Residential Cool Roof/ Roof Insulation Measures

Stakeholder Meeting #2

California Statewide Utility Codes and Standards Program

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Cool Roof/Roof Insulation

- Summary of current code requirements
- Typical practice
- Code change proposals
- Methodology
- High Reflectance Cool Roof Cost effectiveness
- Below Deck Insulation Cost Effectiveness
- Duct Insulation Cost Effectiveness

Cool Roof/Roof Insulation

Current Code Requirements

- 2008 Title 24 – Low-Rise Residential
  - Prescriptive approach – steep-sloped roofs weighing more than 5 lbs/sf
    - Concrete & clay tile, some metal roofs
    - Minimum ***aged*** solar reflectance of 0.15, thermal emittance of 0.75
    - All climate zones 1-16
  - Steep-sloped roofs weighing <5 lbs/sf
    - Asphalt shingle, some metal roofs
    - Minimum ***aged*** solar reflectance of 0.2, thermal emittance of 0.75
    - Only climate zones 10-15 (inland valleys)

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Current Code Requirements

- 2008 Title 24 – Low-Rise Residential
  - Additions & alterations – Steep-sloped re-roofing (minimum of 50% of roof area or 1000 sf)
    - Must also meet prescriptive requirements, but there are many exceptions
      - Minimum R-30 ceiling insulation
      - Insulated & sealed attic ducts OR no ducts in attic
      - Radiant barrier is properly installed
      - Roof deck insulation of at least R-0.85, or at least R-3 in climate zones 10, 11, 13 & 14
      - 1/150 Attic ventilation with 30% at roof ridge in climate zones 10, 12 & 13

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Current Code Requirements

- **Raised Heel Truss:** current code does not require raised heel trusses and does not give credit for them
- **Roof Deck Insulation:** Current code requires 1:150 or 1:300 attic ventilation (CBC 1203.2)
  - 50% of ventilating area to be located at least 3 feet above eave/cornice vents
  - Restrictions in wild land interface areas
  - 1:300 ventilation allowed if vapor barrier installed on warm side of insulation
  - Unvented attics may be approved on an exceptional basis

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Code Change Proposals

Measure	Type	Detail
Roof Deck Insulation	Vented Attic Package	Insulation varies by climate; Maintain existing cool roof requirements
Duct Insulation		Increase to R-8 in all climates; existing cool roof requirements
Raised Heel Truss		Require RHT; existing cool roof requirements
Increased Attic Insulation	Prescriptive Requirement	R-30 to R-38; R-38 to R-49 existing cool roof req.
Higher Reflectance Cool Roof	Compliance Option	Level to be equivalent to vented attic package with roof deck insulation
Unvented Attic	Compliance Option; Reach Code	To be determined

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Typical Practice

- New Residential Construction
  - Concrete tile roofing seems to be prevalent on steep-sloped roofs
    - Over 5 lbs/sf, minimum aged SR of 0.15
    - Aged values of solar reflectance are not available for many roof materials: equivalent to initial SR = 0.13

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Typical Practice

- Residential Re-roofing
  - Asphalt shingle seems to be the most prevalent replacement roof
    - Less than 5 lbs/sf, minimum aged SR of 0.20
    - At minimum aged SR = 0.20, initial SR = 0.20

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Typical Practice

- Standard practice includes the use of conventional wood trusses
  - Insulation is compressed near the eaves, reducing thermal performance
  - Cold corners can lead to condensation and moisture problems, ice dams in cold climates

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Typical Practice

- Typical attic ventilation involves the use of soffit and ridge vents; attic insulation is installed above the ceiling
  - Duct leakage and conduction are a major source of energy loss
  - Attic ventilation has only minor effect on cooling loads with a well-insulated ceiling

Cool Roof/Roof Insulation

Code Change Proposals

- Hot Climate Vented Attic Prescriptive Package
  - Below Deck Insulation
  - Duct Insulation Level of R-8 *if cost-effective*
  - Existing requirements for attic insulation
  - Keep existing cool roof requirements
  - Raised heel truss if cost effective
- Temperate Climate Attic Prescriptive Package
  - Similar requirements
  - Below deck insulation if cost effective
  - Raised heel truss if cost effective
- Higher reflectance cool roof as a compliance option (alternative to below deck insulation)

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Code Change Proposals

- Roof deck insulation
  - At or below roof deck
  - Both cooling and heating benefit
  - Investigating spray foam insulation and batt insulation options
- Higher reflectance cool roof considered as a compliance option to roof deck insulation
  - Many tile products have reflectance to 0.35 to 0.4 with marginal additional cost
  - Asphalt shingle reflectance generally limited to 0.28; higher reflectance products carry significant additional cost

Cool Roof/Roof Insulation

Code Change Proposals

- Raised Heel Truss: New prescriptive requirement for raised heel trusses in new construction
  - Any change must be shown to be cost-effective
  - Change may be climate dependent, based on energy benefits
- Increased duct insulation requirements
  - R-8 if cost-effective

Cool Roof/Roof Insulation

Methodology

- "Rolling Base Case" for Vented Attic Package
  - Start with current prescriptive standards as base case
  - Remove radiant barrier
  1. Determine optimal below deck insulation level for each climate
  2. Use results of step 1 as base case; determine cost effectiveness of increasing duct insulation level to R-8
  3. Use results of step 2 as base case to determine cost effectiveness of raised heel truss for each climate
- Higher Reflectance Cool Roof Compliance Option
  - Determine required roof reflectance to achieve energy equivalence to below deck insulation level above

Cool Roof/Roof Insulation

Methodology

- Unvented Attic Compliance Option
  - Verify that unvented option uses no more energy than prescriptive package
  - Determine if unvented attic meets requirement for Reach Code
- Increased Attic Insulation
  - Analyzed separately, independent of other measures

