridor	(332)	(286)	(274)	(262)	(277)	(223)	(218)	(207)	(214)	(207)	(229)	(251)	(217)	(236)	(156)	(328)
Mid-Rise Mixed Use	(213)	(185)	(181)	(170)	(183)	(152)	(148)	(141)	(142)	(138)	(148)	(165)	(142)	(150)	(90)	(173)
High-Rise Mixed Use	(174)	(152)	(149)	(142)	(151)	(128)	(126)	(120)	(122)	(119)	(125)	(137)	(120)	(125)	(83)	(134)

First-Year Natural Gas Savings

First Year Natural Gas Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_MPRetP

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(60)
Loaded Corridor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(1)
Mid-Rise Mixed Use	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
High-Rise Mixed Use	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

First-Year Long-Term System Cost (LSC) Savings

LSC Savings Cost Savings (2026 PV$) Per Dwelling Unit by Climate Zone (CZ)-Central - HPWH_MPRetP

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	(2022)	(1711)	(1611)	(1514)	(1591)	(1154)	(1106)	(1040)	(1099)	(1050)	(1251)	(1404)	(1150)	(1288)	(696)	(2031)
Loaded Corridor	(2240)	(1955)	(1852)	(1748)	(1863)	(1449)	(1449)	(1348)	(1393)	(1349)	(1537)	(1691)	(1443)	(1564)	(1066)	(2208)
Mid-Rise Mixed Use	(1469)	(1331)	(1257)	(1174)	(1310)	(1030)	(1041)	(936)	(947)	(920)	(1005)	(1130)	(958)	(1004)	(593)	(1142)
High-Rise Mixed Use	(1175)	(1061)	(1029)	(977)	(1052)	(879)	(886)	(796)	(804)	(794)	(845)	(918)	(812)	(837)	(543)	(866)

First-Year Source Energy Savings

First Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_ MPRetP

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Low-Rise Garden	(440)	(385)	(337)	(349)	(344)	(228)	(211)	(213)	(235)	(224)	(300)	(326)	(261)	(325)	(128)	(501)
Loaded Corridor	(506)	(455)	(414)	(421)	(420)	(322)	(311)	(308)	(323)	(318)	(381)	(408)	(356)	(404)	(246)	(528)
Mid-Rise Mixed Use	(346)	(321)	(308)	(304)	(309)	(251)	(249)	(244)	(251)	(242)	(256)	(292)	(247)	(274)	(160)	(253)
High-Rise Mixed Use	(283)	(267)	(256)	(256)	(258)	(216)	(208)	(197)	(204)	(200)	(213)	(237)	(210)	(223)	(142)	(190)

First-Year Electricity Savings

First Year Electricity Savings (kWh) Per Dwelling Unit by Climate Zone (CZ) - Central – HPWH_SPwMPTM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Mid-Rise Mixed Use	486	426	417	390	420	361	353	332	337	326	340	377	321	352	206	671
High-Rise Mixed Use	407	350	334	316	337	284	277	260	264	253	278	308	254	293	154	564

First-Year Peak Electricity Demand Reductions

First Year Peak Demand Reduction (kW) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_SPwMPTM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Mid-Rise Mixed Use	(6)	(3)	(2)	(3)	(1)	0	1	(0)	1	(0)	(5)	(1)	(4)	(2)	1	14
High-Rise Mixed Use	(1)	(1)	1	(2)	4	3	4	2	3	2	(2)	1	(3)	2	11	9

First-Year Natural Gas Savings

First Year Natural Gas Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_SPwMPTM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Mid-Rise Mixed Use	(2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(7)
High-Rise Mixed Use	(2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(4)

First-Year Long-Term System Cost (LSC) Savings

LSC Savings Cost Savings (2026 PV$) Per Dwelling Unit by Climate Zone (CZ)-Central - HPWH_SPwMPTM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Mid-Rise Mixed Use	3087	2840	2742	2472	2738	2278	2271	2084	2111	2038	2119	2397	1999	2214	1334	4527
High-Rise Mixed Use	2609	2280	2180	1928	2210	1783	1794	1618	1641	1566	1691	1898	1548	1828	966	3832

