CALIFORNIA STATEWIDE
UTILITY CODES AND STANDARDS PROGRAM

2016 Title 24 Codes & Standards Enhancement (CASE) Proposal

Nonresidential Opaque Envelope

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Pre-rulemaking Workshop: Agenda

- Code change overview
- Summary of current code requirements
- Typical practices
- Methodology for analyses
- Nonresidential life cycle cost analysis
- High-Rise Residential life cycle cost analysis
- Proposed code requirements
- Stakeholder Feedback Summary

Proposed Code Change Overview

- **Nonresidential Opaque Envelope Update**
- The opaque envelope U-factor prescriptive requirements will be updated
  - All nonresidential and high-rise residential buildings
  - Opaque exterior walls, exterior roofs and exterior above-grade floors
    - No changes to fenestration requirements
    - No changes to slab-on-grade floor insulation or exterior door requirements
  - Prescriptive (Table 140.3-B and 140.3-C)
    - Performance approach baseline will reflect new prescriptive levels

California Climate Zones

- North / Central Coast
  - Arcata (CZ 1), Oakland (CZ 3), Santa Maria (CZ5)
- Southern Coast
  - Torrance (CZ6), San Diego (CZ7), Fullerton (CZ8)
- Inland Valleys
  - Santa Rosa (CZ2), San Jose (CZ4), Burbank (CZ9), Riverside (CZ10), Sacramento (CZ12)
- Desert and Inland Empire
  - Red Bluff (CZ11), Fresno (CZ13), Palmdale (CZ14), Palm Springs (CZ15)
- Mountains
  - Blue Canyon (CZ16)

- Added flexibility in choosing from an expanded set of weather locations for performance method

Proposed Code Change History

- Envelope Requirements last updated for the 2008 code cycle
  - Mandatory requirements introduced in the 2013 code update cycle
- Insulation Technologies that are readily established can exceed code requirements
- The Building Envelope is a foundational element to energy efficiency:
  - Improvements have persistence relative to other efficiency measures
  - Improvements have secondary benefits: reduced loads, downsized equipment can lead to downsized HVAC equipment
  - Envelope retrofits to existing buildings can be difficult and costly

Current Code Requirements

- Existing Title 24 Requirements
  - Prescriptive requirements in Standards Tables 140.3-B and 140.3-C
  - Mandatory minimum requirements in 120.7
  - Varying insulation level requirement by construction assembly types and climate zone
- ASHRAE 90.1-2013 has slightly more stringent requirements for roof insulation

Current Envelope Requirements – CZ 1-8

TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS)				Climate Z							
				1	2	3	4	5	6	7	8
Envelope	Maximum U-factor	Roofs/ Ceilings	Metal Building	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
			Wood Framed and Other	0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.067
		Walls	Metal Building	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061
			Metal-framed	0.098	0.062	0.082	0.062	0.062	0.098	0.098	0.062
			Mass Light[1]	0.196	0.170	0.278	0.227	0.440	0.440	0.440	0.440
			Mass Heavy[1]	0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690
			Wood-framed and Other	0.102	0.059	0.110	0.059	0.102	0.110	0.110	0.102
		Floors/ Soffits	Mass	0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269
			Other	0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071

Current Envelope Requirements – CZ 9-16

TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS)				9	10	11	12	13	14	15	16
Envelope	**Maximum U-factor**	**Roofs/ Ceilings**	Metal Building	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
			Wood Framed and Other	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
		Walls	Metal Building	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
			Metal-framed	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
			Mass Light[1]	0.440	0.170	0.170	0.170	0.170	0.170	0.170	0.170
			Mass Heavy[1]	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
			Wood-framed and Other	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059
		Floors/ Soffits	Mass	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
			Other	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039

Stakeholder Feedback Summary (cont.)

- ASHRAE 90.1 vs. Title 24 JA4
  - Stakeholders indicate that 90.1 U-factors for some steel-framed assemblies are closer than Title 24 to tested values
  - No plan to align Title 24 U-factors with ASHRAE 90.1 under this scope
- Prototype Models
  - Considered a range of internal gain levels when determining cost-effective insulation levels

ASHRAE 90.1 to Title 24 Comparison – CZ1-8

Comparing assemblies (not U-factors):

- ASHRAE 90.1 is more stringent for metal building and wood-framed roofs
- Title 24 is as or more stringent than 90.1-2013 for most wall types

		1	2	3	4	5	6	7	8
Metal Building	T24-2013	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
	T24 Assembly		R-19	R-19	R-19	R-19	R-19	R-19	R-19
	90.1-2013		0.041	0.041	0.041	0.041	0.041	0.041	0.041
	90.1 Assembly		R-10+R-19 FC	R-10+R-19 FC	R-10+R-19 FC	R-10+R-19 FC	R-10+R-19 FC	R-10+R-19 FC	R-10+R-19 FC
Wood Framed and Other	T24-2013	0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.067
	T24 Assembly		R-25	R-25	R-25	R-19	R-11	R-13	R-13
	90.1-2013		0.027	0.027	0.027	0.027	0.027	0.027	0.027
	90.1 Assembly		R-38	R-38	R-38	R-38	R-38	R-38	R-38
Mass Medium	T24-2013	0.196	0.17	0.278	0.227	0.44	0.44	0.44	0.44
	T24 Assembly	R2.83	R3.61	R1.32	R2.13	8" CMU	8" CMU	8" CMU	8" CMU
	90.1-2013		0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123
	90.1 Assembly		R-7.6 ci	R-7.6 ci	R-7.6 ci	R-7.6 ci	R-7.6 ci	R-7.6 ci	R-7.6 ci
Metal Building	T24-2013	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061
	T24 Assembly	R-13	R10+R-13	R-13	R10+R-13	R10+R-13	R-13	R-13	R10+R-13
	90.1-2013		0.094	0.094	0.094	0.094	0.094	0.094	0.094
	90.1 Assembly		R-9.8 ci	R-9.8 ci	R-9.8 ci	R-9.8 ci	R-9.8 ci	R-9.8 ci	R-9.8 ci
Steel-Framed	T24-2013	0.098	0.062	0.082	0.062	0.062	0.098	0.098	0.062
	T24 Assembly	R-8 c.i.	R-14 ci.i.	R-10 c.i.	R-14 ci.i.	R-14 ci.i.	R-8 c.i.	R-8 c.i.	R-14 ci.i.
	90.1-2013		0.077	0.077	0.077	0.077	0.077	0.077	0.077
	90.1 Assembly		R-13+R-5ci	R-13+R-5ci	R-13+R-5ci	R-13+R-5ci	R-13+R-5ci	R-13+R-5ci	R-13+R-5ci
Wood-Framed and Other	T24-2013	0.102	0.059	0.11	0.059	0.102	0.11	0.11	0.102
	T24 Assembly	R-11	R-13+R-7 c.i.	R-13	R-13+R-7 c.i.	R-11	R-13	R-13	R-11
	90.1-2013		0.089	0.089	0.089	0.089	0.089	0.089	0.089
	90.1 Assembly		R-13	R-13	R-13	R-13	R-13	R-13	R-13