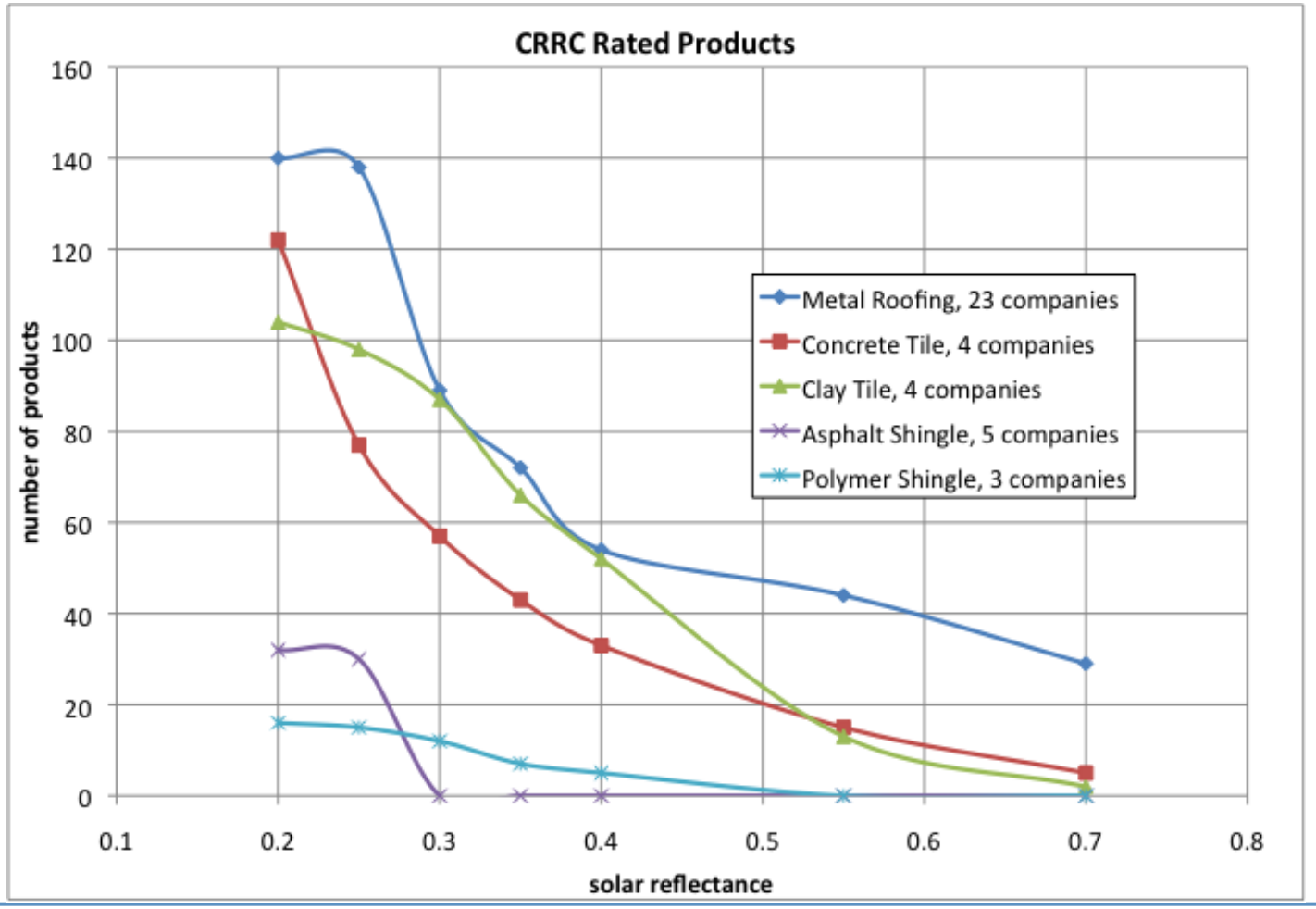
Base Code

HIGHER REFLECTANCE COOL ROOF

Cool Roof/Roof Insulation

Cool Roofs: Initial Findings

- Higher reflectance steep-sloped roof materials do exist



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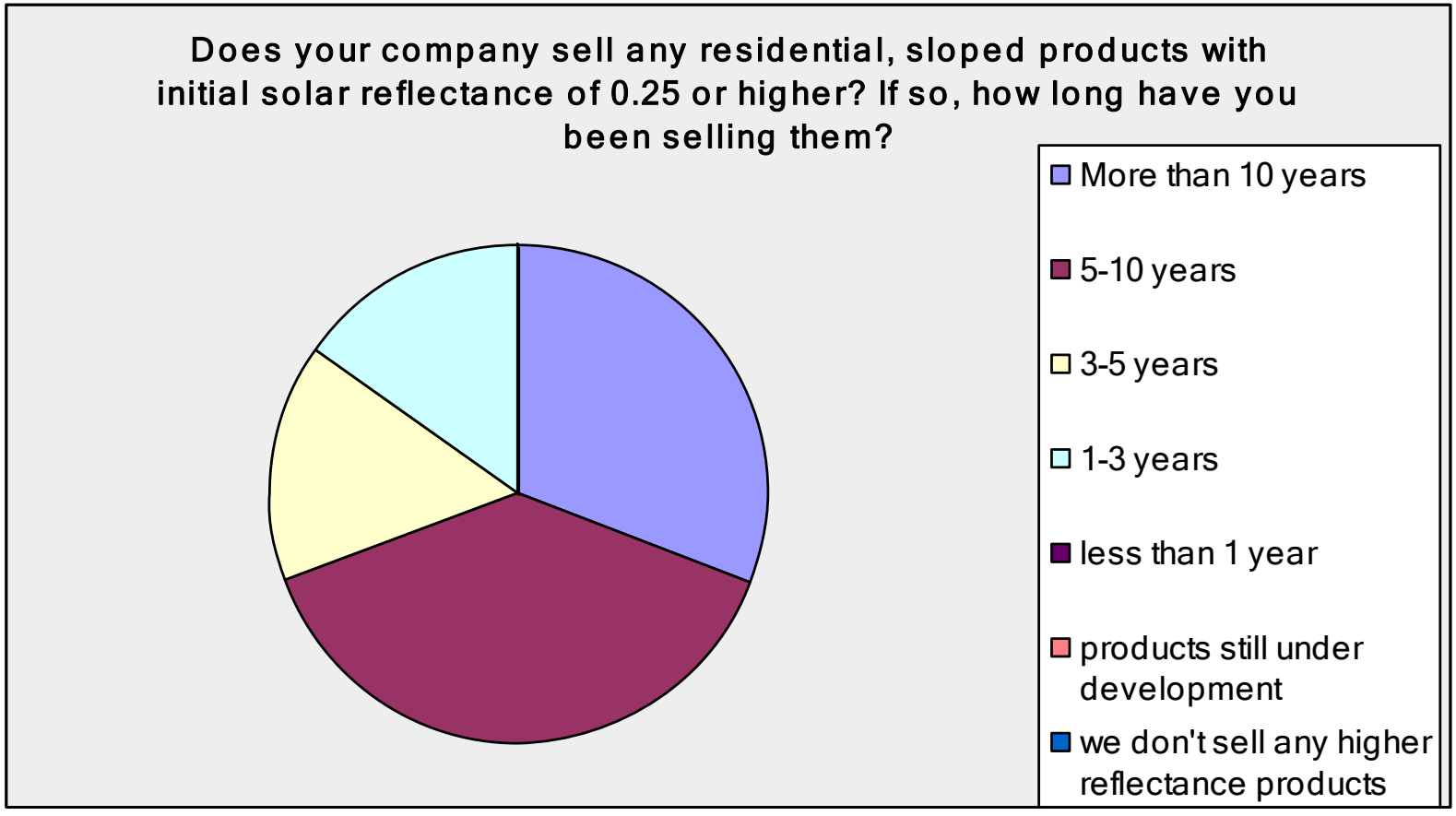
Survey Results: Roofing Manufacturers



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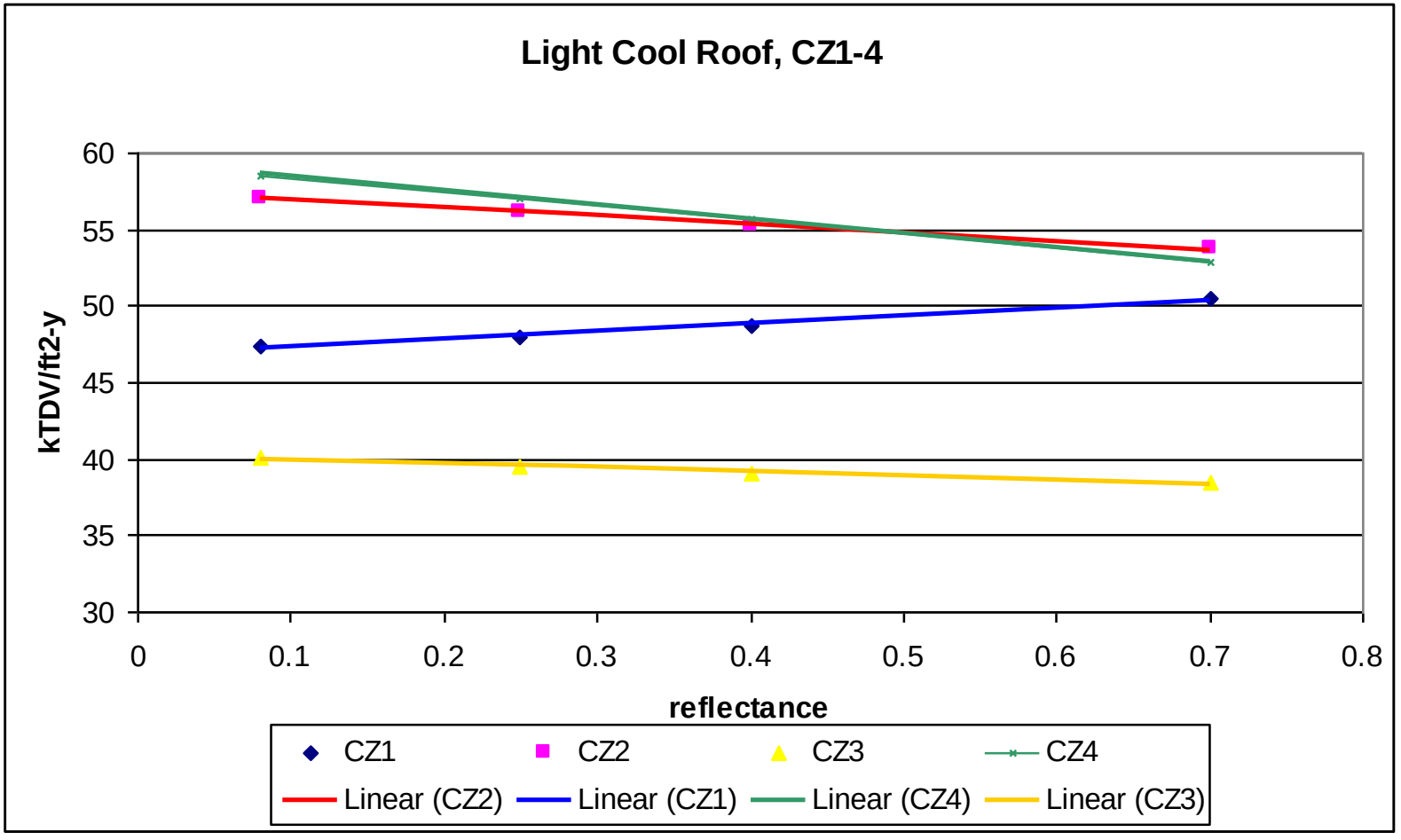
Cool Roof Energy Benefits: North Coast



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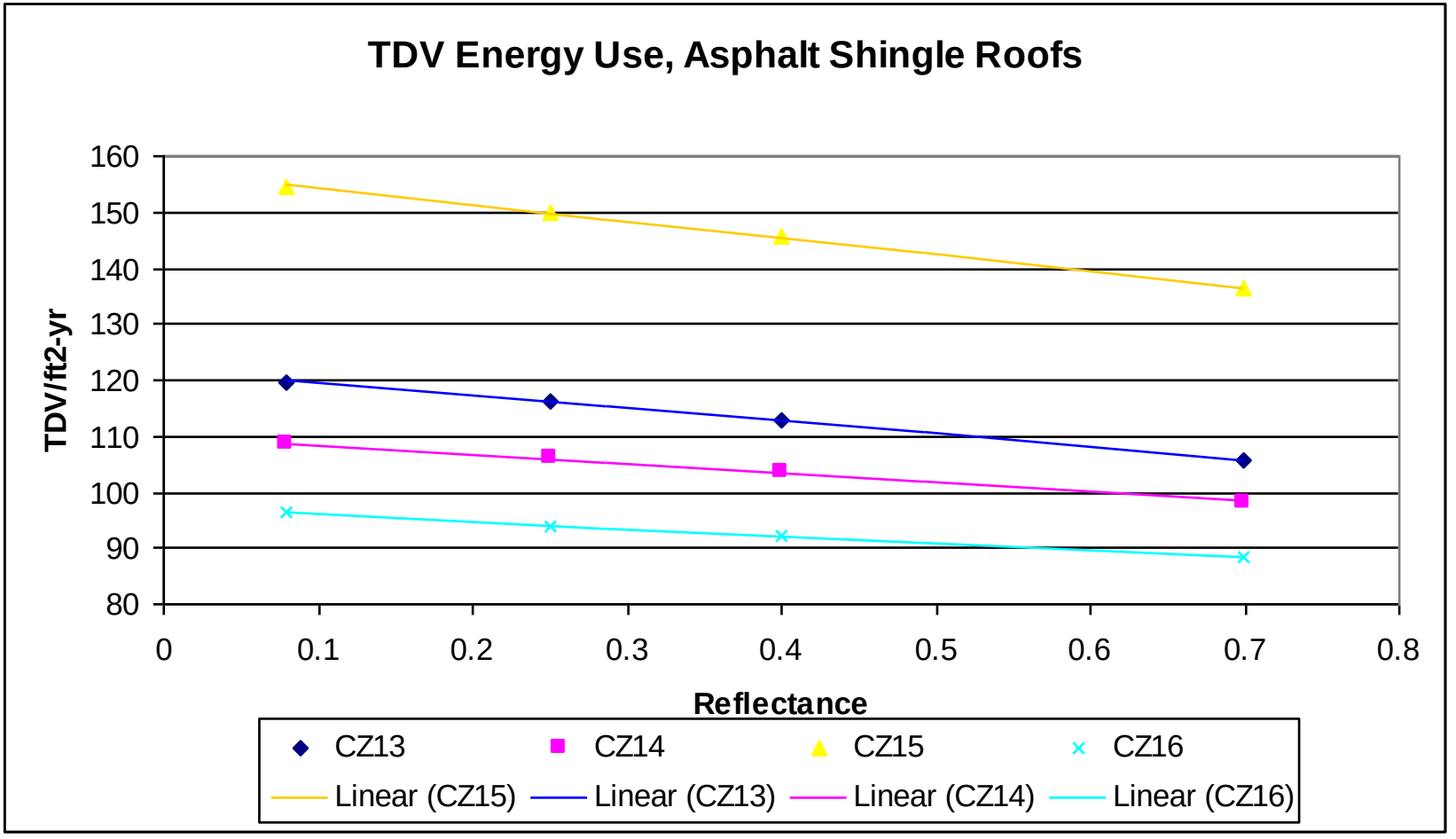
Cool Roof Benefits: Southern Valley and Desert



Cool Roof/Roof Insulation

Cost Effectiveness in Temperate Climates

- Asphalt shingle reflectance limited to 0.25 to 0.28 with current products on market
- For asphalt shingle, roof reflectance of 0.25 is cost effective in nearly all climates
- Not cost effective in CZ1 (Arcata), CZ2 (Santa Rosa), CZ3 (Oakland) and CZ5 (Santa Maria)

