



2016 Building
Energy
Efficiency
Standards

PRE-RULEMAKING
WORKSHOP

Draft Proposal for

High Performance
Attics

or

Ducts in
Conditioned Space

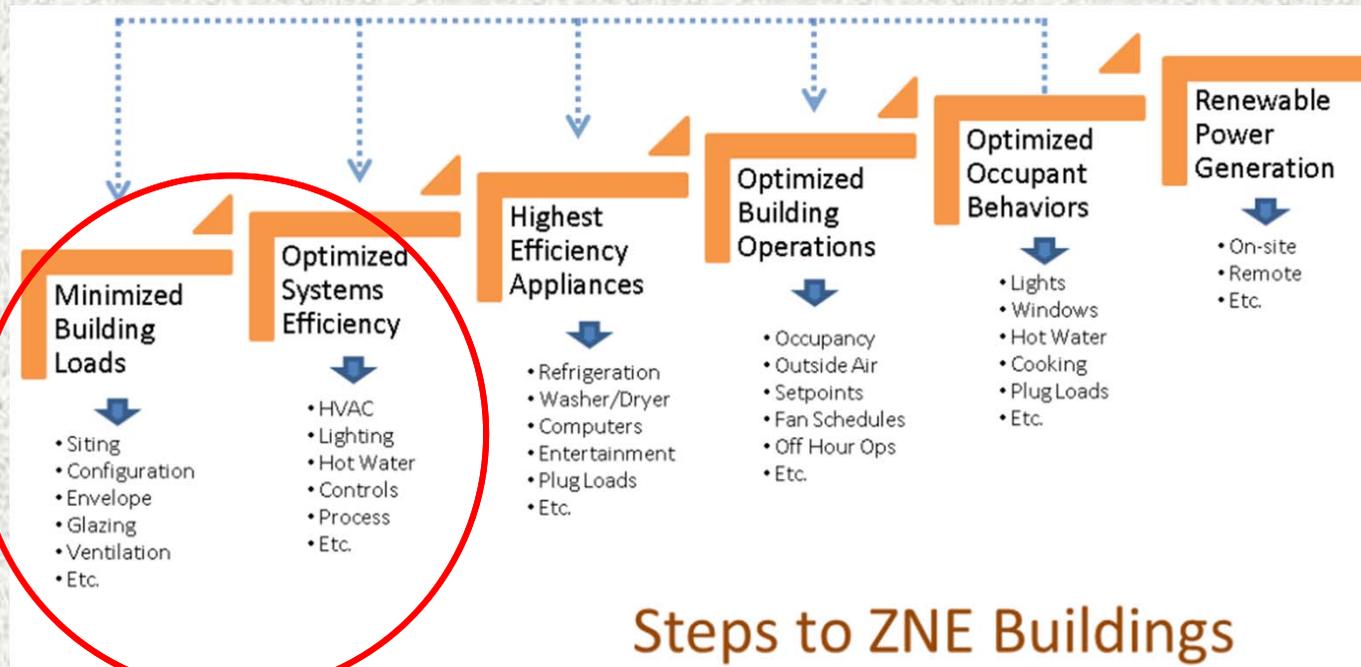
Bruce A. Wilcox, PE
July 21, 2014

Proposed Code Change Overview

Why are we proposing this measure?

Align with California's ZNE goal for residential new construction by 2020 according to the loading order

- Reduce cooling efficiency impacts of cold ducts in hot attics
- Reduce space cooling and heating loads



Source: HMG 2012

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Proposed Code Change Overview

Prescriptive Package(s) in CZ 1, 2, 4, 8-16

High Performance Vented Attic (HPA)

- R-13 Insulation Below Roof Deck
- R-38 Ceiling Insulation
- Radiant Barrier Not Required
- Ducts: Possible R-8 Insulation and Lower Leakage

OR

Ducts in Conditioned Space (DCS)*

- Locate ducts and air handler in conditioned space
 - HERS verification of no duct leakage to outside
- * Ductless systems as alternative to DCS

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Current Code Requirements

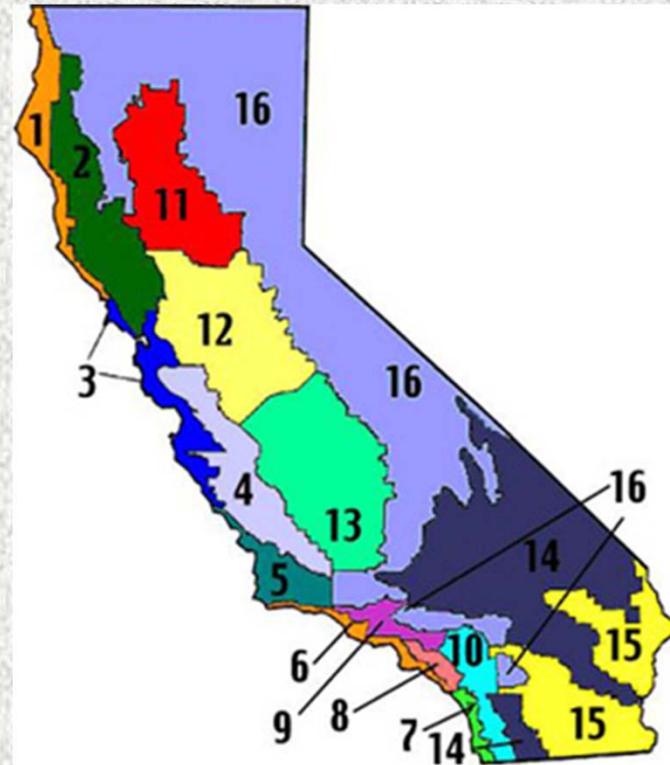
2013 Title 24 Requirements

Mandatory

- Duct leakage rate: 6% verified
- R-30 ceiling insulation

Prescriptive Requirements

- Ceiling insulation:
 - R-30 (CZ 2-10) or
 - R-38 (CZ 1,11-16)
- Duct insulation:
 - R-6 (CZ 1-10,12,13) or
 - R-8 (CZ 11, 14-16)