First-Year Source Energy Savings

First Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - Central - HPWH_ SPwMPTM

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Mid-Rise Mixed Use	638	651	630	633	628	595	575	573	579	570	581	611	554	641	435	1223
High-Rise Mixed Use	631	568	557	503	559	479	465	447	456	441	496	518	448	539	313	1093

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH_SPST – Low-Rise Garden Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$2,808	$0	$2,808
2	$2,660	$0	$2,660
3	$2,601	$0	$2,601
4	$2,372	$0	$2,372
5	$2,626	$0	$2,626
6	$2,286	$0	$2,286
7	$2,368	$0	$2,368
8	$2,138	$0	$2,138
9	$2,129	$0	$2,129
10	$2,067	$0	$2,067
11	$2,098	$0	$2,098
12	$2,341	$0	$2,341
13	$2,005	$0	$2,005
14	$2,070	$0	$2,070
15	$1,463	$0	$1,463
16	$2,760	($44)	$2,715
Total	$2,272	($0.16)	$2,272

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH SPST – Loaded Corridor Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$2,872	$0	$2,872
2	$2,604	$0	$2,604
3	$2,498	$0	$2,498
4	$2,203	$0	$2,203
5	$2,459	$0	$2,459
6	$2,027	$0	$2,027
7	$2,044	$0	$2,044
8	$1,832	$0	$1,832
9	$1,858	$0	$1,858
10	$1,795	$0	$1,795
11	$1,882	$0	$1,882
12	$2,093	$0	$2,093
13	$1,795	$0	$1,795
14	$1,959	$0	$1,959
15	$1,168	$0	$1,168
16	$2,708	($6)	$2,701
Total	$2,039	($0.02)	$2,039

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH SPST – Mid-Rise Mixed Use Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$3,282	$0	$3,282
2	$3,013	$0	$3,013
3	$2,922	$0	$2,922
4	$2,580	$0	$2,580
5	$2,923	$0	$2,923
6	$2,479	$0	$2,479
7	$2,500	$0	$2,500
8	$2,231	$0	$2,231
9	$2,265	$0	$2,265
10	$2,176	$0	$2,176
11	$2,204	$0	$2,204
12	$2,510	$0	$2,510
13	$2,084	$0	$2,084
14	$2,336	$0	$2,336
15	$1,385	$0	$1,385
16	$4,696	($9)	$4,686
Total	$2,450	($0.04)	$2,450

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH_SPST – High-Rise Mixed Use Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$2,814	$0	$2,814
2	$2,467	$0	$2,467
3	$2,361	$0	$2,361
4	$2,062	$0	$2,062
5	$2,355	$0	$2,355
6	$1,933	$0	$1,933
7	$1,983	$0	$1,983
8	$1,742	$0	$1,742
9	$1,772	$0	$1,772
10	$1,694	$0	$1,694
11	$1,803	$0	$1,803
12	$2,016	$0	$2,016
13	$1,650	$0	$1,650
14	$1,963	$0	$1,963
15	$1,048	$0	$1,048
16	$4,058	($5)	$4,053
Total	$1,948	($0.02)	$1,948

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH_MPRetP – Low-Rise Garden Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	($2,022)	$0	($2,022)
2	($1,711)	$0	($1,711)
3	($1,611)	$0	($1,611)
4	($1,514)	$0	($1,514)
5	($1,591)	$0	($1,591)
6	($1,154)	$0	($1,154)
7	($1,106)	$0	($1,106)
8	($1,040)	$0	($1,040)
9	($1,099)	$0	($1,099)
10	($1,050)	$0	($1,050)
11	($1,251)	$0	($1,251)
12	($1,404)	$0	($1,404)
13	($1,150)	$0	($1,150)
14	($1,288)	$0	($1,288)
15	($696)	$0	($696)
16	($1,954)	($77)	($2,031)
Total	($1,251)	($0.27)	($1,252)