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
TDV/sfr	-1.30	1.81	1.21	2.77	-1.43	3.58	2.92	3.82
PV $/sfr	-0.23	0.31	0.21	0.48	-0.25	0.62	0.51	0.66
PV $/sq	-22.55	31.25	20.94	48.00	-24.80	61.85	50.58	66.04
Cost $/sq	$32.00	$32.00	$32.00	$32.00	$32.00	$32.00	$32.00	$32.00
NPV/sq	($54.55)	($0.75)	($11.06)	$16.00	($56.80)	$29.85	$18.58	$34.04
BCR	-0.70	0.98	0.65	1.50	-0.78	1.93	1.58	2.06

Costs and present value of savings are shown per square (100 ft^2)

Cool Roof/Roof Insulation
Cost Effectiveness in Hot and Mountain Climates

For asphalt shingle, roof reflectance of 0.25 is cost effective in inland valley, desert and mountain climates

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
TDV/sfr	5.06	5.12	6.05	4.90	6.35	4.79	8.34	4.21
PV $/sfr	0.88	0.89	1.05	0.85	1.10	0.83	1.44	0.73
PV $/sq	87.62	88.59	104.69	84.72	109.85	82.79	144.32	72.80
Cost $/sq	$32.00	$32.00	$32.00	$32.00	$32.00	$32.00	$32.00	$32.00
NPV/sq	$55.62	$56.59	$72.69	$52.72	$77.85	$50.79	$112.32	$40.80
BCR	2.74	2.77	3.27	2.65	3.43	2.59	4.51	2.28

Costs and present value of savings are shown per square (100 ft^2)

Cool Roof/Roof Insulation

Cost Effectiveness for Tile Roof

- Concrete tile is 80% to 90% of new construction market
- Cool roof products with reflectance to 0.35 to 0.40 have zero or marginal markup ($0-6/square) relative to current requirements in the Standard
- Cool roof tile with reflectance of 0.35 is cost effective in all climates
- Higher reflectance tile (0.60 or higher) may have aesthetic issues with color
- Cool roof tile is cost effective alone, but this will be considered as a compliance option due to temporary lack of cool roof options for shingles
- Considered for Reach Code

Base Code

ROOF DECK INSULATION

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Roof Deck Insulation Options

- Above deck insulation
  - An effective option for tile, but asphalt shingles require a nailable base, adding cost
  - Continuous thermal barrier at roof deck
- Below deck insulation
  - Install closed-cell spray foam or fiberglass batts between trusses
  - R-13 insulation below the deck is thermally equivalent to R-10 to R-11 above the deck
- R-5 below deck insulation is thermally equivalent to a increase in roof reflectance to 0.40

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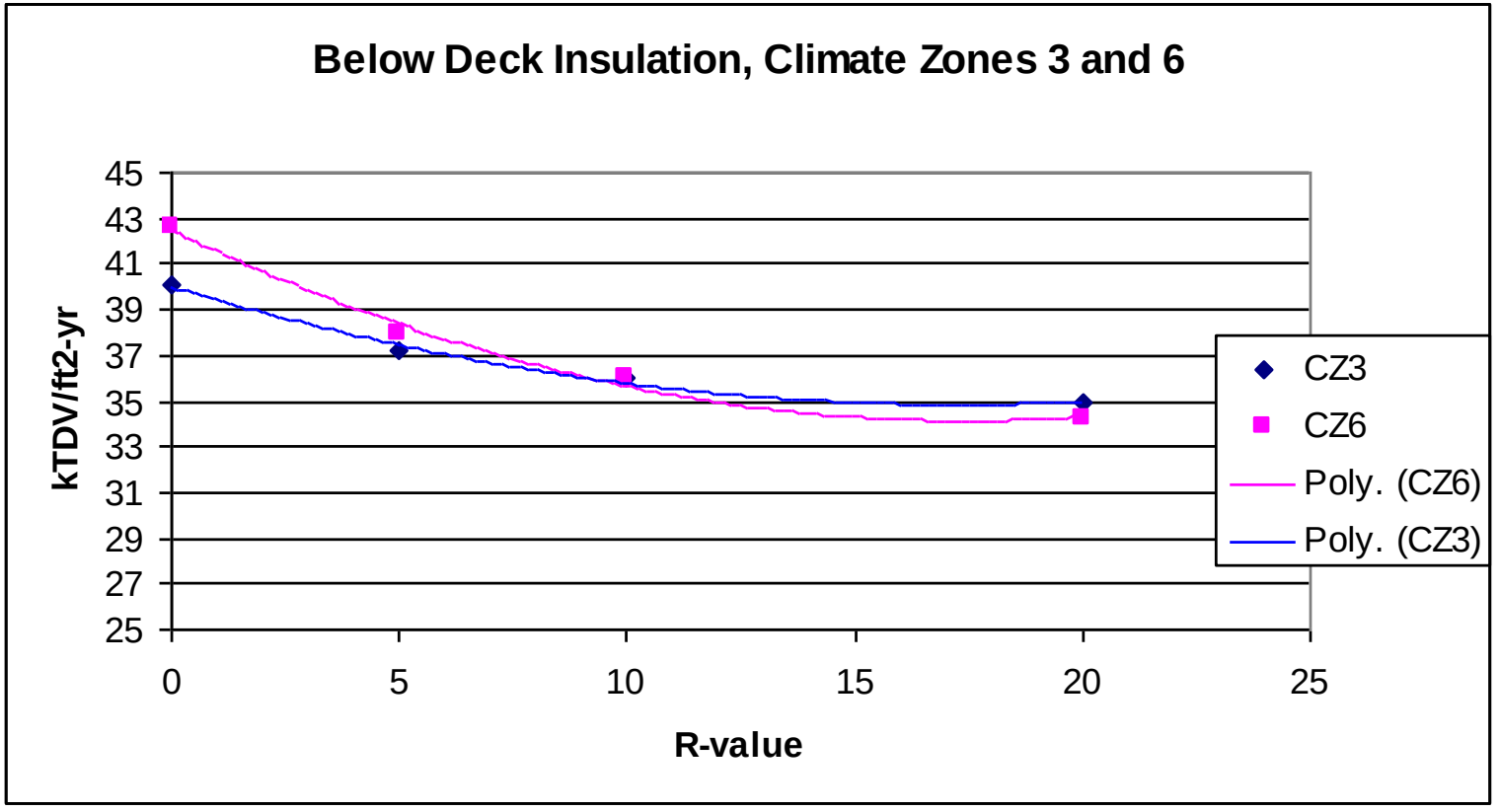
Below Deck Insulation Simulation Results

Biggest benefit for CZ3 (Oakland) and CZ6 (Torrance): insulation to R-10



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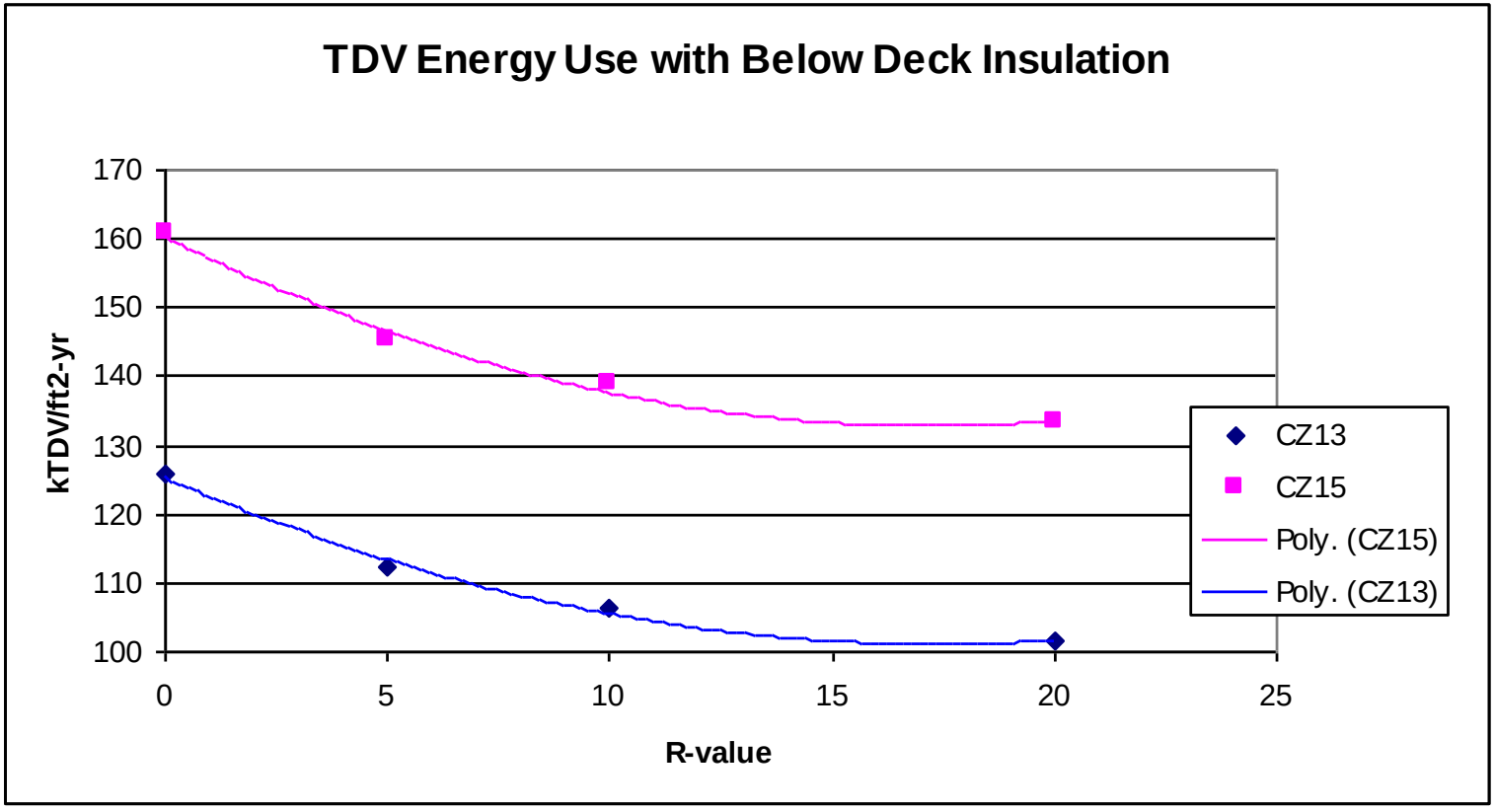
Below Deck Insulation Simulation Results

Below deck insulation very effective for inland climates up to R-10; additional insulation shows diminishing returns from R-10 to R-20