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Current Code Requirements

2013 Performance Approach Standard Design Assumptions

- Ducts and equipment located in unconditioned space
 - 100% in attic for single-story
 - 65% in attic/35% in conditioned space for 2 or more stories
- Supply duct surface area is 27% of Conditioned Floor Area
- 1 to 300 attic ventilation
 - Higher with whole house fan

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Current Code Requirements

2013 Performance Compliance Options

- Ducts located outside of the attic
- Roof deck insulation: above- and below-deck
- Sealed attic
- Low solar absorptivity cool roof
- Verified Low Leakage Air Handler and reduced duct leakage
- Increased duct insulation, buried ducts
- Verified duct design for reduced duct surface area
- Increased attic insulation, raised heel truss

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Current Code Requirements

– 2012 IECC for comparison

Ceiling insulation: R-38 for most of CA

Allows R-30 if insulation uncompressed at edges (i.e., raised heel truss)

Supply ducts insulation R-8 in attic

Duct sealing (Mandatory): Total leakage shall be ≤ 4 cfm25 per 100 s.f. CFA

For a 2100 s.f. home with 3.5 ton system, matches 6% duct leakage requirement in Title 24

Air handlers shall have an air leakage of $\leq 2\%$ of design air flow rate

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Typical Practice

Current CA standard practice

- Ducts and air handler in vented attic
- Insulation at the ceiling
- Measured duct leakage rate consistently less than 6%
- Duct insulation is a mix of R-4.2, R-6 and R-8
- No duct design, default area



Current High Performance Practice

DCS, Ducts in Conditioned Space homes in CA

Strategy Implemented	Builders with DCS strategies implementation experience
Dropped ceiling	Elliott Homes, De Young Properties, GJ Gardner
Conditioned plenum	Pulte Homes, K. Hovnanian Homes, GJ Gardner, Wathan Castanos, Northwest Homes
Unvented attic	Meritage Homes, RJ Walter Homes, Mission West Properties, Inc., Shea Homes, KB Homes, Brookfield Homes
Ductless systems	Brookfield Homes

Design Strategy	CA Utilities Emerging Technology Programs			National Programs	
	PG&E	SCE	SMUD	Building America	DOE Challenge Home
Dropped ceiling	●			●	●
Conditioned plenum	●	●		●	●
Open web truss				●	●
Unvented attic	●	●	●	●	●
Ductless systems	●	●			●

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High Performance Buildings in CA

Project Type	Roof/Ceiling	Ducts & Indoor Equipment	CZ	Status/Number of Homes Built
Production Bldr	conditioned plenum above ceiling plane using modified truss	Indoor mechanical closet with ducts in conditioned plenum	13	starting construction on five homes
Production Bldr	conditioned attic with R-30/38 spray foam under roof deck	ducts and equipment in conditioned attic	Various	have been building this way since 2011; 3700 built/sold in CA to date, 18,000 nationwide under construction
Production Bldr	R-38 + air barrier, conditioned plenum above ceiling plane	Indoor mechanical closet with ducts in plenum	11	
Production Bldr	conditioned plenum space	ducts in conditioned plenum, furnace in interior closet or unconditioned attic	Various	production advanced houses
Production Bldr	dropped ceiling below ceiling plane	ducts in dropped ceiling projects; considering open web floor truss	12	production advanced houses
Production Bldr	ccSPF below deck	Multi mini-splits (ductless)	10	ZNE production house
DOE Challenge Home	R-22 blown-in with netting	ducts and equipment in conditioned attic	10	construction complete
Modified existing	R-11 batt at roof deck; R-38 ceiling insulation	R-8 attic ducts; 4% duct leakage	12	construction complete
Test House	R-38 + air barrier, conditioned plenum above ceiling plane using modified truss	Indoor mechanical closet with ducts in conditioned plenum	13	complete, considering another test house
Demonstration House	conditioned attic; spray foam(R-50) insulation + air barrier at roof deck	ducts and furnace in conditioned attic	12	SMUD Home of the Future
Demonstration House	conditioned attic; insulation + air barrier at roof deck (R-38)	ducts and furnace in conditioned attic	12	SMUD Home of the Future
Demonstration House	dropped ceiling below ceiling plane; R-49 blown-in with RB in the attic	ducts and handler in dropped ceiling	13	ZNE demonstration house
Production Bldr	Typical	Multi mini-splits (ductless)	1	26 lots planned

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High Performance Buildings in the U.S.

Project Type	Roof/Ceiling	Ducts & Indoor Equipment	CZ	Status/Number of Homes Built
Production Bldr	conditioned attic with netted blown cellulose	ducts in conditioned attic	Las Vegas NV	started building this way since 2008; ~1500/yr in Vegas metro area
Production Bldr	spray foam under roof deck	ducts in conditioned attic	San Antonio TX	for all its homes since 2008
Production Bldr	vented attic with R-49 blown-in cellulose	ducts in dropped ceiling or open web truss; with interior mech closet	Northwest	4 test homes in 2008
Production Bldr	vented attic with R-49 blown-in cellulose	ducts in open web truss with interior mech closet	Northwest	300 in 2008
Production Bldr	vented attic with R-38 to R-42 blown-in cellulose	ducts in open web truss; handler in 2nd floor sealed utility closet	Seattle, WA	37 detached townhouses
Production Bldr	vented attic with R-49 blown-in cellulose	ducts in open web truss; handler in sealed utility closet in the garage	Portland, OR	20 homes
Production Bldr	R-38 open-cell spray foam under roof deck	ducts in conditioned attic; heat pump	Aztec NM	132 homes completed in AZ, NM and CO

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Methodology for Savings Analysis

Energy Modeling Assumptions

	Occupancy Type	Area (Square Feet)	Number of Stories	Relative Weight to Estimates	Other Notes
Prototype 1	Residential	2100	1	45%	Tile roof with 20% window area equally in all orientations
Prototype 2		2700	2	55%	