ASHRAE 90.1 to Title 24 Comparison – CZ9-15

Comparing assemblies (not U-factors):

- ASHRAE 90.1 is more stringent for metal building and wood-framed roofs
- Comparison for CZ16 difficult (maps to ASHRAE CZ 3,4,5,6)

		9	10	11	12	13	14	15	16
Metal Building	T24-2013	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
	T24 Assembly	R-19	R-19	R-19	R-19	R-19	R-19	R-19	
	90.1-2013	0.041	0.041	0.041	0.041	0.041	0.041	0.041	TBD
	90.1 Assembly	R-10+R-19 FC	R-10+R-19 FC	R-10+R-19 FC	R-10+R-19 FC	R-10+R-19 FC	R-10+R-19 FC	R-10+R-19	FC
Wood Framed and Other	T24-2013	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
	T24 Assembly	R-25	R-25	R-25	R-25	R-25	R-25	R-25	
	90.1-2013	0.027	0.027	0.027	0.027	0.027	0.027	0.028	
	90.1 Assembly	R-38	R-38	R-38	R-38	R-38	R-38	R-38	
Mass Medium	T24-2013	0.44	0.17	0.17	0.17	0.17	0.17	0.17	0.17
	T24 Assembly	8" CMU	R3.61	R3.61	R3.61	R3.61	R3.61	R3.61	R3.61
	90.1-2013	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	
	90.1 Assembly	R-7.6 ci	R-7.6 ci	R-7.6 ci	R-7.6 ci	R-7.6 ci	R-7.6 ci	R-7.6 ci	
Metal Building	T24-2013	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
	T24 Assembly	R10+R-13	R10+R-13	R10+R-13	R10+R-13	R10+R-13	R10+R-13	R-13+R-13	R10+R-13
	90.1-2013	0.094	0.094	0.094	0.094	0.094	0.094	0.094	
	90.1 Assembly	R-9.8 ci	R-9.8 ci	R-9.8 ci	R-9.8 ci	R-9.8 ci	R-9.8 ci	R-9.8 ci	
Steel-Framed	T24-2013	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	T24 Assembly	R-14 ci.i.	R-14 ci.i.	R-14 ci.i.	R-14 ci.i.	R-14 ci.i.	R-14 ci.i.	R-14 c.i.	R-14 c.i.
	90.1-2013	0.077	0.077	0.077	0.077	0.077	0.077	0.084	
	90.1 Assembly	R-13+R-5ci	R-13+R-5ci	R-13+R-5ci	R-13+R-5ci	R-13+R-5ci	R-13+R-5ci	R-13+R-3.8	c.i.
Wood-Framed and Other	T24-2013	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059
	T24 Assembly	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-14 c.i.	R-13+R-7 c.i.
	90.1-2013	0.089	0.089	0.089	0.089	0.089	0.089	0.089	
	90.1 Assembly	R-13	R-13	R-13	R-13	R-13	R-13	R-13	

Typical Practices

- Current practices
  - Metal Building Roofs: screw-down or standing seam metal roof
  - Steel-Framed Walls: 1” to 3” of continuous exterior insulation is common (with or without cavity ins.)
  - Wood-Framed Walls: trend towards increasing stud thickness to avoid/minimize continuous insulation
- Trends
  - General feedback is most designers build to meet minimum prescriptive requirements, except for LEED and special incentivized projects

Methodology for Savings Analysis

- Energy and Demand Impacts
  - For each prototype and each construction class, run parametric energy simulations with CBECC-Com or E+ of varying U-factors corresponding to discrete, feasible construction assemblies
  - Take installed cost differentials and apply CEC LCC analysis to determine lowest total LCC
    - Demand impacts through CEC LCC methodology
  - Prototype Buildings
    - Nonresidential: DOE Medium Retail Building prototype (approx. 25,000 ft2, one story)
    - High-rise Residential: 4-story Hotel Prototype, 42,000 ft2 conditioned area, guestrooms and common spaces

Initial Data and Findings

- Cost Data
  - Include installed costs of insulation per ft2 for a range of construction assemblies
  - Focus is not on construction costs of entire assembly, but the insulation/fasteners used for that assembly system
  - Developed average costs from Costworks and multiple distributors

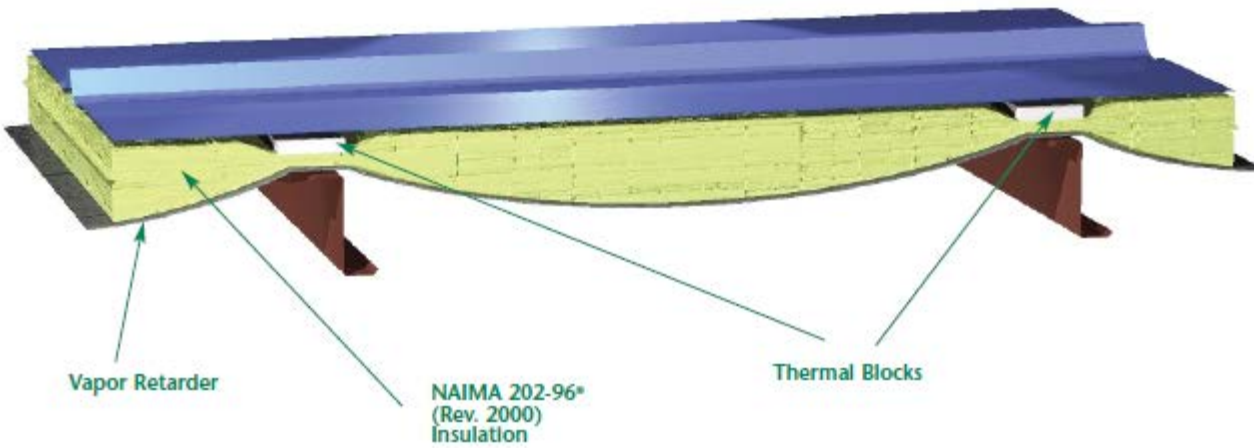
Initial Cost Data and Approach

Description	Insulation R-value	Assembly U-factor	Total O&P	
Isocyanurate insulation, rigid, for walls, 4' x 8' sheet, 3/4" thick, foil faced, both sides	4.2	0.156	$	1.21
Isocyanurate insulation, rigid, for walls, 4' x 8' sheet, 1" thick, foil faced, both sides	5.6	0.128	$	1.40
Isocyanurate insulation, rigid, for walls, 4' x 8' sheet, 1-1/2" thick, foil faced, both sides	8.4	0.094	$	1.61
Isocyanurate insulation, rigid, for walls, 4' x 8' sheet, 2" thick, foil faced, both sides	11.2	0.075	$	1.78
Wall insulation, rigid, isocyanurate, foil faced, both sides, 4' x 8' sheet, 3" thick	16.8	0.053	$	2.83
Wall insulation, rigid, isocyanurate, foil faced, both sides, 4' x 8' sheet, 4" thick	22.4	0.041	$	3.06
Extruded polystyrene insulation, rigid, for walls, 25 PSI compressive strength, 2" thick, R10	10	0.082	$	2.06
Wall insulation, rigid, extruded polystyrene, 25 PSI compressive strength, 3" thick, R15	15	0.058	$	2.52
Foam board insulation, polystyrene, expanded, 1" thick, R4	4	0.161	$	1.25
Foam board insulation, polystyrene, expanded, 2" thick, R8	8	0.098	$	1.52

Construction Assemblies Considered

- Metal building roofs
  - Standing seam, single or double layer of insulation
  - Standing seam, filled cavity
- Title 24 based on single layer, R-19
- New 90.1 prescriptive requirements based on filled cavity method
  - (U=0.041 for R-19+R-10)

Note: Diagrams not to scale.