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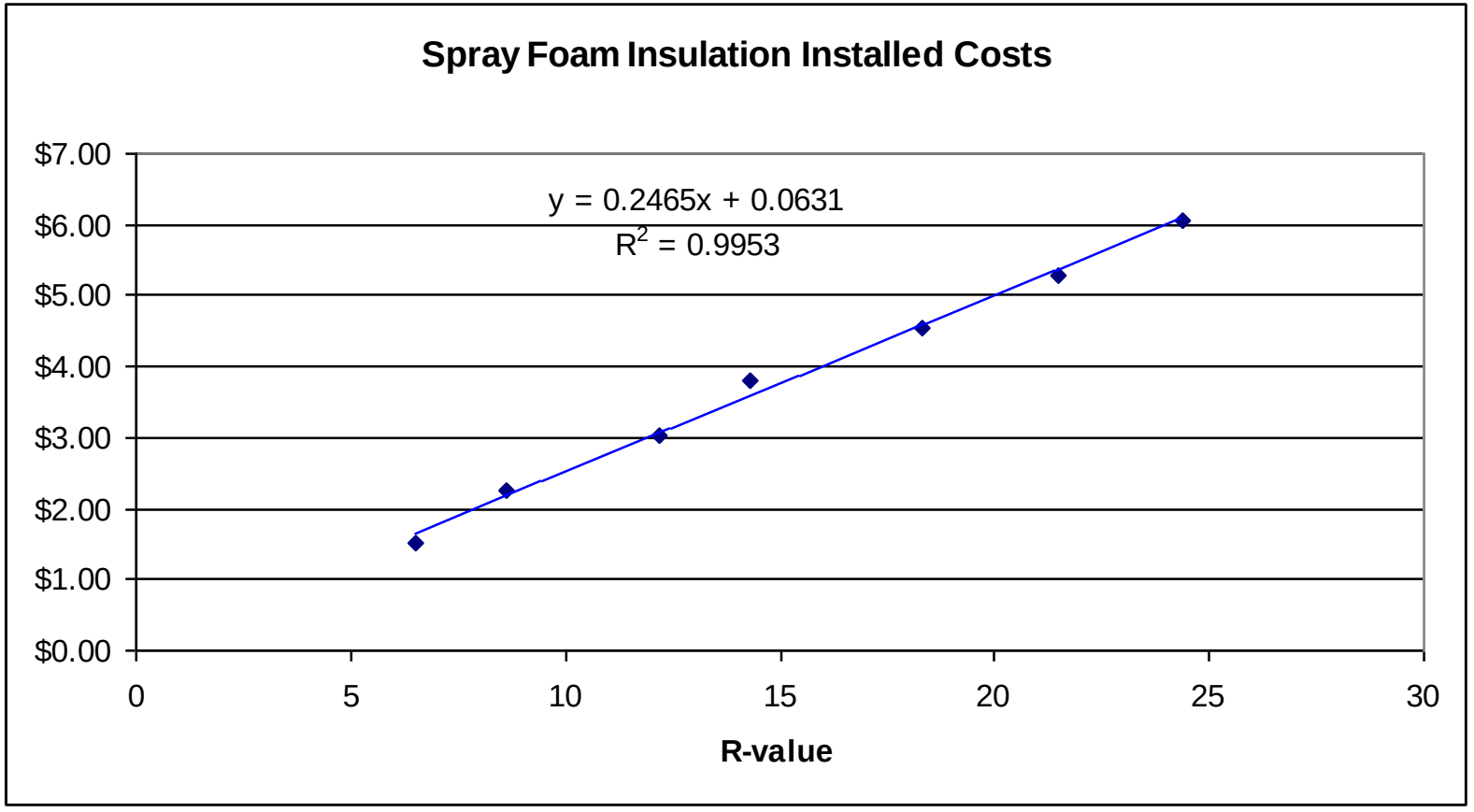
Below Deck Insulation Costs

Spray Foam Costs: average of survey data and RS Means
- additional cost of $0.25/ft^2 for an ignition barrier



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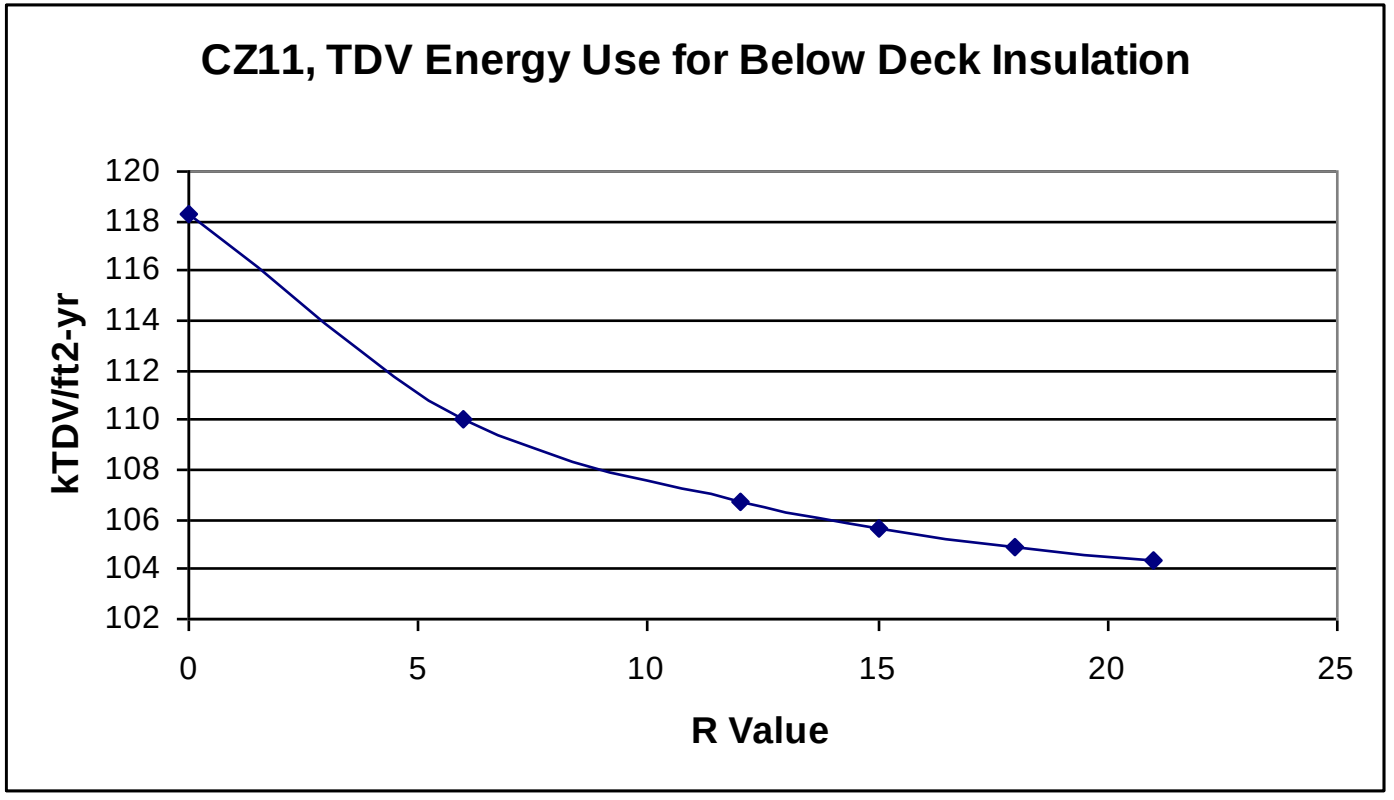
Below Deck Insulation: Simulation Results

Diminishing returns after 2" of spray foam (R-12) is installed



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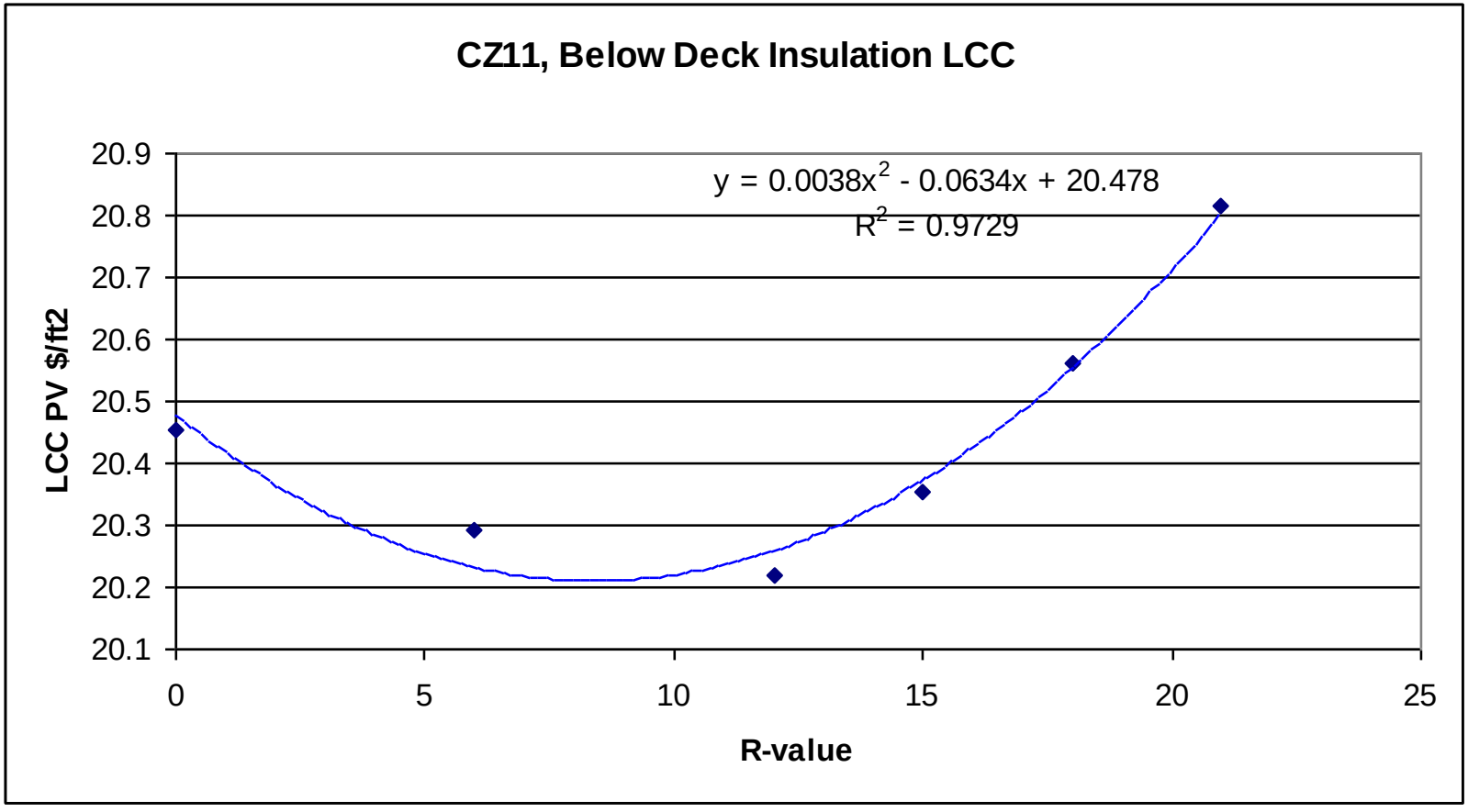
Below Deck Insulation: Life-Cycle Cost Analysis