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH_MPRetP – Loaded Corridor Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	($2,240)	$0	($2,240)
2	($1,955)	$0	($1,955)
3	($1,852)	$0	($1,852)
4	($1,748)	$0	($1,748)
5	($1,863)	$0	($1,863)
6	($1,449)	$0	($1,449)
7	($1,449)	$0	($1,449)
8	($1,348)	$0	($1,348)
9	($1,393)	$0	($1,393)
10	($1,349)	$0	($1,349)
11	($1,537)	$0	($1,537)
12	($1,691)	$0	($1,691)
13	($1,443)	$0	($1,443)
14	($1,564)	$0	($1,564)
15	($1,066)	$0	($1,066)
16	($2,207)	($1)	($2,208)
Total	($1,539)	($0.004)	($1,539)

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH_MPRetP – Mid-Rise Mixed Use Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	($1,470)	$0	($1,470)
2	($1,331)	$0	($1,331)
3	($1,257)	$0	($1,257)
4	($1,174)	$0	($1,174)
5	($1,310)	$0	($1,310)
6	($1,030)	$0	($1,030)
7	($1,041)	$0	($1,041)
8	($936)	$0	($936)
9	($947)	$0	($947)
10	($920)	$0	($920)
11	($1,005)	$0	($1,005)
12	($1,130)	$0	($1,130)
13	($958)	$0	($958)
14	($1,004)	$0	($1,004)
15	($593)	$0	($593)
16	($1,143)	$2	($1,142)
Total	($1,049)	$0.01	($1,049)

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH_MPRetP – High-Rise Mixed Use Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	($1,176)	$0	($1,176)
2	($1,061)	$0	($1,061)
3	($1,029)	$0	($1,029)
4	($977)	$0	($977)
5	($1,052)	$0	($1,052)
6	($879)	$0	($879)
7	($886)	$0	($886)
8	($796)	$0	($796)
9	($804)	$0	($804)
10	($794)	$0	($794)
11	($845)	$0	($845)
12	($918)	$0	($918)
13	($812)	$0	($812)
14	($837)	$0	($837)
15	($543)	$0	($543)
16	($868)	$2	($866)
Total	($878)	$0.01	($878)

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH_SPRetP – Low-Rise Garden Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$491	$0	$491
2	$549	$0	$549
3	$602	$0	$602
4	$548	$0	$548
5	$568	$0	$568
6	$666	$0	$666
7	$687	$0	$687
8	$684	$0	$684
9	$665	$0	$665
10	$671	$0	$671
11	$611	$0	$611
12	$593	$0	$593
13	$636	$0	$636
14	$616	$0	$616
15	$839	$0	$839
16	$577	($91)	$487
Total	$641	($0.32)	$640

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH_SPRetP – Loaded Corridor Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$82	$0	$82
2	$116	$0	$116
3	$127	$0	$127
4	$121	$0	$121
5	$111	$0	$111
6	$159	$0	$159
7	$146	$0	$146
8	$173	$0	$173
9	$173	$0	$173
10	$176	$0	$176
11	$144	$0	$144
12	$123	$0	$123
13	$166	$0	$166
14	$151	$0	$151
15	$243	$0	$243
16	$84	$3	$87
Total	$151	$0.01	$151

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH SPRetP – Mid-Rise Mixed Use Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$64	$0	$64
2	$103	$0	$103
3	$123	$0	$123
4	$94	$0	$94
5	$91	$0	$91
6	$136	$0	$136
7	$106	$0	$106
8	$143	$0	$143
9	$147	$0	$147
10	$148	$0	$148
11	$104	$0	$104
12	$116	$0	$116
13	$125	$0	$125
14	$78	$0	$78
15	$197	$0	$197
16	$15	$0	$15
Total	$127	$0.0001	$127

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions–Central HPWH - HPWH_SPRetP – High-Rise Mixed Use Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	($16)	$0	($16)
2	($3)	$0	($3)
3	$1	$0	$1
4	($12)	$0	($12)
5	$26	$0	$26
6	$21	$0	$21
7	($21)	$0	($21)
8	$26	$0	$26
9	$34	$0	$34
10	$32	$0	$32
11	($8)	$0	($8)
12	$14	$0	$14
13	$18	$0	$18
14	($25)	$0	($25)
15	$56	$0	$56
16	($87)	($0.12)	($88)
Total	$13	$0.00	$13