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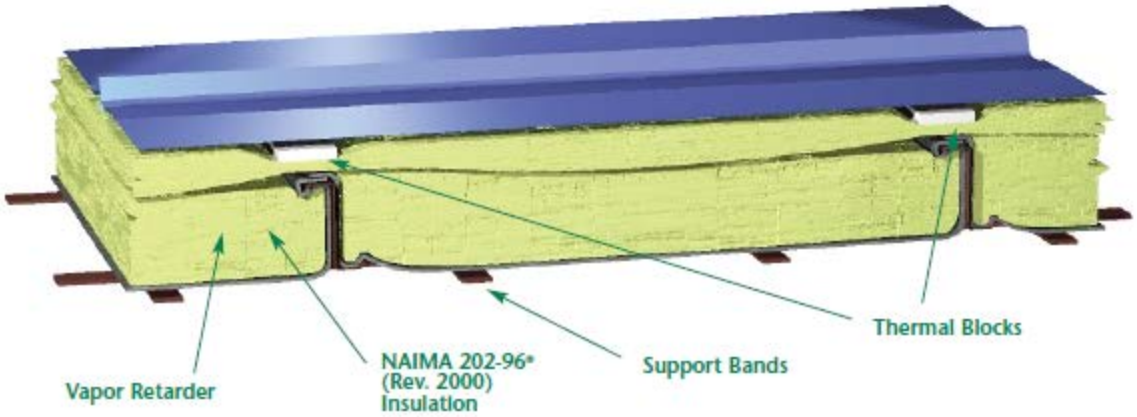


Construction Assemblies Considered (cont.)

- Wood-Framed Rafter Roofs
  - Cavity, continuous insulation or both
- Steel-Framed Walls
  - Cavity, continuous insulation, EIFS systems
- Other Construction Assemblies (lower priority)
  - Wood-framed walls
  - Mass Walls
  - Raised Floors

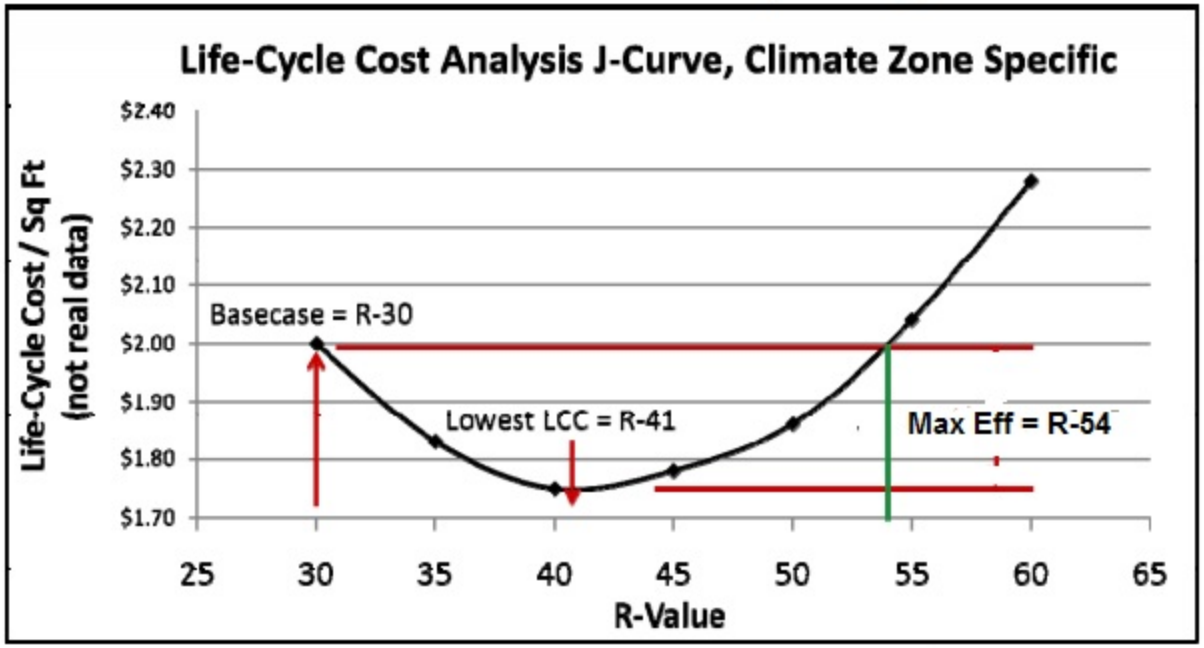
Scope of Parametric Study

	Parameter	No. of Variations	Description
Dimension 1	Prototype	2	medium office or retail; hotel for high-rise residential requirements
Dimension 2	Climate Zone	16	varies baseline opaque envelope components
Dimension 3	Construction Studied	6	four wall types analyzed; two roof types
Dimension 4	Insulation Levels	4	minimum of 3 insulation levels for each construction type studied
Total		768	

- One prototype model for each table in 140.3
- Possibly look at sensitivity of internal gains on results
    - Only one set of assumptions will be used for final LCC analysis

Life-Cycle Cost Methodology

- "J Curve" – goal is to maximize efficiency with no increase in total life cycle cost (LCC)
- Other important metric is Benefit to Cost Ratio (B/C)



Initial Data and Findings continued

- Plan for Energy Savings Summary
  - Parametric runs for each construction assembly using prototype models
  - Run in each of 16 CEC climate zones
  - Run with available TDV data as energy metric
- Result will be recommended U-factor prescriptive requirement for each construction assembly type and climate zone
  - No changes planned for Reference Appendix JA4, but new entries may be required to support new prescriptive recommendations
- Example: if U-factor steel framed wall of R-15 were shown to be cost effective, U-factor requirement of 0.082 would be lowered to 0.058