Component Description	Component Description	
	2100 sf , 1-story prototype	2700 sf, 2-story prototype
Ceiling height	9	9
Conditioned floor area (sf)	2100	2700
Conditioned volume (ft ³)	18,900	25,750
Gross Ceiling Area (sf)	2100	1450

Alternative	Parameter	Assumption
DCS	Verified Low Leakage Ducts in Conditioned Space	No duct conduction loss, no duct leakage to outside. 2013 Prescriptive vented attic
HPA	Insulation	Below roof deck: R-13, Ceiling R-38. vented attic
	Ducts	2013 Prescriptive ducts

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Methodology for Cost Analysis

Cost estimates from multiple sources

Industry experts for cost data and assessment of feasibility:

- Builders
- Manufacturers
- Distributors
- Contractors
- Energy Consultants/HERS inspectors
- Program implementers

Online and 'big-box' retailers

- Local costs for readily available materials
- Added labor costs and mark-up from RS Means

RS Means

- Usually most costly/conservative estimate

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Incremental Costs – HPA (vented)

Parameter	2100 sf prototype	2700 sf prototype	Notes
Insulation at Roof Deck	\$1,058	\$730	R-13 blown-in cellulose + netting
Vapor Retarder	\$97	\$67	With Class II vapor retarder, for CZ 14, 16 only
Ceiling Insulation (increasing from R30 to R38)	\$292	\$201	For CZ 2-10 only since their 2013 prescriptive levels are R30
Eliminate Radiant Barrier	-\$348	-\$240	No radiant barrier with below deck insulation
Weighted Total Cost of R-13 below deck	\$589 (CZ 1, 11-13, 15) \$670 (CZ 14, 16) \$831 (CZ 2-10)		Based on 44/55 prototype split

HPA components	\$/unit	Source
Below Deck Roof Insulation	\$0.29/s.f. roof	Online Retailers; Stakeholder Interview
Insulation Netting (blown-in)	\$0.13/s.f. roof	Online Retailers
Vapor Retarder (CZ 14, 16 with air permeable insulation)	\$0.04/s.f. roof	Online Retailers
TOTAL for Below Deck Insulation	\$0.42/s.f. (CZ 1-13,15) \$0.46/s.f. (CZ 14, 16)	



High Performance Attics (HPA)

Concept: reduce attic temperature in vented attics

Proposing a package of measures including one or more of the following:

- a. Roof deck insulation: above or below deck
- b. Increase duct insulation
- c. Lower duct leakage rate

(Potential additional measures)

- a. Raised Heel Trusses or Extension Trusses
- b. Reduce supply duct surface area

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Example HPA below deck insulation

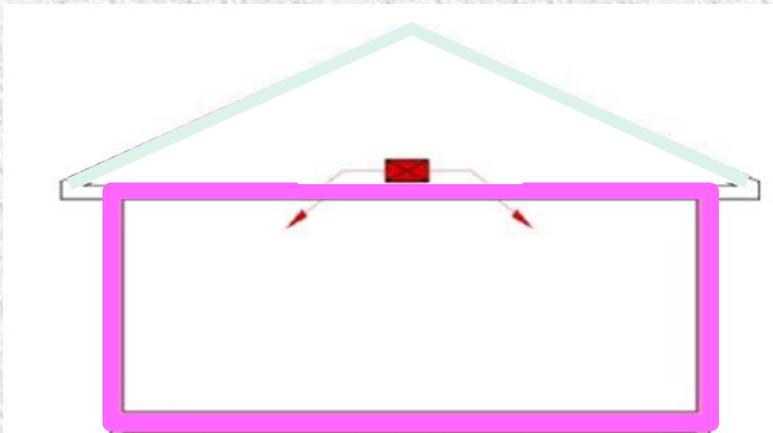


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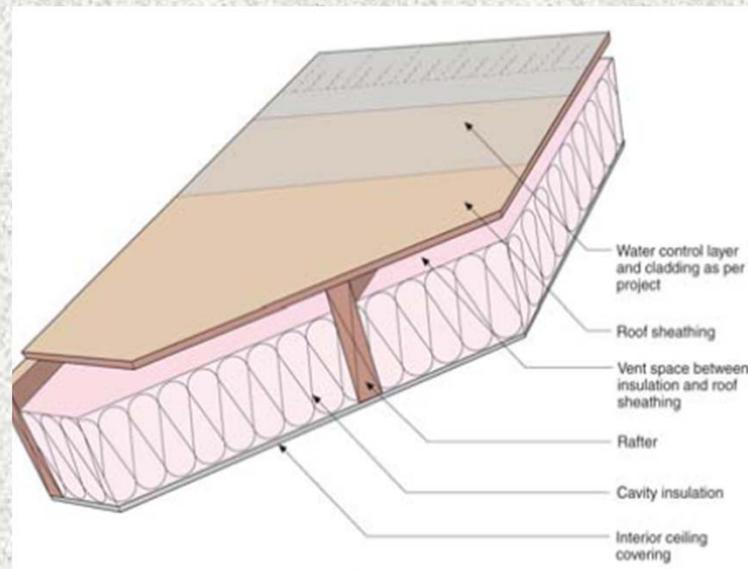