Total Life Cycle Cost for CZ11 (Red Bluff) – equal LCC at R-16.7



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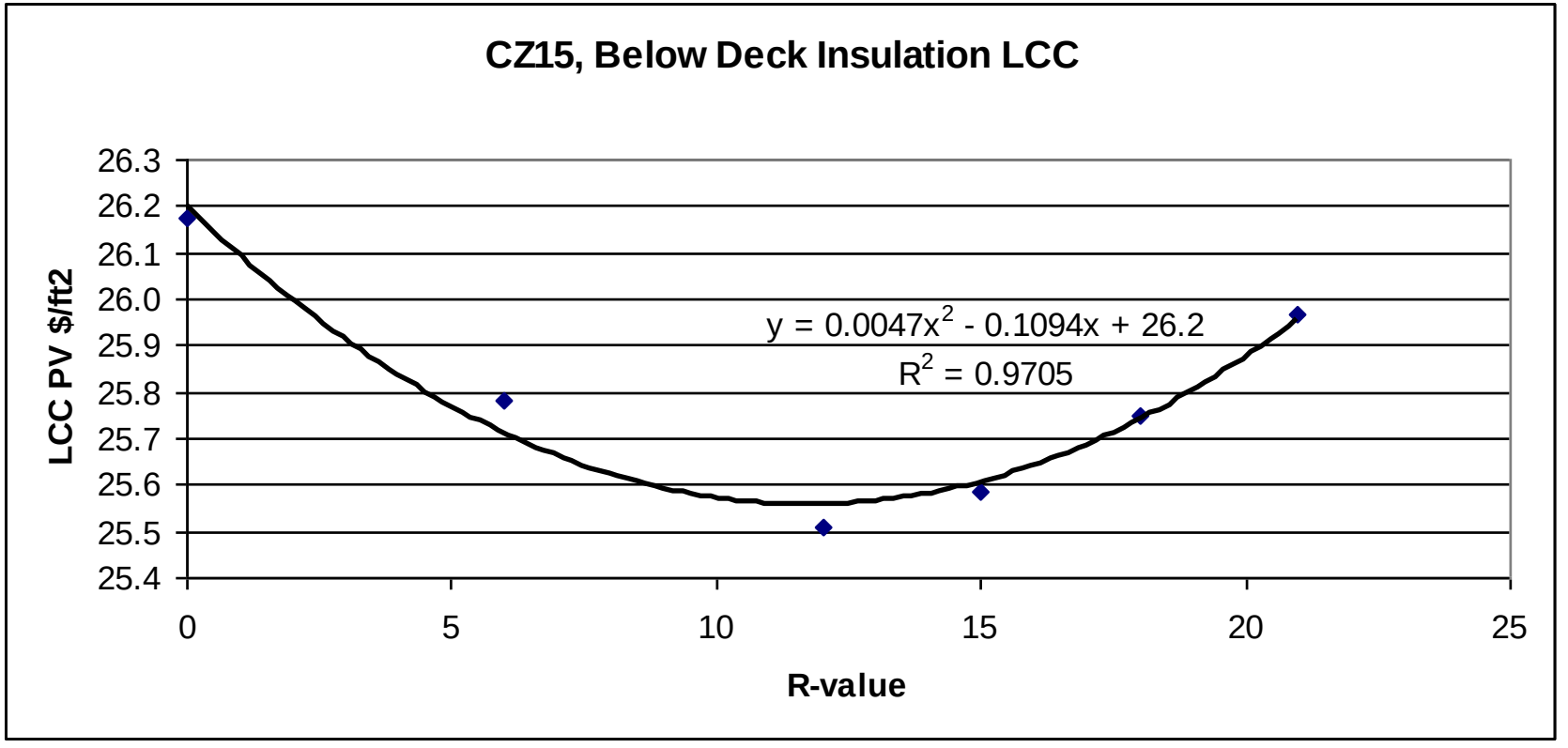
Below Deck Insulation: Life-Cycle Cost Analysis

Total Life Cycle Cost for CZ15 (Palm Springs) – equal LCC at R-23



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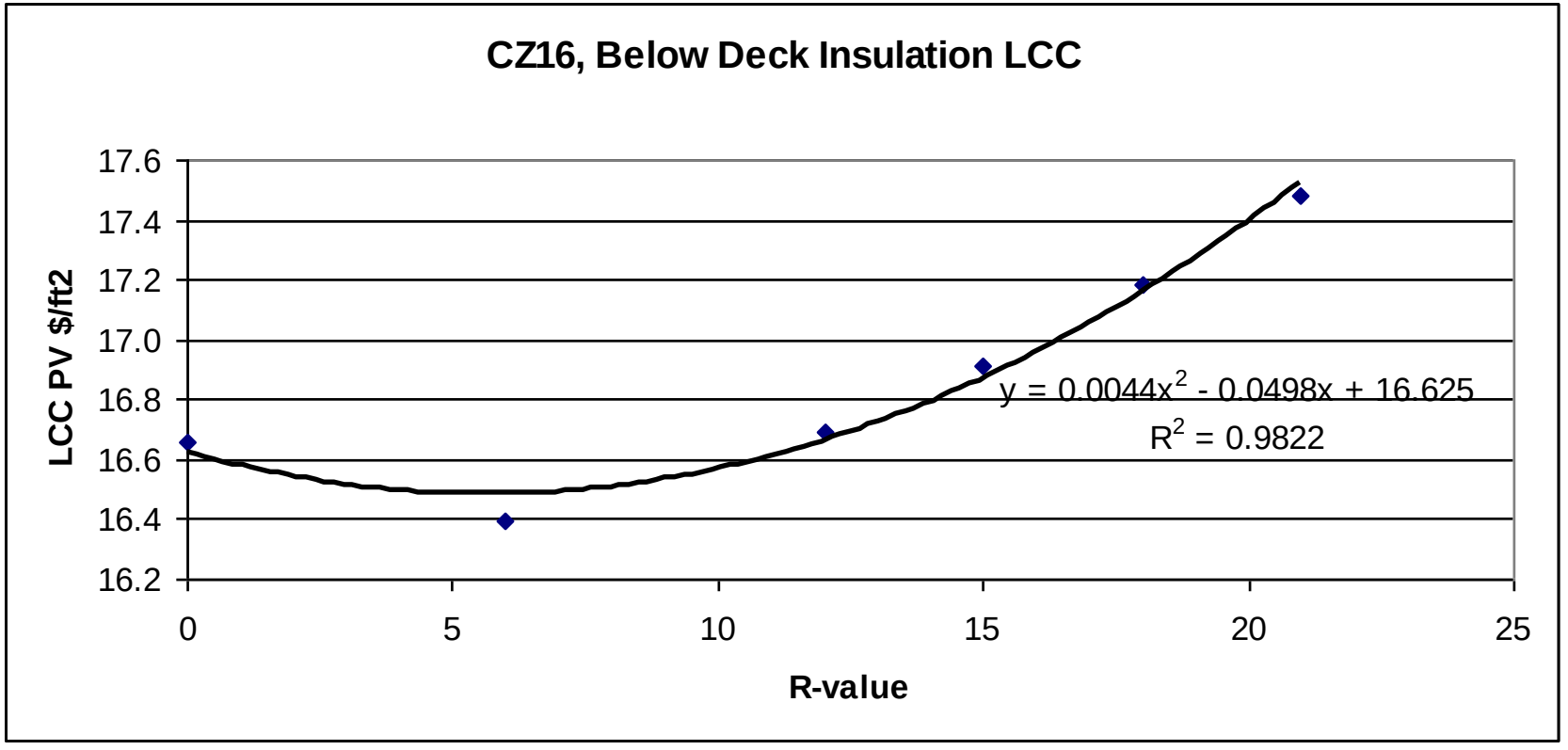
Below Deck Insulation: Life-Cycle Cost Analysis

Total Life Cycle Cost for CZ16 (mountains) – equal LCC at R-11.3



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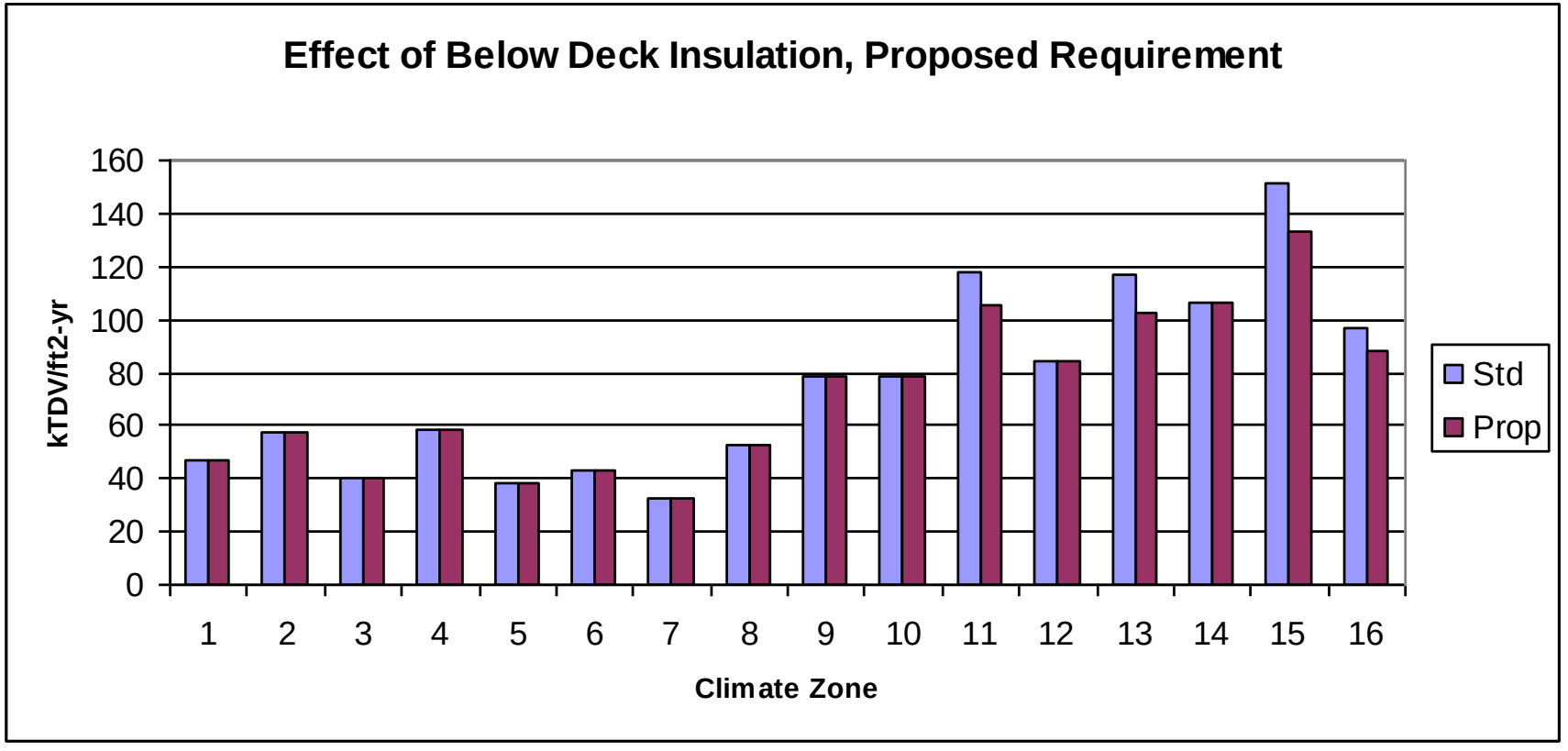
Below Deck Insulation Cost Effectiveness