Steel-Framed Wall Costs

Description	Insulation R-value	Assembly U-factor	Total O&P
Wall Insulation, R-13 batt insulation	13 b	0.217	$ 0.80
Wall Insulation, R-13 batt +1" EPS	13+R-5	0.104	$ 2.05
Wall Insulation, R-13 batt + 1" polysio	15+R-6.2	0.093	$ 2.20
Polyiso, rigid, 1" thick, foil faced	5.6	0.128	$ 1.40
Polyiso, rigid, 2" thick, foil faced	12.4	0.069	$ 1.78
Polyiso, rigid, foil faced, 3" thick	18.6	0.048	$ 2.83
EPS, rigid, 25 psi, 2" thick, R10	10	0.082	$ 2.06
EPS, rigid, 25 psi, 3" thick, R15	15	0.058	$ 2.52
Expanded polystyrene,, 1" thick, R4	5	0.139	$ 1.25
Expanded polystyrene,, 2" thick, R8	8	0.098	$ 1.52
R-13 cavity+ 2" polyiso	11.2	0.089	$ 2.53
R-13 cavity+ 3" polyiso	16.8	0.060	$ 3.58

- *Complete list of assemblies and cost breakdown are included in CASE report*

Wood-Framed Wall Costs

Construction Assembly	Insulation	U-factor	Material	Labor	Fasteners	Total O&P
2x4, R-11 batt	11	0.11	0.385	0.42		$ 0.93
2x4,R-13 batt	13	0.102	0.594	0.42		$ 1.14
2x4 R-15 batt	15	0.095	0.70	0.42		$ 1.25
2x6, R-19 batt	19	0.074	0.66	0.42		$ 1.21
2x6.R-21 batt	21	0.069	0.8	0.42		$ 1.35
2x4, R-13 batt + R-5 c.i. (EPS)	13+5ci	0.068	0.6342	0.3000	0.0620	$ 1.93
2x4, R-13-batt + R-6.2 c.i (polyiso)	13+6.2ci	0.063	0.491563	0.3	0.062	$ 1.99
2x4, R-13 batt + R-10 c.i. (EPS)	13+10ci	0.051	1.2684	0.4000	0.0786	$ 2.99
2x4, R-13-batt + R-12.4 c.i (polyiso)	13+12.4ci	0.045	0.8027	0.4000	0.0786	$ 2.49

- *Estimates derived from multiple quotes from distributors and RS Means*
- *2x6 Framing not used in cost analysis, since not a basis of current prescriptive requirements*
- *Continuous Insulation of EPS or polyiso considered, with costs of fasteners added*

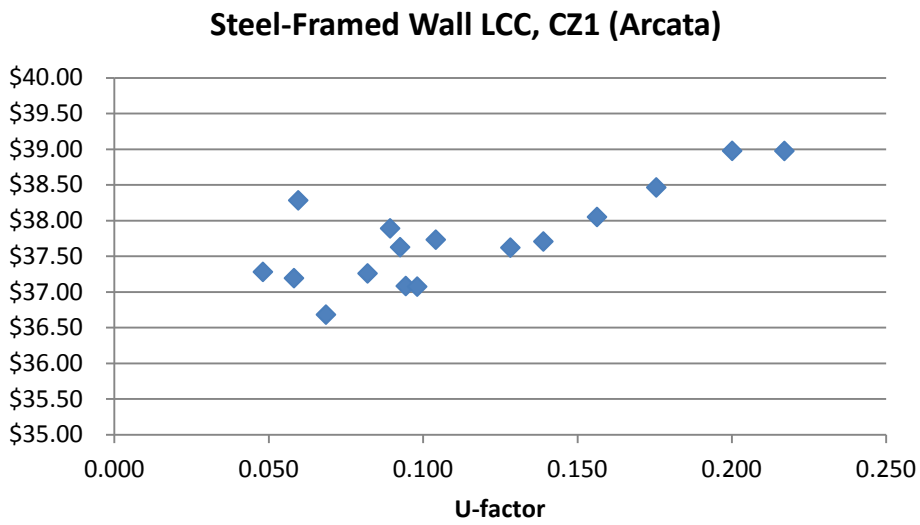
Steel-Framed Walls Life-Cycle Cost Results

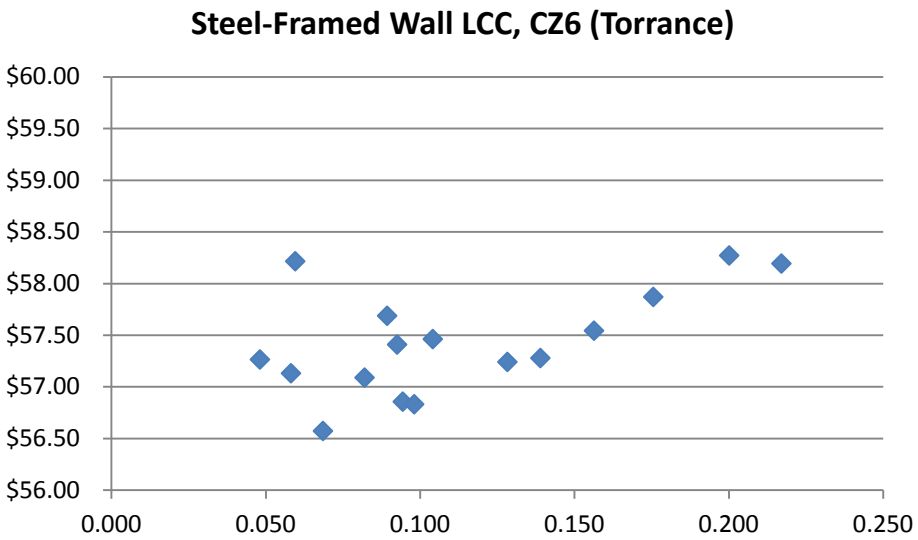
	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.098	0.062	0.082	0.062	0.098	0.098	0.098	0.062
Assembly	R-8 c.i.	R-14 c.i.	R-10 c.i.	R-14 c.i.	R-8 c.i.	R-8 c.i.	R-8 c.i.	R-14 c.i.
Proposed	0.069	N.C.	N.C.	N.C.	N.C.	0.069	0.069	N.C
Assembly	R-12.4	R-14 c.i.	R-10 c.i.	R-14 c.i.	R-8 c.i.	R-12.4	R-12.4	R-14 c.i.
B/C	3.36	n/a*	n/a	n/a	n/a	1.99	2.15	n/a