HPA – Roof Deck Insulation

Install insulation above or below roof deck



Source: www.ductsinside.org



Source: BSC 2012

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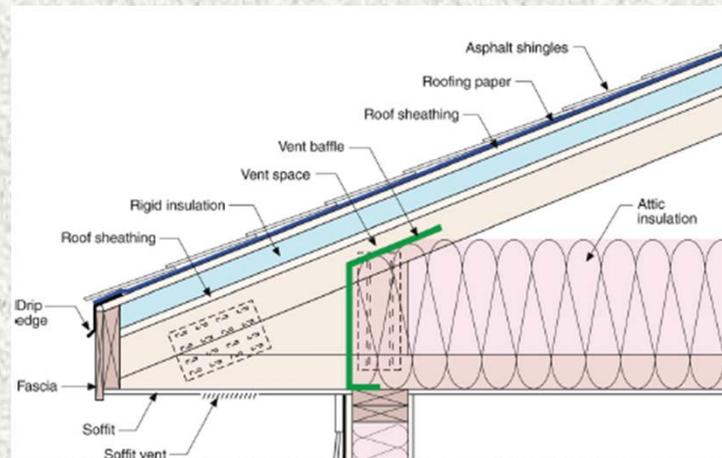
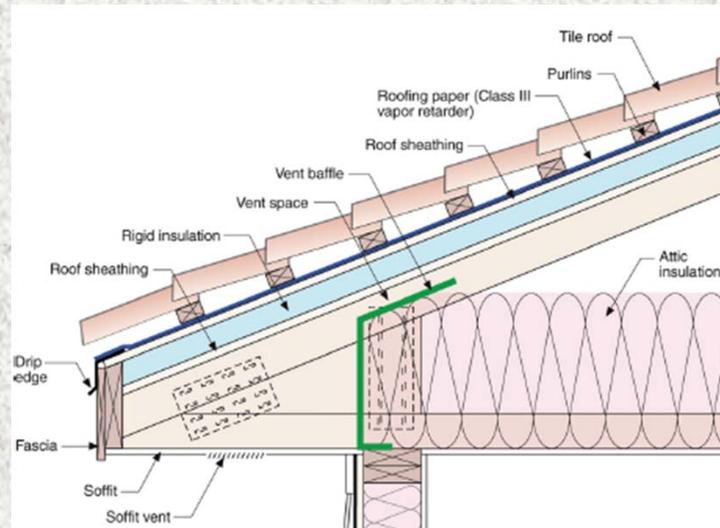
Above Deck Insulation

Product types

- Polystyrene: EPS (expanded) and XPS (extruded)
- Polyisocyanurate
- Polyurethane

Industry discussions

- Roof product fire rating
- Roof product attachment and ventilation
- Moisture management



Source: BSC 2011

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Above Deck Insulation Options



Source: CVRH - PolyFoam

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Above Deck Insulation Options



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Below Deck Insulation

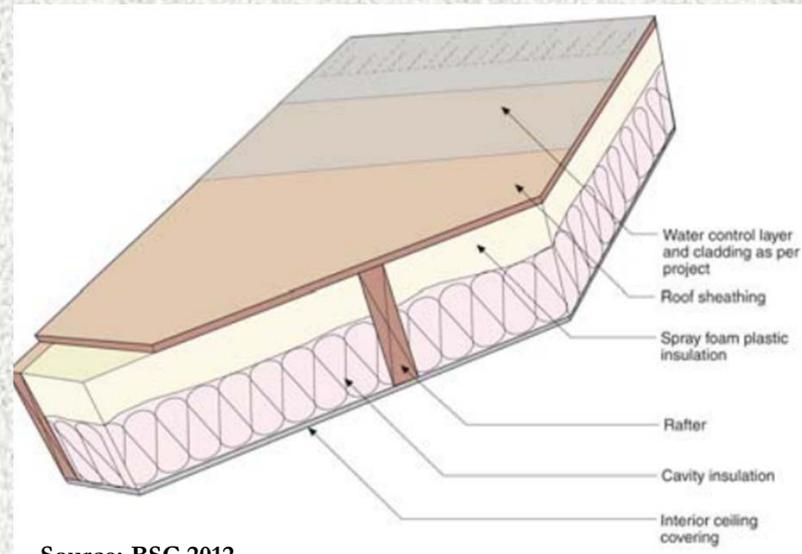
Product types

- Batt insulation
- Loose fill, blown-in
- Open cell and close cell Spray Polyurethane Foam (SPF)

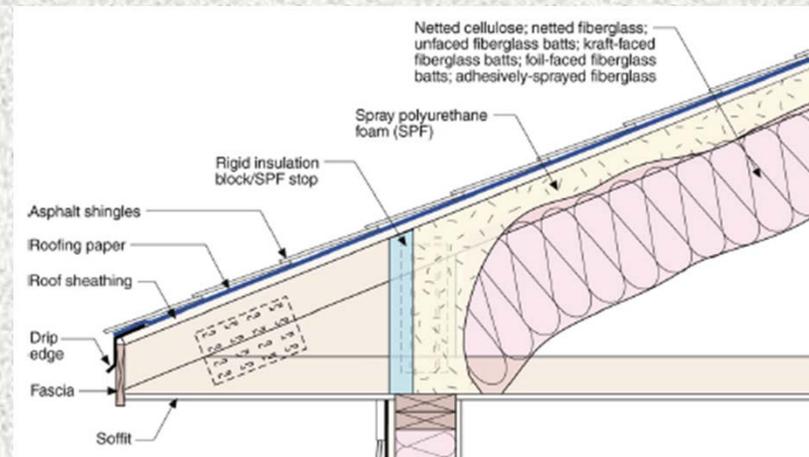
Each requires different construction technique and is at various cost points

Industry discussions

- Moisture management
- Roof product fire rating



Source: BSC 2012



Source: BSC 2011

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HPA – Increase Duct Insulation

R-8 in all CZ

Benefits

- Little change in installation practice
- minimal incremental costs, once it is more widely available

Design/Construction Impact

- Size and maneuverability of ducts

Observations and Findings

- Transition from R-4.2 to R-6 as standard practice, and increased use of R-8 is already taking place



Source: www.owenscorning.com

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HPA – Lower Duct Leakage

Lower allowed duct leakage rate to 0% - 5%

Benefits

- Potential air quality improvement

Design/Construction Impact

- Increases use of low leakage air handler
- Requires better installation practices

Observations and Findings

- Standard duct installations in CA often meet or exceed the 6% duct leakage requirement



Source: www.energyconservatory.com

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HPA Potential Measure – Raised Heel or Extension Trusses