8-12% reduction in TDV energy use in CZ11,13,15,16



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Below Deck Insulation Cost Effectiveness

- Below Deck Insulation Levels
  - R-9 cost effective in CZ16 (mountains)
  - R-15 cost effective in CZ 11 (Red Bluff)
  - R-18 cost effective in CZ 13 (Fresno)
  - R-21 cost effective in CZ 15 (Palm Springs)
  - Below deck insulation would be cost effective in more climates if fiberglass batts could be used directly below the deck
- Next Steps
  - Determine cost effective levels of duct insulation
  - Determine cost effectiveness of raised heel truss
  - Analyze cooler roof and unvented attic compliance options

Base Code

DUCT INSULATION

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Duct Insulation Measure

- Proposal: increase duct insulation thickness to R-8
  - R-4.2 required in southern CA coast (CZ 6-8)
  - R-6 required in climate zones 1-5, 9-13
  - R-8 already required in CZ 14-16
- Incremental Costs
  - R-4.2 to R-8: $\$0.24/ft^2$ to $\$0.90/ft^2$
  - R-6 to R-8: $\$0.13/ft^2$ to $\$0.59/ft^2$
  - Labor Costs under further investigation

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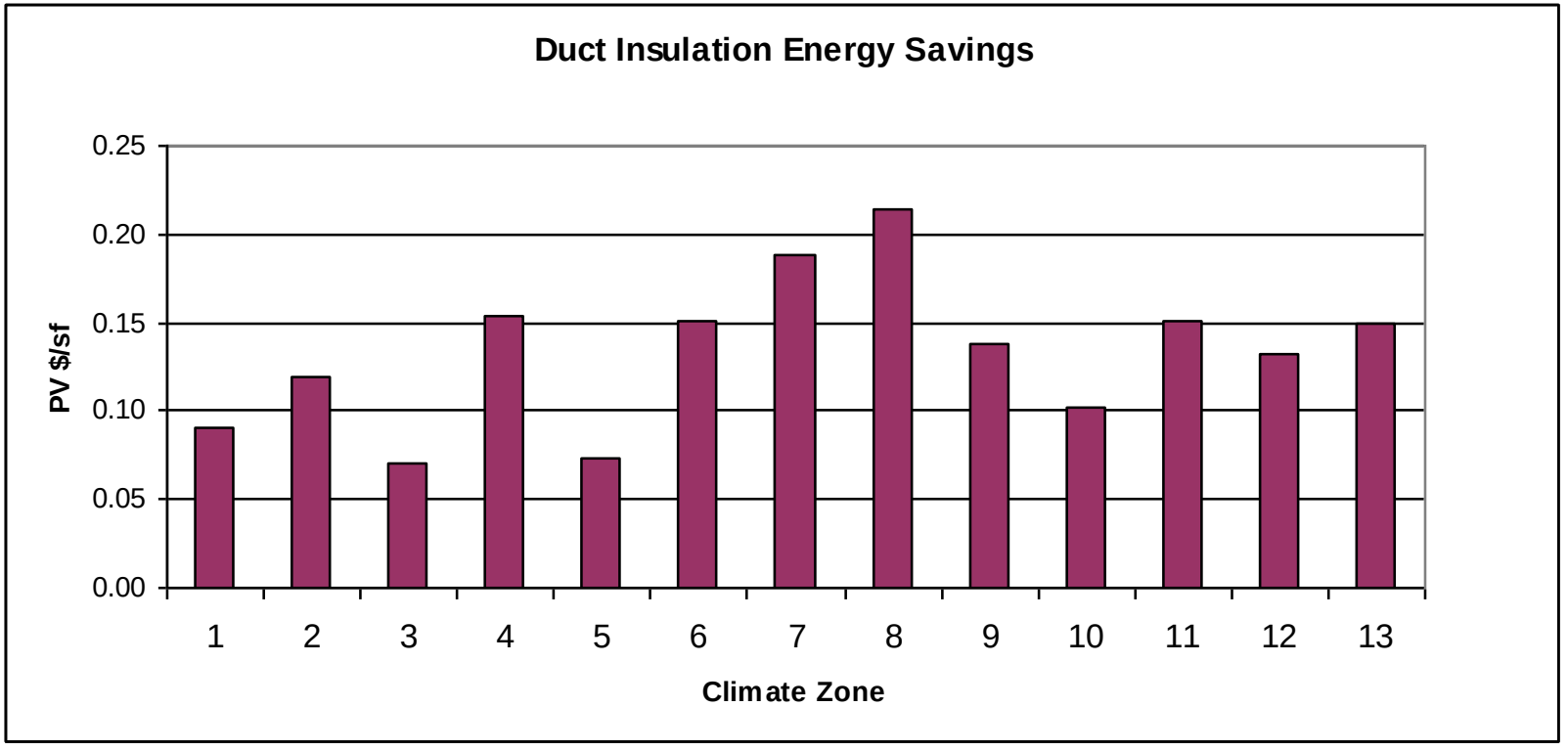
Duct Insulation Measure

Energy Savings – use ACM assumption on duct surface area - $0.07/ft^2 to $0.21/ft^2 life-cycle cost savings



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Duct Insulation: Conclusions

- Duct Insulation cost effective if little labor markup for additional insulation
- Additional survey data will verify cost effectiveness
- Results of Roof Deck Insulation and Duct Insulation measures will be starting point for analyzing raised heel trusses

Base Code

RAISED HEEL TRUSS

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Initial Findings

- Raised Heel Trusses
  - Incorporated into Building America homes and other high-performance homes
  - Included in many green building standards
  - Proposed as a prescriptive requirement in Energy Star 2011
  - Credit provided for R.H.T. in IECC 2006
    - R-30 in place of R-38
    - R-38 in place of R-49

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Methodology

- Determine cost effectiveness of raised heel truss measure in isolation
- Assess interactive effects by evaluating measures for vented attic:
  - Roof Deck Insulation
  - Duct Insulation
  - Raised Heel Truss
- Determine required cool roof reflectance as a compliance option

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Methodology

- Raised Heel Truss: modified U-factor calculation procedure for de-rating roofs with compressed insulation near the eaves
  - Calculate roof area where insulation is compressed and assume average of half-depth insulation
  - Apply JA4 framing factors to perimeter
  - Use parallel path method to calculate U-factors
- U-factors for raised heel truss similar to published values in JA4
- De-rating used to assess benefits of raised heel truss

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Methodology

- Raised Heel Truss De-Rating Procedure
  - Based on parallel path method
  - 5:12 roof, framing 24" o.c.

Insulation	Effective R-Value	R-Value Compressed	U-factor JA4	U-factor Compressed
R-30	32.3	28.4	0.031	0.0353
R-38	40.0	33.2	0.025	0.0301
R-49	52.6	39.3	0.019	0.0254

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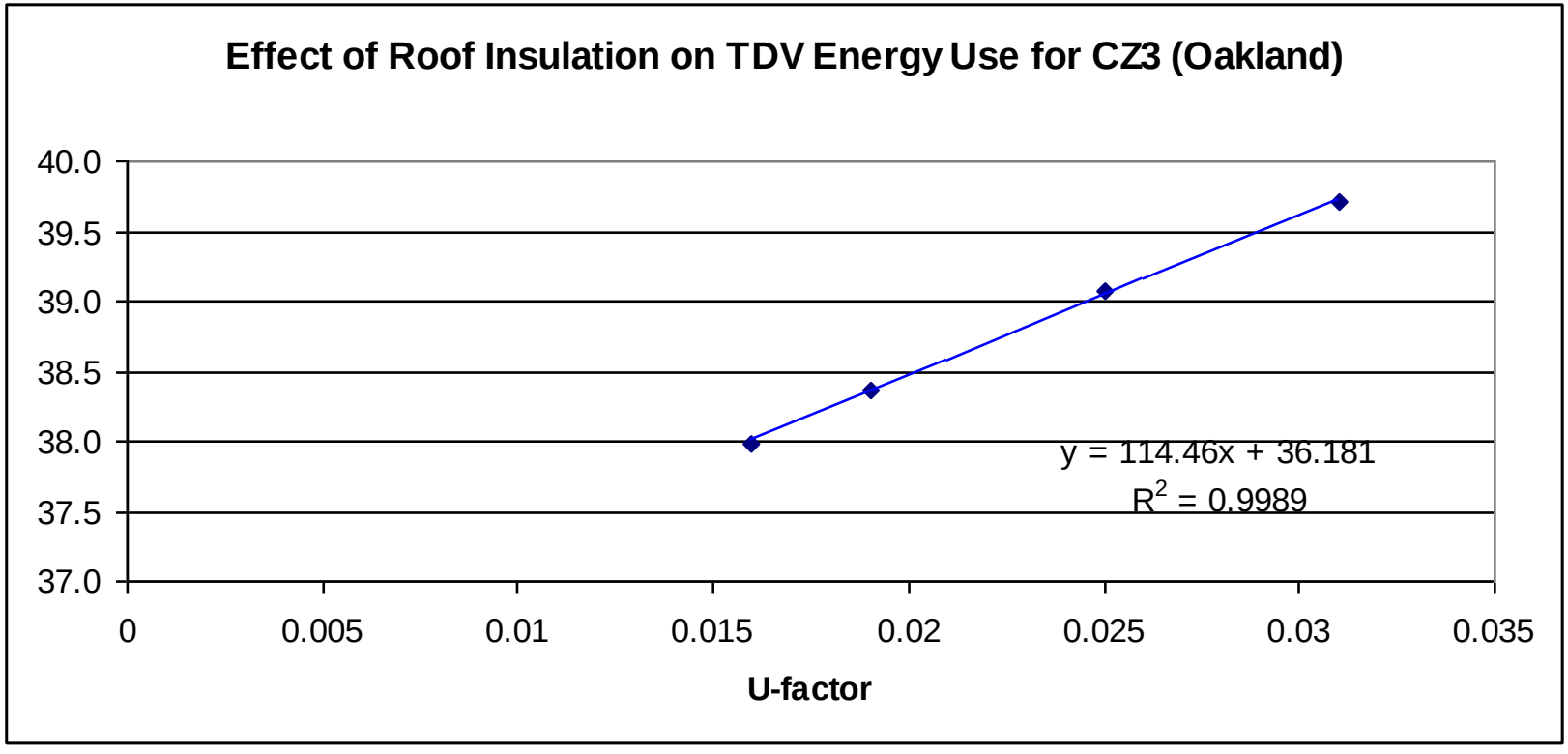
Raised Heel Truss Cost Effectiveness