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH_SPwMPTM – Mid-Rise Mixed Use Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$3,090	$0	$3,090
2	$2,840	$0	$2,840
3	$2,742	$0	$2,742
4	$2,472	$0	$2,472
5	$2,738	$0	$2,738
6	$2,278	$0	$2,278
7	$2,271	$0	$2,271
8	$2,084	$0	$2,084
9	$2,111	$0	$2,111
10	$2,038	$0	$2,038
11	$2,119	$0	$2,119
12	$2,397	$0	$2,397
13	$1,999	$0	$1,999
14	$2,214	$0	$2,214
15	$1,334	$0	$1,334
16	$4,537	($9.40)	$4,527
Total	$2,296	($0.04)	$2,296

30-Year Electricity and Natural Gas Savings

2026 PV LSC Savings Over 30-Year Period of Analysis –New Construction and Additions– Central HPWH - HPWH_SPwMPTM – High-Rise Mixed Use Prototype

Climate Zone	30-Year LSC Electricity Savings (2026 PV $)	30-Year LSC Gas Savings (2026 PV $)	Total 30-Year LSC Savings (2026 PV $)
1	$2,611	$0	$2,611
2	$2,280	$0	$2,280
3	$2,180	$0	$2,180
4	$1,928	$0	$1,928
5	$2,210	$0	$2,210
6	$1,783	$0	$1,783
7	$1,794	$0	$1,794
8	$1,618	$0	$1,618
9	$1,641	$0	$1,641
10	$1,566	$0	$1,566
11	$1,691	$0	$1,691
12	$1,898	$0	$1,898
13	$1,548	$0	$1,548
14	$1,828	$0	$1,828
15	$966	$0	$966
16	$3,837	($4.66)	$3,832
Total	$1,805	($0.02)	$1,805

Individual Heat Pump Water Heater Ventilation

Key Assumptions

- HPWHs will achieve 100% market share of individual water heaters by 2050.
- New Construction will adopt HPWHs faster than Existing.
- Ventilation issues are predominantly in closet installs, so garage installs are no included in this analysis.
- Exterior closets are less likely to be implemented in New Construction Mid and High Rise.

	Exterior Closets	Exterior Closets	Interior Closets	Interior Closets
Construction Forecast Building Type	Newly Constructed Floorspace Impacted (%)	Existing Floorspace Impacted (%)	Newly Constructed Floorspace Impacted (%)	Existing Floorspace Impacted (%)
SF500	1.76%	0.16%	33.35%	2.94%
SF2100	1.76%	0.09%	1.76%	0.22%
SF2700	1.76%	0.09%	1.76%	0.22%
Low-rise Garden	8.00%	1.29%	2.86%	1.29%
Loaded Corridor	3.51%	0.81%	1.17%	0.81%
High-rise Multifamily	0.00%	0.01%	0.15%	0.23%
Mid-rise Multifamily	0.00%	0.05%	4.49%	1.53%

First-Year Electricity Savings – Exterior Closets

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
High-Rise Mixed Use	1,017	815	919	775	885	737	744	675	684	651	634	721	613	615	445	650
Loaded Corridor	1,054	845	955	806	921	767	773	703	714	681	657	746	636	642	465	674
Low-Rise Garden	1,036	830	933	787	899	747	754	683	693	661	641	731	622	623	450	662
Mid-Rise Mixed Use	1,038	833	940	792	905	754	760	691	701	668	647	735	626	630	457	664
SF500	953	768	870	734	836	703	711	648	653	617	607	684	583	587	431	611
SF2100	1,226	985	1,130	953	1,092	913	917	841	858	823	771	863	747	772	562	784
SF2700	1,357	1,096	1,247	1,056	1,198	1,001	1,017	921	943	908	872	976	842	848	616	855