No compression at insulation edge with raised heel or extension trusses

Benefits

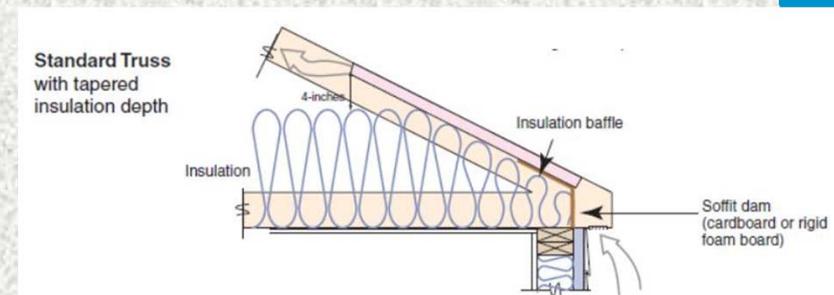
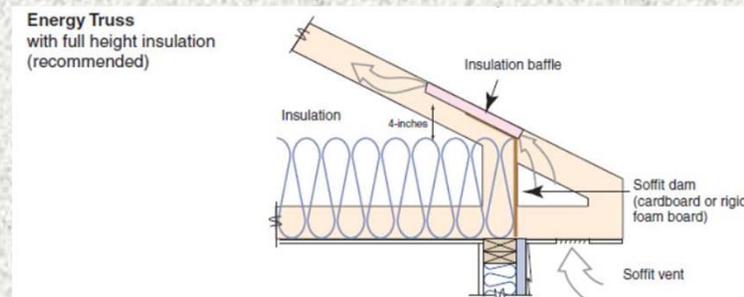
- Helps realize full benefit of insulation

Design/Construction Impact

- Low level of installation experience in California

Observations and Findings

- Other methods to achieve the same outcome include framing with a rafter on raised top plate or utilizing spray foam or rigid foam at the edge



Source: Building America Solution Center (2013)

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HPA Potential Measure – Reduce Duct Surface Area

Efficient duct layout design in unconditioned space to eliminate excess lengths of duct runs

Benefits

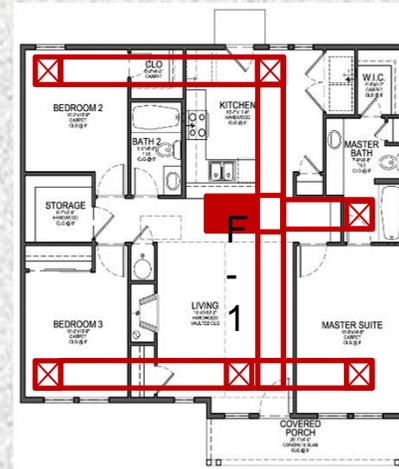
- Improved design and better air flow
- Reduced material costs

Design/Construction Impacts

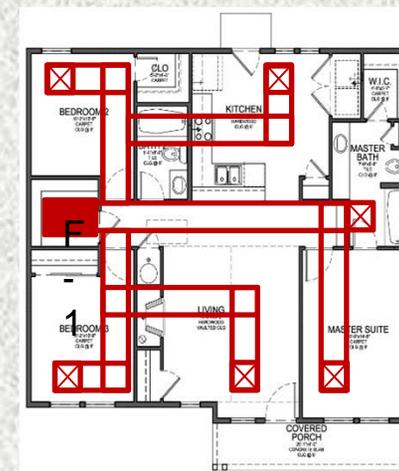
- Requires verification
- Current compliance is burdensome
- Practicality of field verification

Observations and Findings

- Some builders already utilize the compliance credit
- Ducts are not always installed as shown on plans



Improved Design
→ shorter total lengths, more streamlined layout



Standard Design

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Summary of HPA for Vented Attic

- **Reduces attic temperature**
- **Incremental changes to standard practice**
- **No change to duct and air handler location**
- **Package of measures will provide similar savings as having ducts in conditioned space**

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Incremental Costs – DCS

Dropped Ceiling Approach	2100 sf prototype	2700 sf prototype	Notes
Material costs (lumber, air barrier (OSB), drywall) + labor	\$557 (\$249 + \$308)	\$357 (\$159 + \$197)	
Sealed combustion furnace (required)	\$201	\$201	Average among varying capacities; condensing furnaces represent higher end of costs.
Interior Mechanical Closet	\$216	\$216	location of closet in garage corner
HERS Test for Verification of Duct Leakage to Outside	\$125	\$125	
Total Costs	\$1099	\$899	With standard duct design
Weighted Total Cost	\$990		Based on 44/55 prototype split

Parameter	Assumption	Source	Notes
Material costs (lumber, air barrier (OSB), drywall) + labor	\$1.18 - \$2.65/s.f. dropped ceiling	Online retail; RS Means labor	Includes labor
Sealed Combustion Equipment	\$210 - \$360/furnace	Online Retailer	Incremental cost depends on condensing capabilities and equipment capacity.
Mechanical Closet	\$3.80/s.f. closet walls	Online retailer	Located in garage, consists of 2 newly constructed walls adjacent to conditioned space. Includes framing, insulation and drywall/OSB finishing
HERS Test for Verification of Duct Leakage to Outside	\$125	Calls with HERS Raters	Standards already require HERS test for duct leakage. The added cost here is to conduct a blower door at the same time to estimate leakage to outside from ducts.