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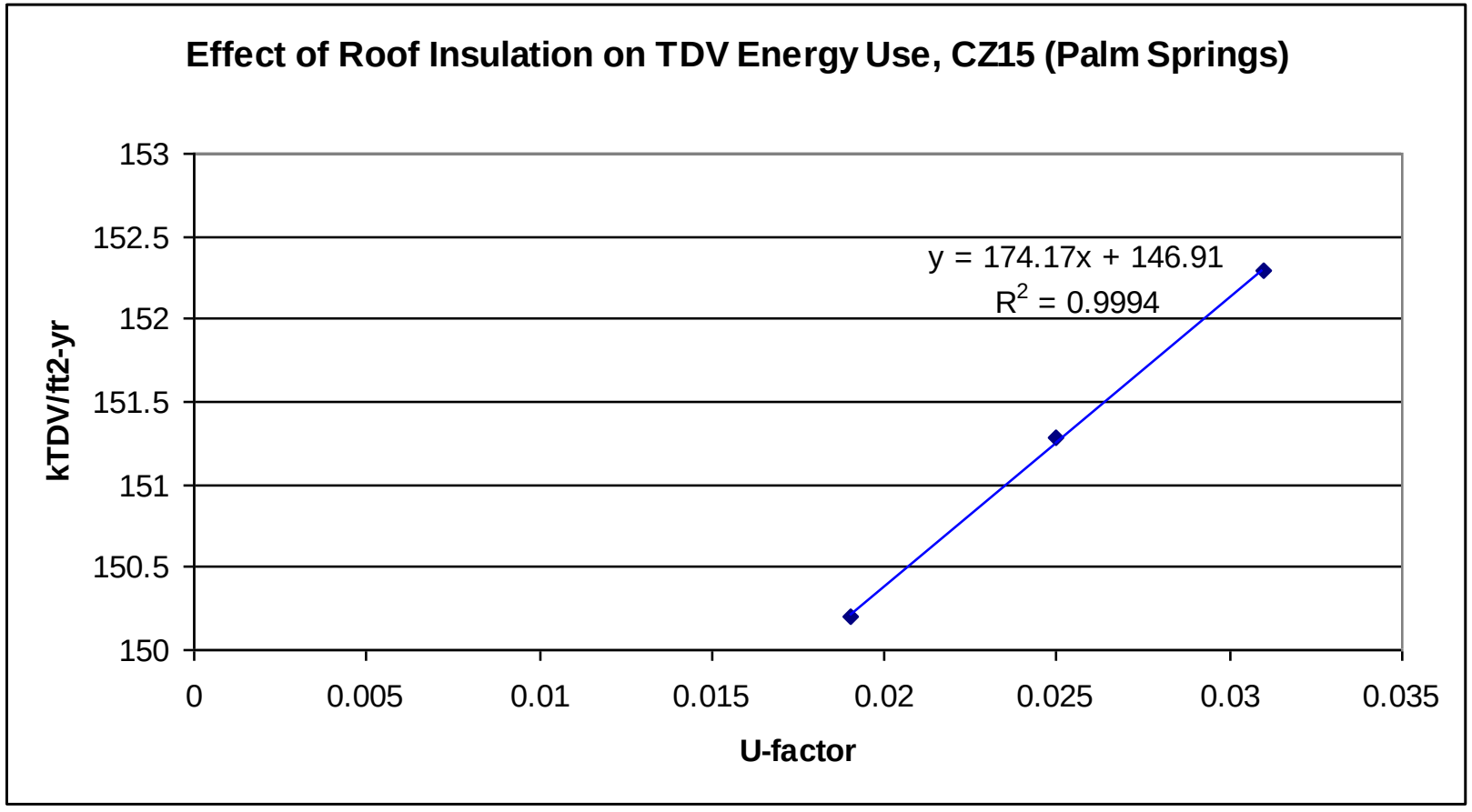
Raised Heel Truss Cost Effectiveness

Steeper Slope → Roof Insulation has greater impact on energy use



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Raised Heel Truss: Isolated Measure

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
PV Savings	$221.32	$242.08	$225.48	$263.62	$104.45	$291.82	$218.86	$215.53
RHT Cost	$355.25	$355.25	$355.25	$355.25	$355.25	$355.25	$355.25	$355.25
NPV	($133.93)	($113.17)	($129.77)	($91.63)	($250.80)	($63.43)	($136.39)	($139.72)
BCR	0.62	0.68	0.63	0.74	0.29	0.82	0.62	0.61

Measure Not Cost Effective in Temperate Climates (CZ1-8)

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Raised Heel Trusses: Isolated Measure

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
PV Savings	$271.92	$240.40	$387.30	$343.84	$393.23	$411.02	$413.01	$586.90
RHT Cost	$355.25	$355.25	$355.25	$355.25	$355.25	$355.25	$355.25	$355.25
NPV	($83.33)	($114.85)	$32.05	($11.41)	$37.98	$55.77	$57.76	$231.65
BCR	0.77	0.68	1.09	0.97	1.11	1.16	1.16	1.65

Measure Cost Effective in Inland Valley and Mountains

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Integrated Analysis

- Incorporate recommendations for below deck insulation and duct insulation
- Re-run simulations for all climate zones to determine cost effectiveness

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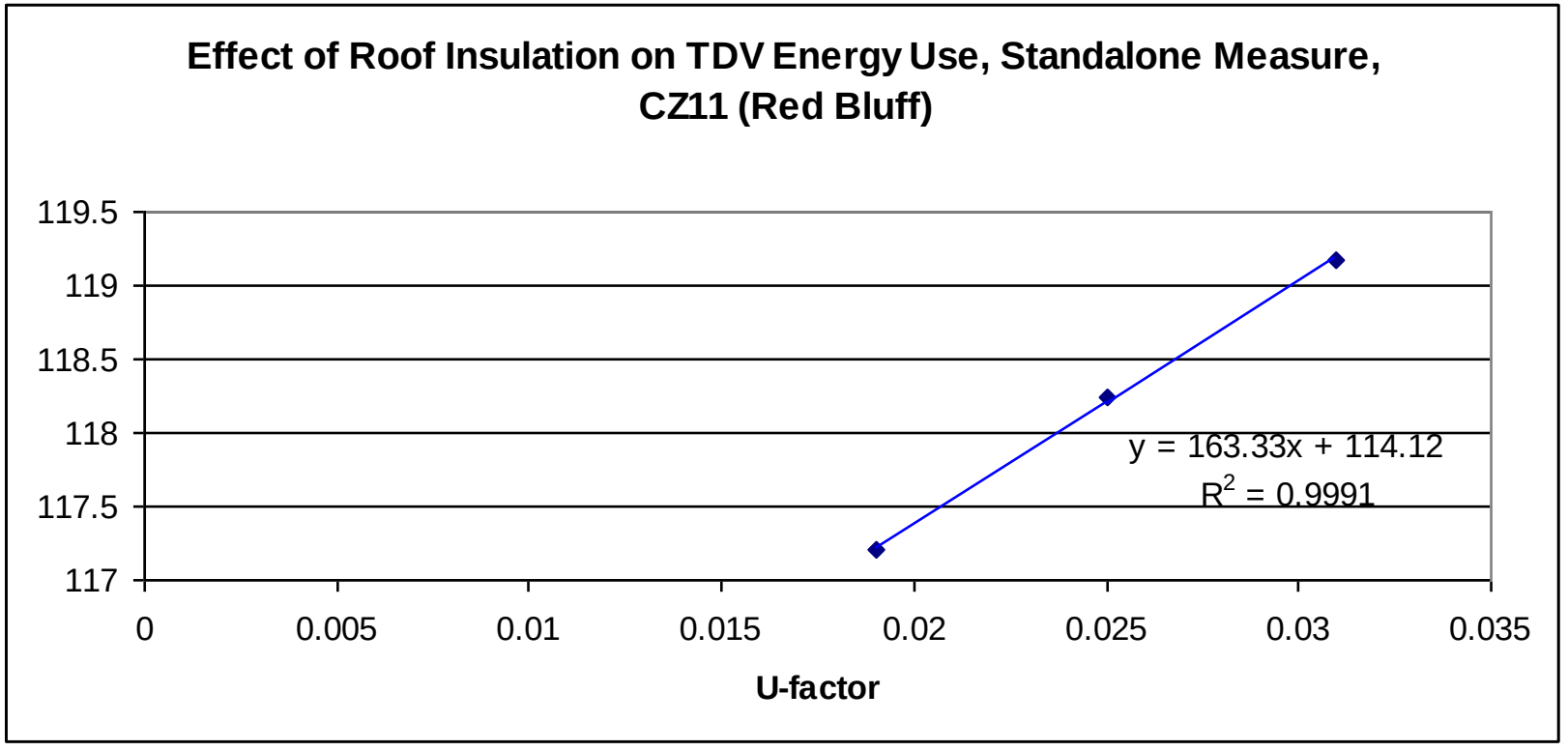
Effect of Integrated Analysis

Energy Benefits are proportional to the slope of the curve



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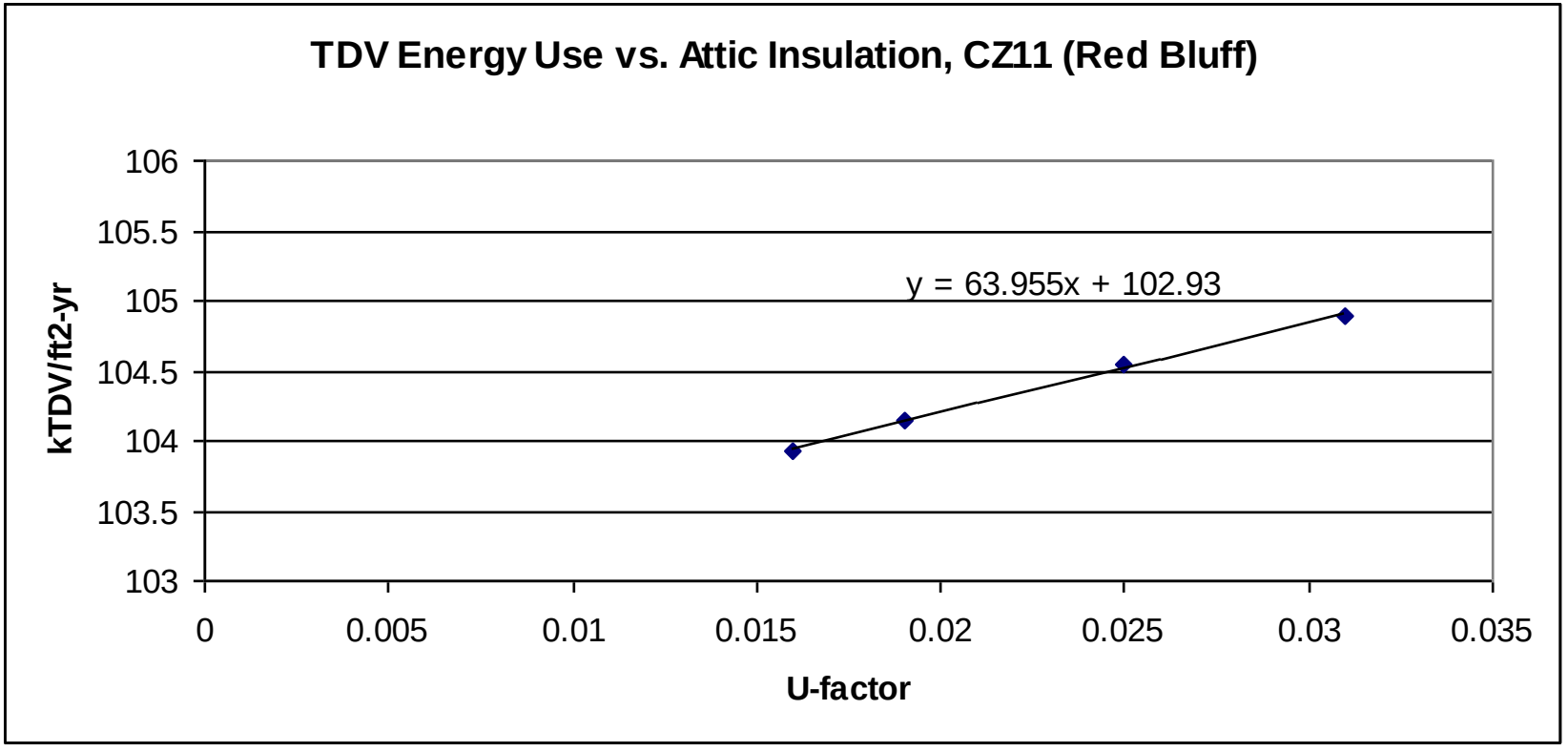
Effect of Integrated Analysis