First-Year Electricity Savings – Interior Closets

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
High-Rise Mixed Use	865	776	776	721	775	690	688	662	670	665	683	721	658	689	513	843
Loaded Corridor	897	806	805	749	805	716	714	687	695	691	710	749	685	717	534	877
Low-Rise Garden	878	788	787	732	787	700	698	672	679	675	693	731	667	698	520	856
Mid-Rise Mixed Use	883	793	792	737	792	705	703	676	684	680	699	737	673	705	525	862
SF500	821	738	737	686	737	657	654	630	637	634	652	687	628	657	490	803
SF2100	1,051	946	942	879	943	840	837	808	818	815	841	881	810	848	634	1,034
SF2700	1,172	1,053	1,049	979	1,049	936	932	898	910	904	932	980	896	940	701	1,148

First-Year Peak Electricity Demand Reductions – Exterior Closets

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
High-Rise Mixed Use	57	57	60	60	62	66	65	63	58	58	43	48	45	40	47	30
Loaded Corridor	63	63	67	64	66	71	69	66	63	60	44	52	46	40	51	32
Low-Rise Garden	62	61	64	63	64	69	67	65	61	60	45	51	47	42	49	32
Mid-Rise Mixed Use	61	61	64	63	64	69	67	64	61	59	43	50	46	40	49	31
SF500	40	45	47	50	53	56	57	53	47	51	36	40	38	33	40	24
SF2100	93	86	99	84	88	91	91	79	84	70	48	66	47	38	69	43
SF2700	83	67	83	76	80	85	86	78	70	59	57	66	59	34	65	49

First-Year Peak Electricity Demand Reductions – Interior Closets

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
High-Rise Mixed Use	59	52	50	49	49	48	48	45	48	44	49	50	52	47	46	56
Loaded Corridor	63	56	55	54	54	52	52	49	52	48	51	54	54	50	48	62
Low-Rise Garden	61	53	52	52	51	51	51	49	52	47	52	52	53	50	49	58
Mid-Rise Mixed Use	61	54	53	52	52	50	50	47	50	46	50	53	53	49	47	60
SF500	52	46	43	40	42	37	37	34	37	35	39	45	49	40	36	52
SF2100	83	76	76	73	76	73	71	64	66	61	60	72	59	64	53	88
SF2700	79	74	76	77	77	69	69	64	63	64	69	80	69	71	51	87

First-Year Natural Gas Savings

- None. This measure only impacts consumer-sized integrated HPWHs, which are all-electric.

From this slide on, natural gas is not included as there is no impact from this measure.

First-Year Long-Term System Cost (LSC) Savings – Exterior Closets

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
High-Rise Mixed Use	6,499	5,405	6,042	5,082	5,841	4,903	4,922	4,483	4,469	4,260	4,059	4,679	3,965	3,931	2,978	4,038
Loaded Corridor	6,743	5,592	6,304	5,292	6,086	5,124	5,141	4,671	4,680	4,459	4,210	4,847	4,109	4,095	3,114	4,194
Low-Rise Garden	6,645	5,505	6,163	5,174	5,954	4,990	5,032	4,561	4,549	4,335	4,123	4,771	4,038	3,991	3,010	4,121
Mid-Rise Mixed Use	6,640	5,513	6,192	5,202	5,982	5,029	5,046	4,590	4,589	4,373	4,145	4,776	4,048	4,024	3,054	4,128
SF500	6,010	5,078	5,638	4,775	5,463	4,614	4,554	4,225	4,208	4,012	3,848	4,372	3,720	3,729	2,874	3,763
SF2100	7,885	6,460	7,535	6,283	7,237	6,169	6,191	5,562	5,681	5,402	4,919	5,624	4,779	4,875	3,774	4,919
SF2700	8,790	7,275	8,144	6,996	7,852	6,609	6,621	6,093	6,164	5,877	5,561	6,300	5,456	5,354	4,078	5,308