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Energy Savings Results

Based on HPA package with R-13 Below Roof Deck + R-38 at Ceiling

Climate Zone	First Year Savings/Home		Per Unit First Year TDV Savings
	Electricity Savings (kWh/yr)	Natural Gas Savings (Therms/yr)	TDV Electricity and Gas Savings (kBTU)
1	54.5	63.4	12,338
2	40.1	40.1	8,752
3	--	--	5,102
4	56.2	34.6	9,211
5	--	--	3,985
6	--	--	4,000
7	--	--	1,171
8	66.8	8.6	6,500
9	145.4	13.7	14,021
10	189.9	16.1	14,589
11	364.3	35.0	26,916
12	131.9	47.2	18,148
13	447.1	36.5	31,405
14	359.2	36.5	25,697
15	970.8	2.4	41,586
16	120.3	91.5	21,416

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Ducts in Conditioned Space

Concept: moving ducts and air handler to conditioned space

Ducts in Conditioned Space (DCS)

Vented Attics

- dropped ceiling, including soffits
- conditioned plenum space
- open-web floor truss

Conditioned/Unvented Attic

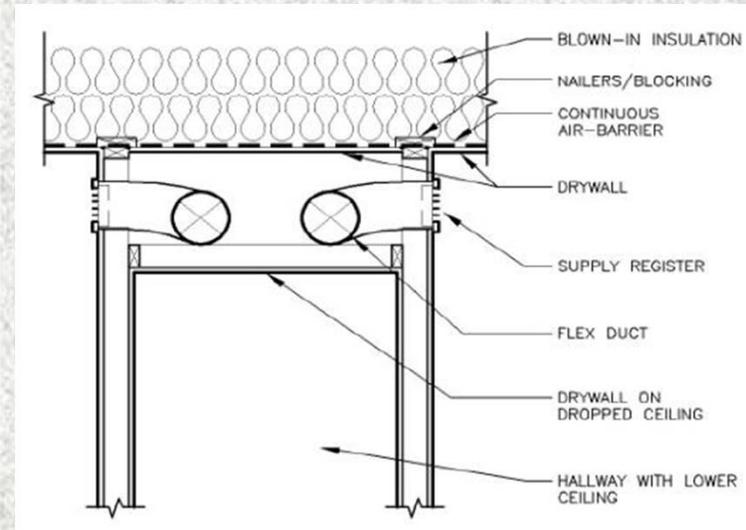
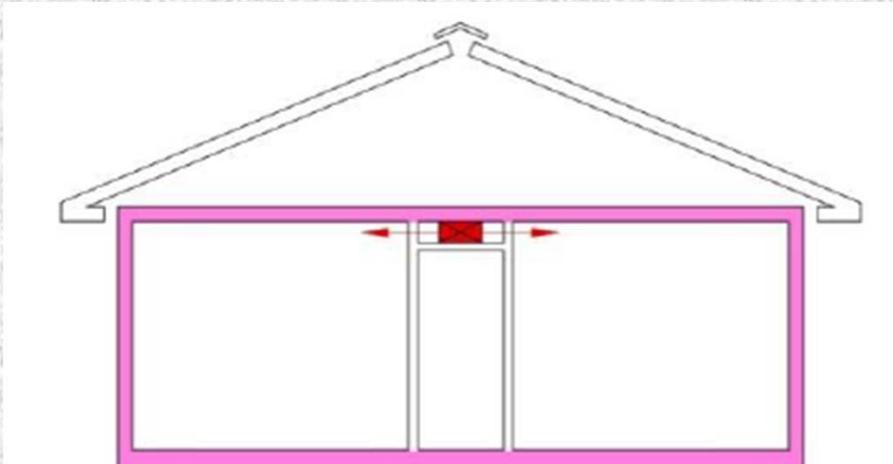
Ductless Systems

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DCS Vented Attics – Dropped Ceiling

Conditioned space for ducts below the ceiling plane



Source: www.ductsinside.org

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Example: DCS – Dropped Ceiling



Source: BIRA Energy, 2014

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Alternative: Ductless Systems

System types

- Mini-splits
- Hydronic
- Packaged terminal heat pump

Benefits

- Elimination of duct losses
- Higher system efficiency
- No need for DCS or HPA measures

Observations and Findings

- Limited design, installation and maintenance experience in CA
- Commission working with industry to develop modelling and installation verification procedures



Source: Manufacturer website Daikin



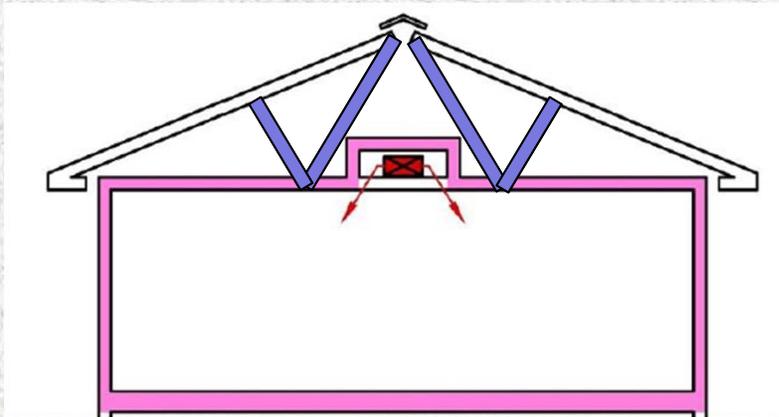
Source: BPA Ductless Mini-split HP webpage

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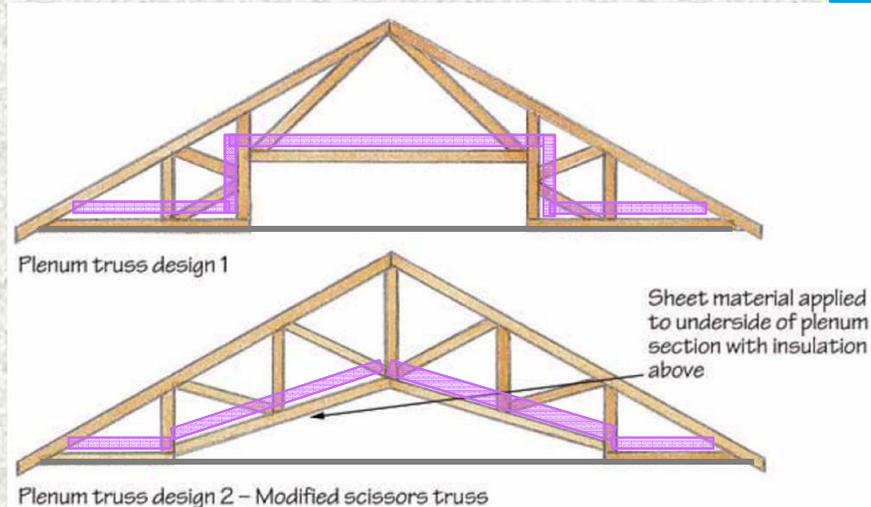