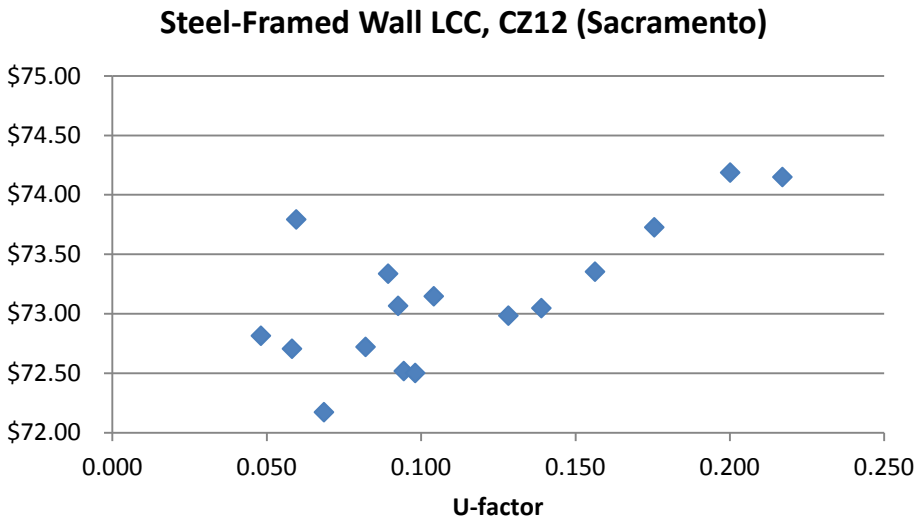
	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.062	0.062	0.062	0.062	0.062	0.062	0.057	0.062
Assembly	R-14 c.i.	R-14 c.i.	R-14 c.i.	R-14 c.i.	R-14 c.i.	R-14 c.i.	R-13+R-14 c.i.	R-14 c.i.
Proposed	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
Assembly	R-12.4	R-12.4	R-12.4	R-12.4	R-12.4	R-12.4	R-12.4	R-12.4
B/C	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

** n/a indicates B/C estimate is not applicable, since no change recommended*

Steel-Framed Walls LCC Graphical Results





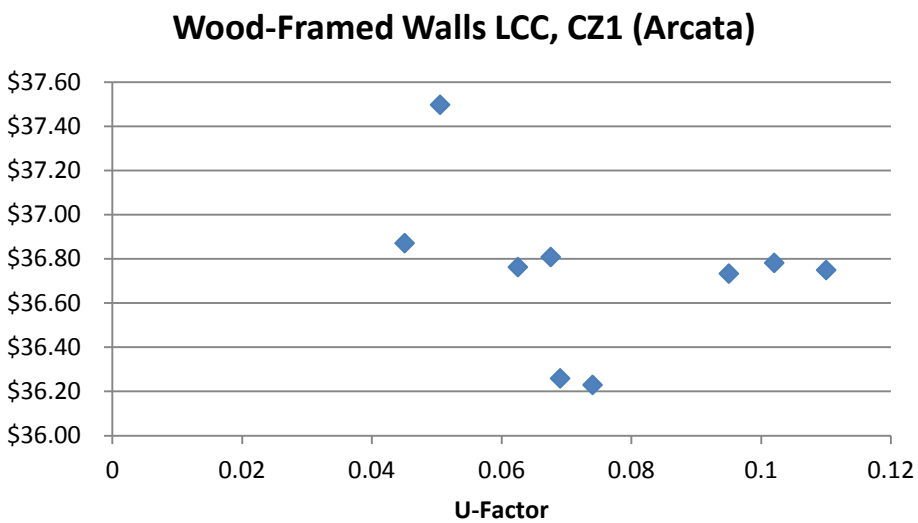


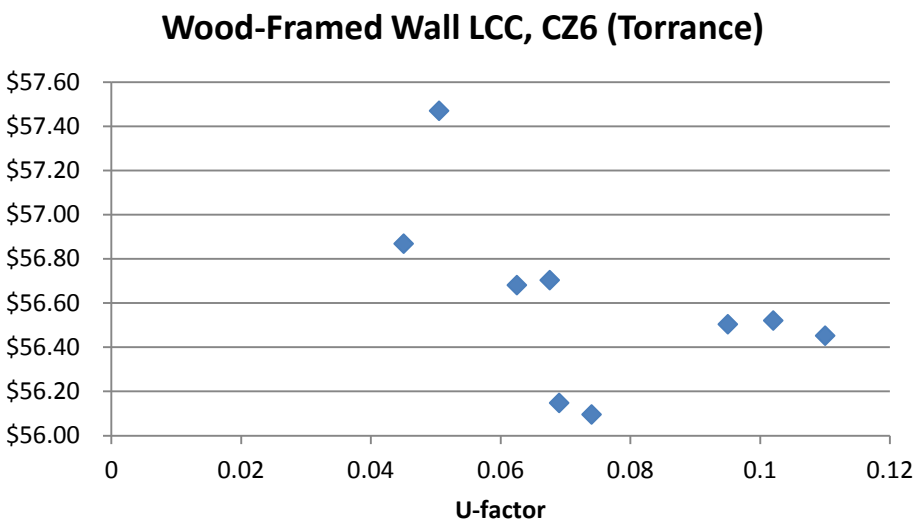
NR Wood-Framed Walls Life-Cycle Cost Results

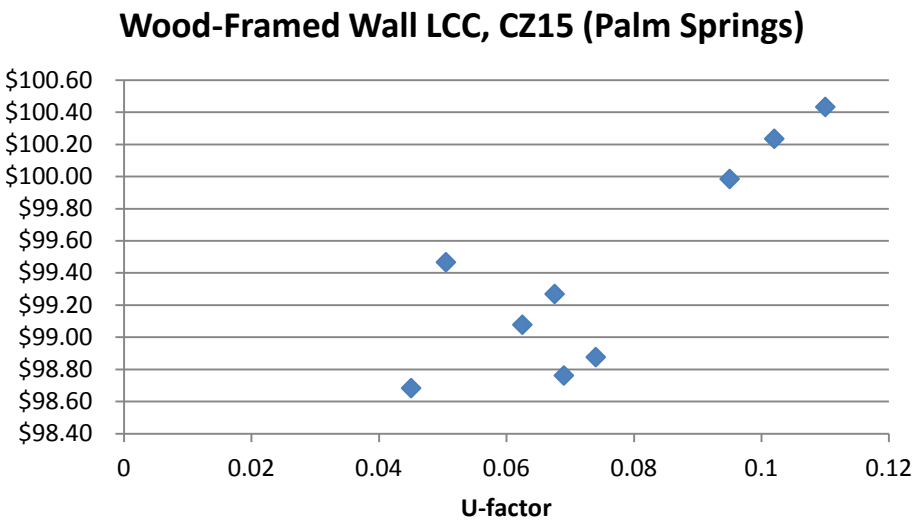
	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.102	0.059	0.110	0.059	0.102	0.110	0.110	0.102
Assembly	R-13	R-13+R-7 c.i.	R-11	R-14 c.i.	R-13	R-11	R-11	R-13
Proposed	**0.095**	N.C.	N.C.	N.C.	N.C	N.C	N.C	N.C
Assembly	R-15	same	same	same	same	same	same	same
B/C	1.46	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059
Assembly	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-14 c.i.	R-13+R-7 c.i.
Proposed	N.C	N.C.	**0.045**	N.C	N.C	N.C	N.C	N.C
Assembly	Same	R-13+R-7 c.i.	R-13+R-12.4 c.i.	same	R-13+R-12.4 c.i.	R-13+R-12.4 c.i.	R-13+R-12.4 c.i.	R-13+R-12.4 c.i.
B/C	n/a	1.01	1.38	n/a	1.37	1.41	1.80	1.61