First-Year Long-Term System Cost (LSC) Savings – Interior Closets

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
High-Rise Mixed Use	5,672	5,127	5,075	4,702	5,096	4,517	4,464	4,315	4,351	4,310	4,453	4,680	4,284	4,448	3,350	5,457
Loaded Corridor	5,884	5,313	5,283	4,892	5,288	4,706	4,662	4,489	4,527	4,489	4,640	4,878	4,460	4,628	3,483	5,704
Low-Rise Garden	5,762	5,191	5,174	4,781	5,191	4,607	4,557	4,405	4,434	4,389	4,532	4,766	4,361	4,517	3,403	5,549
Mid-Rise Mixed Use	5,793	5,232	5,194	4,810	5,206	4,626	4,578	4,415	4,452	4,413	4,560	4,793	4,384	4,550	3,426	5,597
SF500	5,371	4,912	4,747	4,437	4,781	4,217	4,157	4,013	4,073	4,047	4,191	4,395	4,025	4,219	,175	5,147
SF2100	6,885	6,203	6,255	5,790	6,183	5,593	5,591	5,299	5,353	5,329	5,523	5,813	5,289	5,485	4,112	6,879
SF2700	7,788	7,002	6,888	6,553	6,848	6,105	6,097	5,862	5,925	5,864	6,085	6,416	5,855	6,053	4,515	7,619

First-Year Source Energy Savings – Exterior Closets

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
High-Rise Mixed Use	1,364	1,212	1,397	1,219	1,335	1,224	1,228	1,115	1,102	1,049	957	1,108	969	918	838	819
Loaded Corridor	1,431	1,267	1,464	1,277	1,404	1,281	1,278	1,169	1,160	1,107	998	1,157	1,013	962	877	846
Low-Rise Garden	886	1,236	1,422	1,239	1,360	1,241	1,240	1,127	1,115	1,066	969	1,127	986	933	843	834
Mid-Rise Mixed Use	1,402	1,243	1,435	1,252	1,374	1,256	1,255	1,145	1,134	1,082	980	1,136	994	943	860	835
SF500	1,247	1,132	1,315	1,155	1,252	1,169	1,187	1,078	1,058	994	917	1,044	913	869	823	770
SF2100	1,744	1,525	1,781	1,553	1,730	1,553	1,535	1,431	1,444	1,382	1,195	1,387	1,222	1,172	1,068	968
SF2700	1,785	1,590	1,863	1,636	1,786	1,616	1,635	1,520	1,522	1,449	1,269	1,484	1,360	1,257	1,112	1,002

First-Year Source Energy Savings – Interior Closets

Prototype	CZ 1	CZ 2	CZ 3	CZ	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
High-Rise Mixed Use	1,277	1,164	1,160	1,086	1,160	1,035	1,034	986	1,002	1,001	1,054	1,089	1,007	1,057	813	1,269
Loaded Corridor	1,341	1,220	1,214	1,135	1,214	1,084	1,081	1,033	1,052	1,050	1,104	1,141	1,057	1,107	845	1,329
Low-Rise Garden	1,066	1,184	1,179	1,103	1,179	1,053	1,051	1,003	1,019	1,018	1,068	1,106	1,022	1,072	821	1,290
Mid-Rise Mixed Use	1,313	1,196	1,191	1,114	1,191	1,063	1,060	1,013	1,031	1,029	1,082	1,119	1,035	1,085	831	1,303
SF500	1,206	1,098	1,096	1,026	1,095	976	977	931	946	944	1,007	1,034	957	1,007	787	1,199
SF2100	1,643	1,486	1,474	1,370	1,471	1,314	1,304	1,259	1,292	1,286	1,343	1,389	1,300	1,349	1,001	1,617
SF2700	1,697	1,556	1,556	1,464	1,548	1,392	1,389	1,341	1,352	1,338	1,416	1,463	1,361	1,426	1,084	1,682

30-Year Long-Term System Cost (LSC) Savings – Exterior Closets

New Construction and Additions

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	7,516	7,516
2	6,041	6,041
3	6,514	6,514
4	5,624	5,624
5	6,753	6,753
6	5,428	5,428
7	5,302	5,302
8	4,862	4,862
9	4,857	4,857
10	4,960	4,960
11	4,847	4,847
12	5,399	5,399
13	4,785	4,785
14	4,601	4,601
15	3,690	3,690
16	4,856	4,856