Curve is flatter with integrated analysis since R-15 roof deck insulation is already present → energy benefits reduced by 60%



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Raised Heel Truss: Integrated Analysis

	1	2	3	4	5	6	7	8
PV Savings	$227	$250	$228	$272	$110	$293	$219	$228
RHT Cost	$355	$355	$355	$355	$355	$355	$355	$355
NPV	-$128	-$105	-$128	-$83	-$246	-$62	-$136	-$127
BCR	0.64	0.71	0.64	0.77	0.31	0.82	0.62	0.64

Measure Not Cost Effective in Temperate Climates (CZ1-8)

Cool Roof/Roof Insulation

Raised Heel Trusses: Integrated Analysis

	9	10	11	12	13	14	15	16
PV Savings	$286	$250	$152	$360	$117	$421	$194	$232
RHT Cost	$355	$355	$355	$355	$355	$355	$355	$355
NPV	-$70	-$105	-$204	$5	-$239	$66	-$161	-$123
BCR	0.80	0.70	0.43	1.01	0.33	1.19	0.55	0.65

Measure Cost Effective in Inland Climates that do not have roof deck insulation requirement

Cool Roof/Roof Insulation

Raised Heel Truss: Conclusions

- With baseline that includes roof deck insulation, not cost effective
  - Verify assemblies (spray foam or batt below deck) meet moisture analysis tests
- Significant cost for high heel trusses when blocking is required
  - Increased use may reduce costs
- Recommend modifying the JA4 table to include U-factors for raised heel truss
- Modify existing U-factors for wood-framed roofs to be more penalizing due to compression near the eaves

Cool Roof/Roof Insulation

Recommended Language: JA4

Table 4.2.1 – U-factors of Wood Framed Attic Roofs

Truss Spacing	R-value of Attic Insulation		Rated R-value of Continuous Insulation1								
			RHT	None	R-2	R-4	R-6	R-7	R-8	R-10	R-14
			R	A	B	C	D	E	F	G	H
16 in. OC	None	1		0.300	0.187	0.136	0.107	0.097	0.088	0.075	0.058
	R-11	2		0.079	0.068	0.060	0.053	0.051	0.048	0.044	0.037
24 in. OC	None	13	0.305	0.305	0.189	0.137	0.108	0.097	0.089	0.075	0.058
	R-11	14	0.076	0.076	0.066	0.058	0.052	0.050	0.047	0.043	0.037
	R-13	15	0.068	0.068	0.060	0.054	0.048	0.046	0.044	0.041	0.035
	R-19	16	0.048	0.048	0.043	0.040	0.037	0.036	0.034	0.032	0.029
	R-21	17	0.043	0.0444	0.040	0.037	0.034	0.033	0.032	0.030	0.027
	R-22	18	0.041	0.043	0.038	0.036	0.033	0.032	0.031	0.029	0.026
	R-25	19	0.037	0.0393	0.034	0.032	0.030	0.029	0.028	0.027	0.024
	R-30	20	0.031	0.0353	0.029	0.028	0.026	0.025	0.025	0.024	0.022
	R-38	21	0.025	0.0301	0.024	0.023	0.022	0.021	0.021	0.020	0.018
	R-44	22	0.021	0.0265	0.020	0.019	0.019	0.018	0.018	0.017	0.016
	R-49	23	0.019	0.0254	0.019	0.018	0.017	0.017	0.017	0.016	0.015
	R-60	24	0.016	0.021	0.016	0.015	0.015	0.014	0.014	0.014	0.013

Base Code

ROOF ATTIC INSULATION

Cool Roof/Roof Insulation

Roof Attic Insulation: Isolated Measure

- We also investigated the cost effectiveness of increasing attic insulation requirements as an alternative to a raised heel truss
  - R-30 to R-38
  - R-38 to R-49
  - Measure analyzed relative to current Standards
- Energy simulations and updated life-cycle cost effectiveness showed that increased attic insulation is not cost effective

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Higher Reflectance Cool Roof Revisited

- Next step: find equivalent cool roof reflectance that yields the same energy use as the vented attic package with roof deck insulation or a raised heel truss
- Very high roof reflectance required for equivalent energy use
- Possibly include raised heel truss in compliance option with increased reflectance requirements

Climate Zone	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Measure	Below Deck	R.H.T.	Below Deck	R.H.T.	Below Deck	Below Deck
Reflectance	> 0.7	0.32	> 0.7	0.26	> 0.7	0.62

Reach Code

UNVENTED ATTIC

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Unvented Attic Compliance Option

- Control moisture entry at the roof plane
- Fully insulate roof deck to place ducts in conditioned space
- Use closed-cell foam as air barrier and vapor retarder
- Duct Sealing becomes less important

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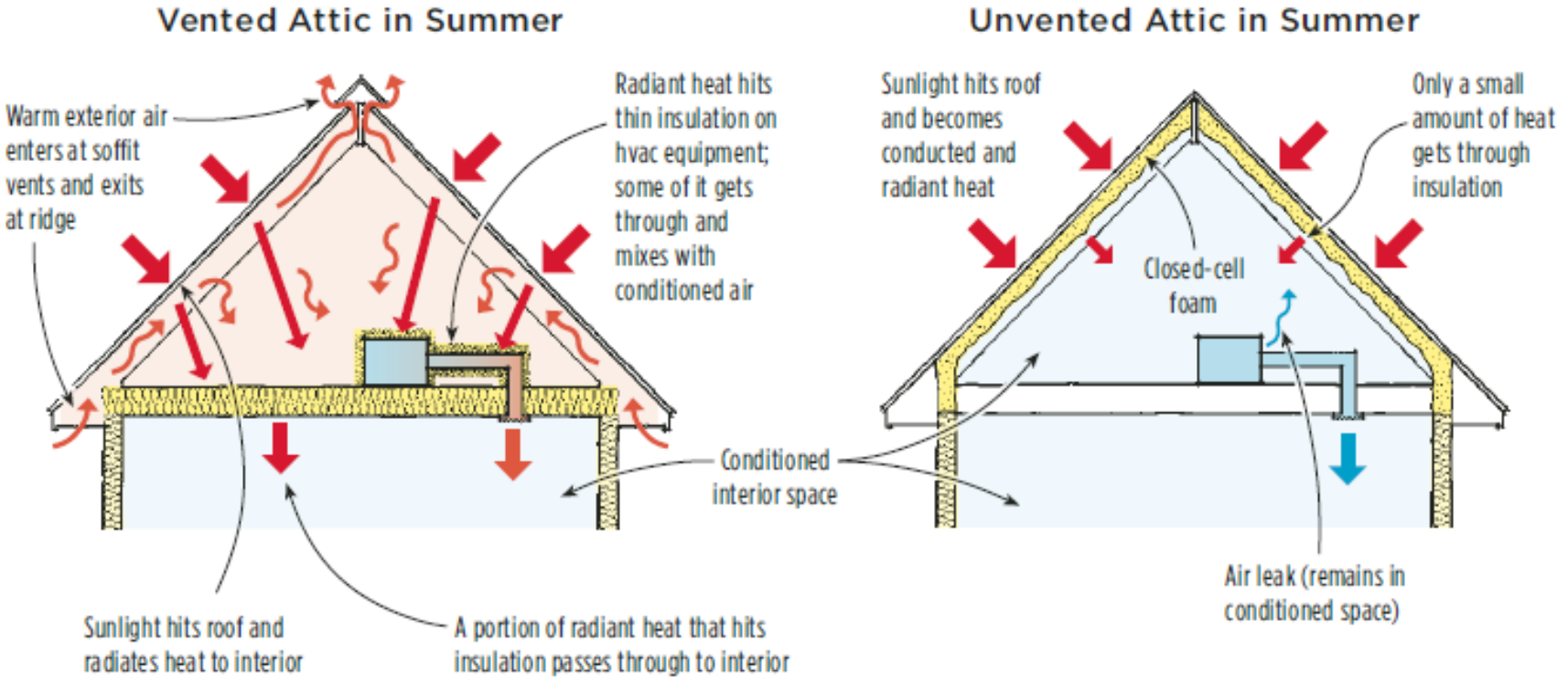
Unvented Attic Compliance Option



Source: JLC

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Unvented Attic: Next Steps

- Verify simulation properly accounts for infiltration with sealed attic
  - Determine air leakage rates with sealed attic
- Run simulations to determine required level of roof deck insulation to have equivalent energy use to prescriptive Standards
- Verify product options for non-condensing furnaces and water heaters located in the attic

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Recommended Language: Table 151-C

Component Package D (**Vented Attic Package**)

		Climate Zone															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Ceilings	R38	R30	R30	R30	R30	R30	R30	R30	R30	R30	R38	R38	R38	R38	R38	R38
	Below Deck Insulation	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**R-15**	**R-6 or RHT**	**R-18**	**R-6 or RHT**	**R-21**	**R-9**
	Duct Insulation*	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**	**R-8**

- Duct Insulation requirements TBD based on updated costs
- Specify exception to below deck insulation requirements if roof reflectance is 0.70 or higher (possibly combine with raised heel truss)

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Next Steps

- Verify costs for duct insulation and cost effectiveness
  - Will not affect other measures
- Complete Reach Code recommendations
  - Unvented attic option
- Complete report and impact analysis
  - Demand reduction, environmental impact

Cool Roof/Roof Insulation

QUESTIONS & COMMENTS

Thank you for your time!

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