Wood-Framed Walls LCC Graphical Results





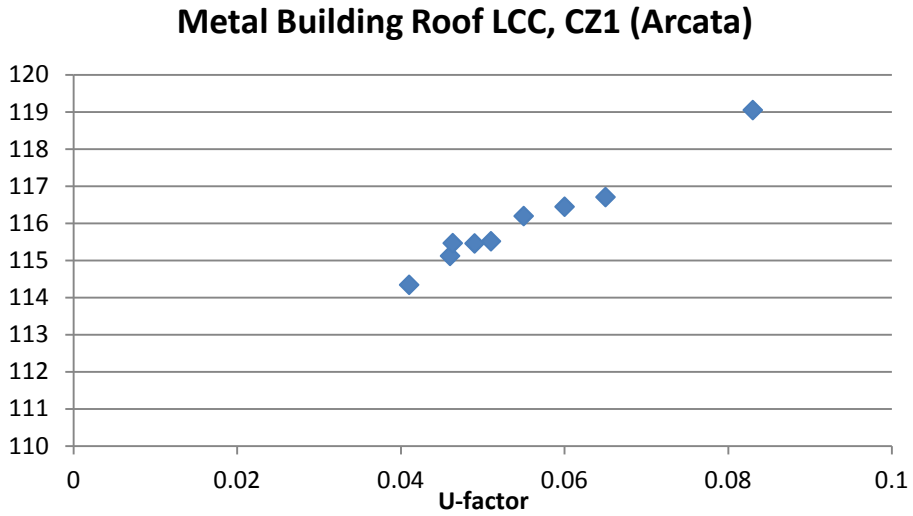


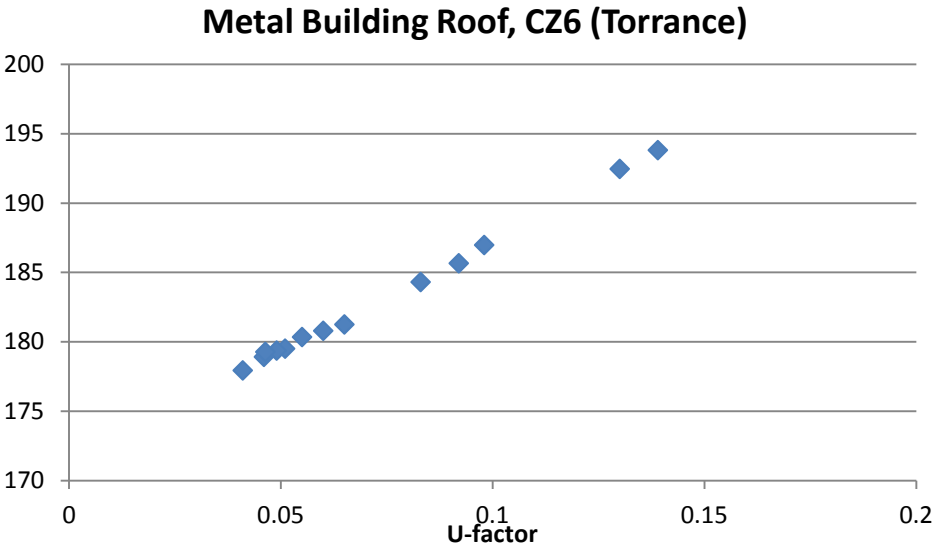
NR Metal Building Roof LCC Results

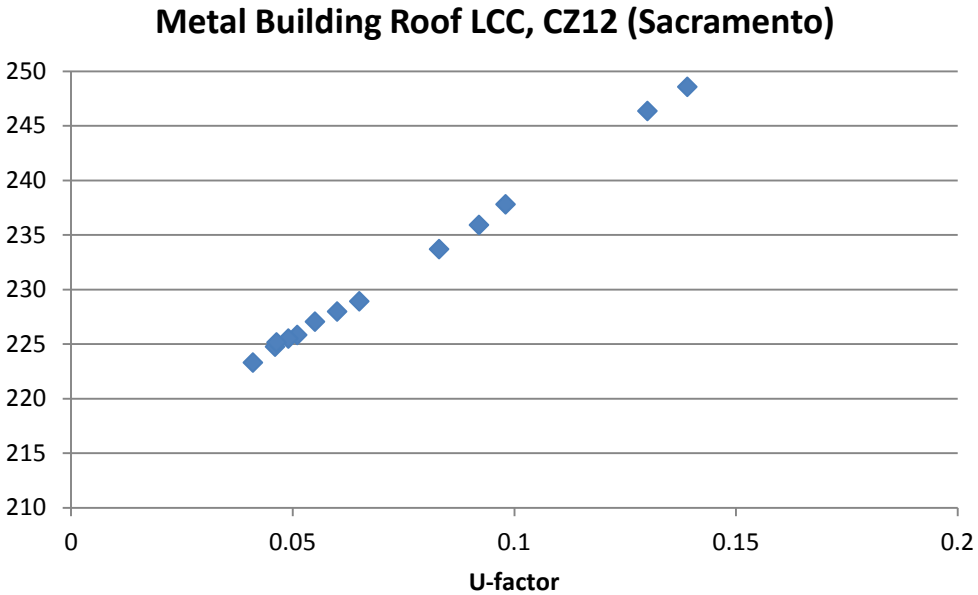
	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Assembly	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
Proposed	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Assembly	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC
B/C	3.78	5.98	3.90	5.46	3.58	4.50	4.25	5.89

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Assembly	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
Proposed	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Assembly	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC
B/C	7.06	7.08	8.77	7.60	9.46	9.21	11.3	8.79

Metal Building Roof LCC Graphical Results







Metal Building Roof Cost - Summary

Roof Type	Details	Insulation	U-factor	First Cost + Markup
Standing Seam Roof	Single Layer of Insulation draped	R-11 batt	0.092	$ 0.69
	over purlins and compressed. Thermal	R-13 batt	0.083	$ 0.89
	blocks at supports (R-5)	R-19 batt	0.065	$ 0.96
Standing Seam Roof	Double layer of insulation. Thermal	R-11 + R-11	0.06	$ 1.37
	blocks at supports (R-5)	R-13 + R-13	0.055	$ 1.79
		R-11 + R-19	0.051	$ 1.65
		R-13 + R-19	0.049	$ 1.85
		R-19 + R-19	0.046	$ 1.92
Standing Seam Roof	Single Layer + 1" polyiso	R-19,R-6.2c.i	0.0463	$ 2.22
	Single Layer + 2" polyiso	R-19,R-12.4c.i.	0.0360	$ 2.75
Filled Cavity with Thermal Blocks	Long Tab Banded	R-19 + R-10	0.041	$ 1.81