DCS Vented Attics – Conditioned Plenum Space

*conditioned space for ducts and equipment above the ceiling plane
(use of plenum truss is one option)*



Source: www.ductsinside.org



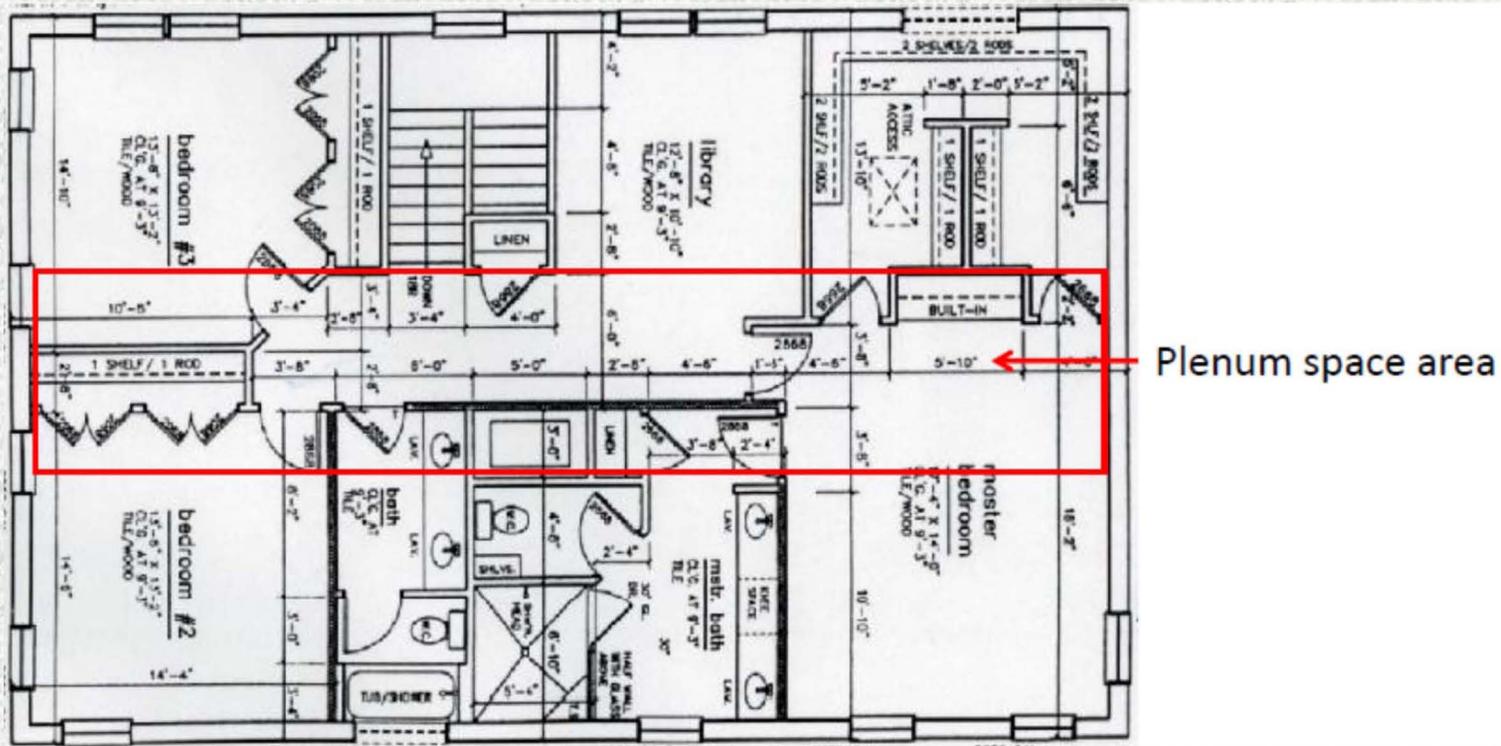
Source: CEC Report “Costs & Savings For Houses Built With Ducts in Conditioned Space” 2003

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Example: DCS Vented Attics – Conditioned Plenum Space

Source: Steven Winter Associates, Inc. 2014

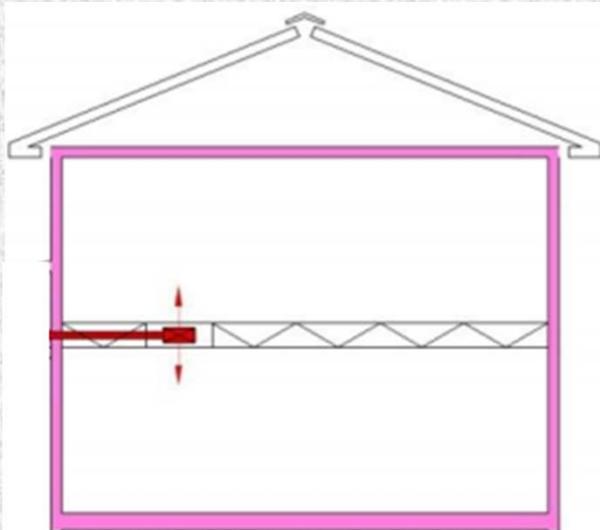


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DCS Vented Attics – Open-Web Floor Trusses