Alterations

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	7,040	7,040
2	5,729	5,729
3	6,336	6,336
4	5,372	5,372
5	6,325	6,325
6	5,192	5,192
7	5,164	5,164
8	4,705	4,705
9	4,706	4,706
10	4,627	4,627
11	4,526	4,526
12	5,063	5,063
13	4,490	4,490
14	4,290	4,290
15	3,455	3,455
16	4,607	4,607

30-Year Long-Term System Cost (LSC) Savings – Interior Closets

New Construction and Additions

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	5,966	5,966
2	5,372	5,372
3	5,247	5,247
4	4,903	4,903
5	5,320	5,320
6	4,692	4,692
7	4,623	4,623
8	4,461	4,461
9	4,500	4,500
10	4,518	4,518
11	4,713	4,713
12	4,930	4,930
13	4,535	4,535
14	4,691	4,691
15	3,551	3,551
16	5,845	5,845

Alterations

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	5,943	5,943
2	5,330	5,330
3	5,237	5,237
4	4,875	4,875
5	5,314	5,314
6	4,680	4,680
7	4,615	4,615
8	4,454	4,454
9	4,489	4,489
10	4,505	4,505
11	4,728	4,728
12	4,921	4,921
13	4,567	4,567
14	4,674	4,674
15	3,578	3,578
16	5,904	5,904

Statewide Impacts - Energy

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 Dwelling Units	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	21	0.02	0.00	0.03	$0.15
2	141	0.13	0.01	0.19	$0.84
3	479	0.43	0.03	0.65	$2.82
4	268	0.22	0.02	0.34	$1.46
5	39	0.04	0.00	0.06	$0.24
6	174	0.14	0.01	0.22	$0.91
7	314	0.24	0.02	0.37	$1.58
8	567	0.41	0.03	0.65	$2.71
9	650	0.48	0.04	0.74	$3.12
10	527	0.41	0.03	0.63	$2.65
11	296	0.24	0.02	0.36	$1.53
12	856	0.72	0.05	1.11	$4.71
13	347	0.27	0.02	0.43	$1.75
14	221	0.17	0.01	0.26	$1.11
15	148	0.09	0.01	0.15	$0.58
16	89	0.08	0.01	0.11	$0.53
Total	5,138	4.09	0.30	6.31	$26.68

Statewide Impacts – Energy

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (PV$ Million)
New Construction & Additions	4.09	0.30	-	6.31	$26.68
Alterations	0.85	0.06	-	1.30	$5.54
Total	4.93	0.37	-	7.61	$32.22

Statewide Impacts - Emissions

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 GHG Emissions[a] (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions[b] ($)
Exterior Closet	1.93	157.44	-	-	157.44	$19,388.34
Interior Closet	3.00	233.85	-	-	233.85	$28,798.09
TOTAL	4.93	391.29	-	-	391.29	$48,186.43

Results Summary

First Year Savings

Type	Savings
Electricity (GWH/yr)	4.93
GHG Emissions from Electricity ($MTCO_2e$)	391.29
Total Value of GHG Emissions from Electricity ($)	$48,186
Embodied GHG (MTCO2e)	(23.85)
Net GHG Emissions (MTCO2e)	367.44
Total Value of Net GHG Emissions ($)	$45,249

Lunch

We will resume at 1:00

15-minute Break

We will resume at 2:45

Comments

- **Comments on Todays Workshop**
- **Due Date: September 5, 2023, by 5:00 PM**

- **Comments to be submitted to:** **https://efiling.energy.ca.gov/Ecomment/Ecomment.aspx?docketnumber=22-BSTD-01**

- Thank you for participating!

Next Workshops

Upcoming 2025 Energy Code Pre-Rulemaking Workshops:

- Thursday, August 24, from 9am to 3pm, topics covered will include:
  - Heat Pump Baselines
  - Solar Photovoltaic and Energy Storage System Requirements
- Tuesday, August 29, from 9am to 3pm, topics covered will include:
  - Field Verification & Diagnostic Testing
  - Nonresidential HVAC Efficiency
- Wednesday, August 30, from 9am to 3pm, topics covered will include:
  - Commercial Kitchens
  - Laboratories
  - Nonresidential Envelope
  - Lighting Requirements

Thank you for participating in today's workshop!