Wood-Framed Roof Insulation Costs

Roof Batt Insulation	Details	U-factor	Insulation Costs	*Framing Increment*	Labor Costs	First Cost + Markup
R-11	2x6	0.075	0.385	*0.00*	0.42	$ 0.81
R-13	2x6	0.067	0.594	*0.00*	0.42	$ 1.01
R-15	2x6	0.06	0.70	*0.00*	0.42	$ 1.12
R-19	2x6	0.054	0.66	*0.00*	0.42	$ 1.08
R-21	2x6	0.049	0.8	*0.00*	0.42	$ 1.22
R-19	2x8	0.049	0.66	*0.50*	0.42	$ 1.58
R-21	2x8	0.046	0.8	*0.50*	0.42	$ 1.72
R-25	2x10	0.039	0.66	*1.00*	0.50	$ 2.16
R-30	2x10	0.034	1.1	*1.00*	0.50	$ 2.60
R-38	2x12	0.027	1.375	*1.75*	0.50	$ 3.63

- *All assemblies are 24" o.c.*
- *All costs are installed costs, $/ft2, with overhead and profit markup included*
- *Comparisons for LCC analysis are only made for the framing depth used in the current prescriptive requirements*
- *For example: for CZ6 (Torrance, Los Angeles), the current requirement corresponds to 2x6 framing. The assemblies considered range from R-11 to R-21, 2x6 framing, with or without continuous insulation*
- *Continuous Insulation of EPS or polyiso considered*

NR Wood-Framed Roof LCC Results

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.039
Assembly	R-19	R-25	R-25	R-25	R-19	R-11	R-13	R-25
Proposed	0.034	0.034	0.034	0.034	0.034	0.049	0.049	NC
Assembly	R-30	R-30	R-30	R-30	R-30	R-19	R-19	Same
B/C	1.46	2.30	1.50	2.10	1.38	10.9	13.2	n/a

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Assembly	R-25	R-25	R-25	R-25	R-25	R-25	R-25	R-25
Proposed	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Assembly	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30
B/C	2.72	2.73	3.38	2.93	3.64	3.55	4.36	3.38

High-Rise Residential Requirements

- Prototype is four-story hotel with guestrooms and common spaces
  - 42,000 ft2 floor area
  - Lower internal loads and occupant density than typical nonresidential buildings
  - 24-hour occupancy
- Requirements apply to high-rise residential buildings, hotel/motel guestrooms and residential spaces in mixed use buildings
- Envelope meets minimum Title 24-2013 requirements
- Four-pipe fan coil system

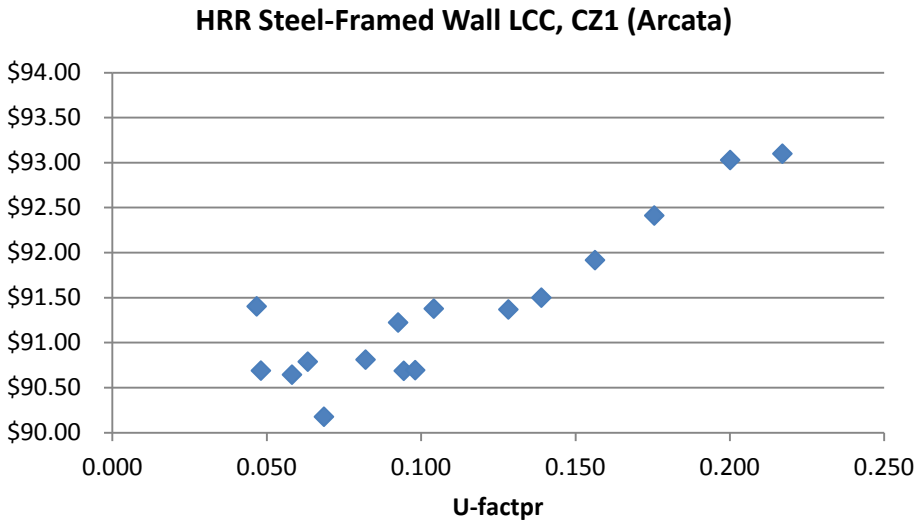
HRR Steel-Framed Walls LCC Results

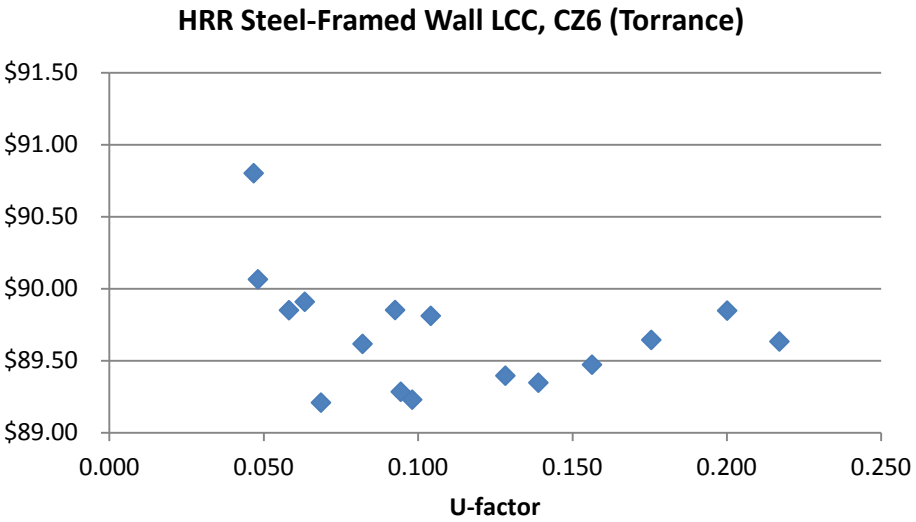
	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
Assembly	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.
Proposed	0.069	0.069	0.069	0.069	0.069	0.069	N.C.	0.069
Assembly	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	Same	R-12.4 ci
B/C	High*	High*	High*	High*	High*	High*	High*	High*

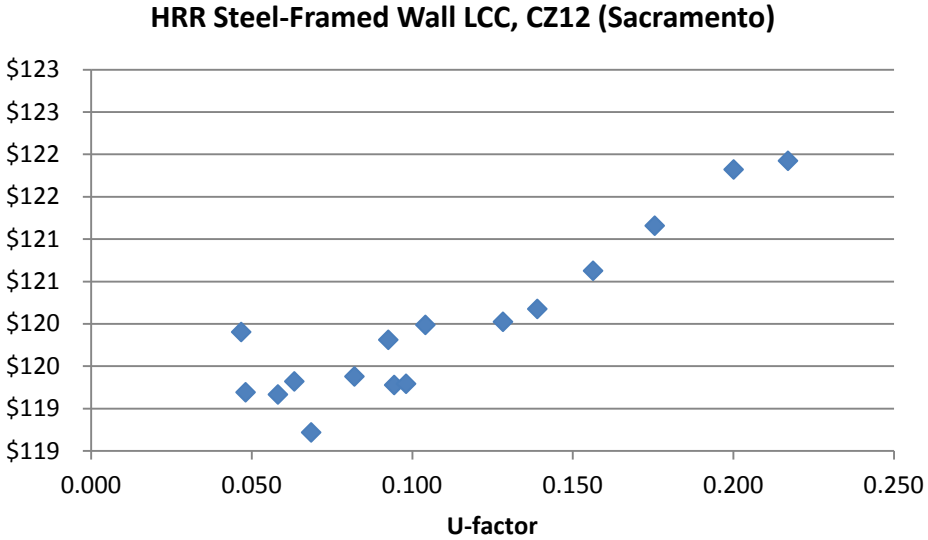
	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
Assembly	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.
Proposed	0.069	0.069	0.069	0.069	0.069	0.069	0.048	0.069
Assembly	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-18.6	R-12.4 ci
B/C	High*	High*	High*	High*	High*	High*	5.0	High*

** A "High" B/C indicates that the recommended construction costs no more than the less efficient construction corresponding to the current efficiency level.*

HRR Steel-Framed Walls LCC Graphical Results







HRR Wood-Framed Walls LCC Results

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Assembly	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.
Proposed	N.C.	N.C.	N.C.	N.C.	N.C	N.C	N.C	N.C
Assembly	same	same	same	same	same	same	same	same
B/C	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.059	0.059	0.042	0.059	0.059	0.042	0.042	0.042
Assembly	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-14 c.i.	R-13+R-7 c.i.
Proposed	N.C	*NC*	NC	N.C	N.C	N.C	N.C	N.C
Assembly	same	same	same	same	same	same	same	same
B/C	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

HRR Metal Building Roof LCC Results

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Assembly	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
Proposed	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Assembly	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC
B/C	7.8	6.9	4.9	5.4	5.9	3.3	2.2	3.7

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Assembly	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
Proposed	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Assembly	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC
B/C	4.9	5.43	7.3	6.8	7.3	7.6	5.5	8.9

HRR Wood-Framed Roof LCC Results

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.034	0.028	0.039	0.028	0.039	0.039	0.039	0.028
Assembly	R-30	R-38	R-25	R-25	R-25	R-25	R-25	R-38
Proposed	0.028	0.028	0.034	0.028	0.034	0.034	NC	0.028
Assembly	R-38	same	R-30	Same	R-30	R-30	same	same
B/C	3.00	n/a	1.92	n/a	2.28	7.33	6.71	n/a

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Assembly	R-38	R-38	R-38	R-38	R-38	R-38	R-38	R-38
Proposed	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Assembly	same	same	same	same	same	same	same	same
B/C	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Summary of Recommendations

- General Findings
  - Greater opportunity for improvement in mild climate zones
  - Greater opportunity for improvement in roof assemblies
- Nonresidential
  - Increase metal building roof insulation requirement from R-19 to filled cavity, R-19+R-10
  - Increase wood-framed roof requirement from R-11 to R-19 in some cases
  - No change planned for steel-framed wall
  - No significant change planned for wood-framed wall
- High-rise residential
  - Increase metal building roof insulation to FC
  - Increase steel-framed wall, similar to nonresidential req.
  - No change planned for steel-framed wall
  - Minor updates to wood-framed wall requirements

Table 140.3-B Nonres Recommendations (CZ1-8)

		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
ROOFS	Metal Bldg	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**
	Wood Framed	**0.034**	**0.034**	**0.034**	**0.034**	**0.034**	**0.049**	**0.049**	0.039
WALLS	Metal Bldg	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061
	Metal Framed	**0.069**	0.062	0.082	0.062	0.098	**0.069**	**0.069**	0.062
	Mass Light	0.170	0.170	0.170	0.170	0.170	0.227	0.227	0.227
	Mass Heavy	0.160	0.160	0.160	0.184	0.211	0.690	0.690	0.690
	Wood-Framed	**0.095**	0.059	0.110	0.059	0.102	0.110	0.110	0.102
FLOORS	Mass	0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269
	Other	0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071

Table 140.3-B Nonres Recommendations (CZ9-16)

		CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
ROOFS	Metal Bldg	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**
	Wood Framed	**0.034**	**0.034**	**0.034**	**0.034**	**0.034**	**0.034**	**0.034**	**0.034**
WALLS	Metal Bldg	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
	Metal Framed	0.062	0.062	0.062	0.062	0.062	0.062	0.057	0.062
	Mass Light	0.440	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-Framed	0.059	0.059	**0.045**	0.059	0.059	0.059	0.042	0.059
FLOORS	Mass	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
	Other	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039

Other Envelope Assemblies

- Walls
  - Not significant evidence for changes in mass walls, not basis for performance method
- Doors
  - Not included in study
- Floors
  - Not significant for changes in raised floor insulation
  - Slab-on-grade insulation not considered for study

Table 140.3-C HRR Recommendations (CZ1-8)

		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
ROOFS	Metal Bldg	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**
	Wood Framed	**0.028**	0.028	**0.034**	0.028	**0.034**	**0.034**	0.039	0.028
WALLS	Metal Bldg	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
	Metal Framed	**0.069**	**0.069**	**0.069**	**0.069**	**0.069**	**0.069**	0.105	**0.069**
	Mass Light	0.170	0.170	0.170	0.170	0.170	0.227	0.227	0.227
	Mass Heavy	0.160	0.160	0.160	0.184	0.211	0.690	0.690	0.690
	Wood-Framed	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
FLOORS	Mass	0.045	0.045	0.058	0.058	0.058	0.069	0.092	0.092
	Other	0.034	0.034	0.039	0.039	0.039	0.039	0.071	0.039

Table 140.3-C HRR Recommendations (CZ9-16)

		CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
ROOFS	Metal Bldg	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**
	Wood Framed	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
WALLS	Metal Bldg	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
	Metal Framed	**0.069**	**0.069**	**0.069**	**0.069**	**0.069**	**0.069**	**0.048**	**0.069**
	Mass Light	0.196	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy	0.690	0.690	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-Framed	0.059	0.059	0.042	0.059	0.059	0.042	0.042	0.042
FLOORS	Mass	0.092	0.069	0.058	0.058	0.058	0.045	0.058	0.037
	Other	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.034

Next Steps

- Recommend adjustment to prescriptive cool roof tradeoff with insulation (Table 140.3) *(current table below)*
- Final CASE Report
  - Revise impact analysis for statewide savings estimate

TABLE 140.3 ROOF/CEILING INSULATION TRADEOFF FOR AGED SOLAR REFLECTANCE

Nonresidential					
Aged Solar Reflectance	Metal Building Climate Zone 1-16 U-factor	Wood framed and Other Climate Zone 1 &5 U-factor	Wood Framed and Other Climate Zone 2-4, 9-16 U-factor	Wood Framed and Other, Climate Zone 6 U-factor	Wood Framed and Other Climate Zone 7 & 8 U-factor
0.62-0.60	0.061	0.045	0.036	0.065	0.059
0.59-0.55	0.054	0.041	0.034	0.058	0.053
0.54-0.50	0.049	0.038	0.032	0.052	0.048
0.49-0.45	0.047	0.035	0.030	0.047	0.044
0.44-0.40	0.043	0.033	0.028	0.043	0.040
0.39-0.35	0.039	0.031	0.027	0.039	0.037
0.34-0.30	0.035	0.029	0.025	0.037	0.035
0.29-0.25	0.033	0.027	0.024	0.034	0.032

Questions?

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