conditioned space for ducts in vertical space create by floor trusses



Sources: www.ductsinside.org



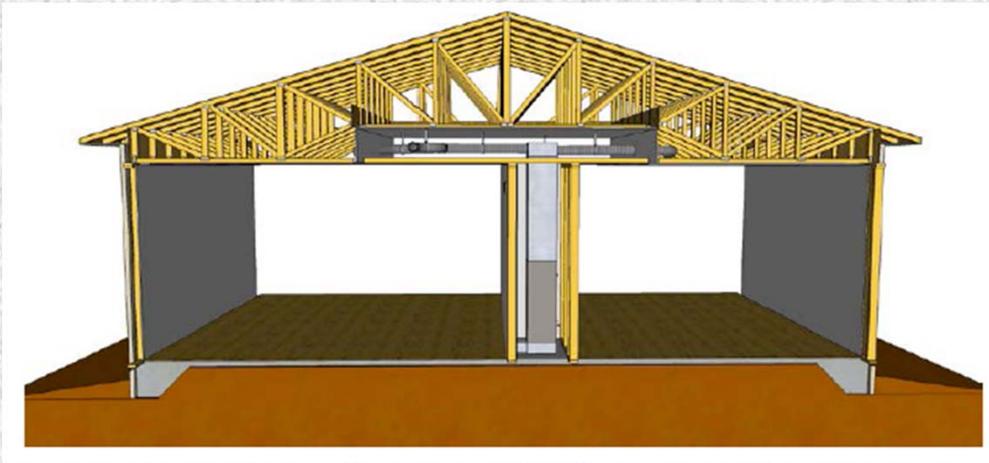
Source: Steven Winter Associates, Inc. 2014

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Ducts in Conditioned Space Air Handler in Mechanical Closet

Use mechanical closet within the thermal boundary for AHU & equipment; Select sealed combustion furnace with combustion air ducted directly into the furnace



Source: IBACOS, Inc. 2013



Source: David Hales, WSU

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Summary - DCS Vented Attics

Benefits

- Incremental changes to standard practice vented attics
- Multiple buildable options
- Moving ducts out of hot attics
- Potential to downsize equipment

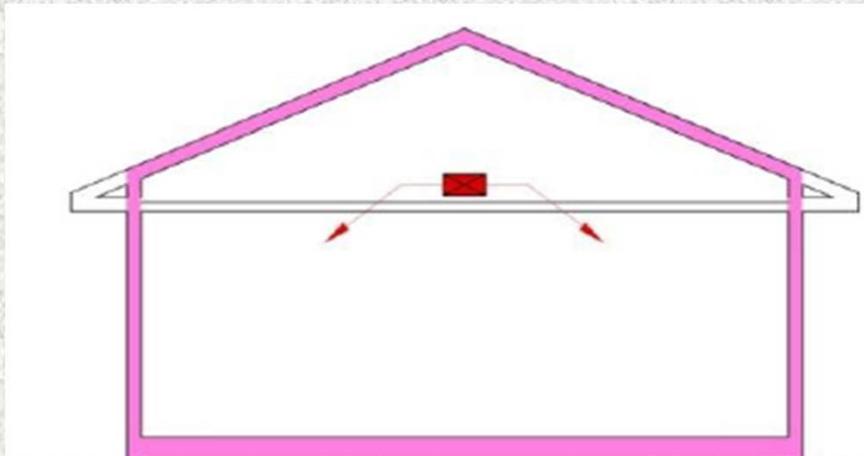
Design/Construction Impact

- Need to seal the soffit/plenum/floor truss perimeters
- May need mechanical closet for air handlers

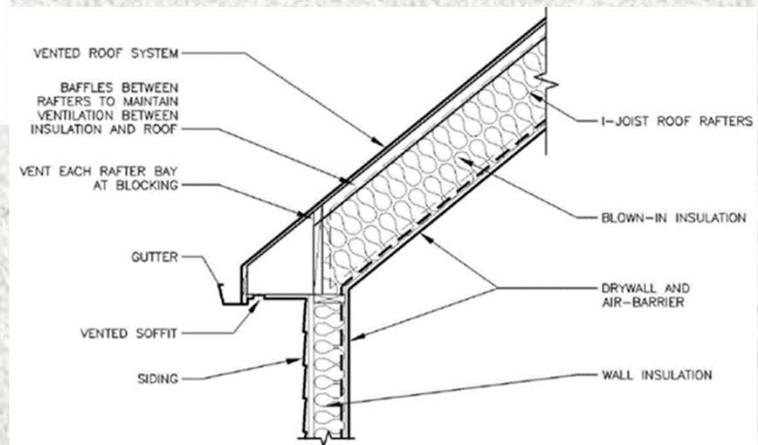
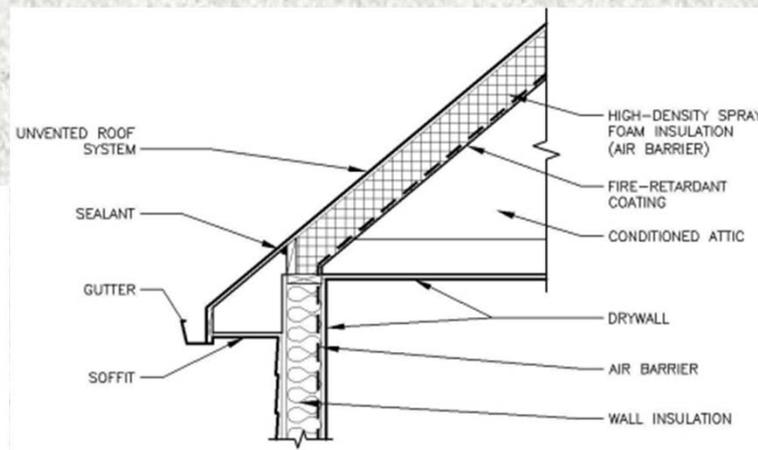


DCS – Conditioned/Unvented Attic

Use above- or below-deck insulation as a primary insulation



Source: www.ductsinside.org



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DCS Conditioned/Unvented Attics

Benefits

- Lowering attic temperature
- Potential to downsize equipment
- No need to seal ceiling plane (can lighting, sprinklers)

Design/Construction Impact

- Need to address moisture management (similar to HPA options)
- Need to seal attic-to-deck junction
- Use of sealed combustion equipment
- Increases insulated envelope area
- Can't install normal whole house fan

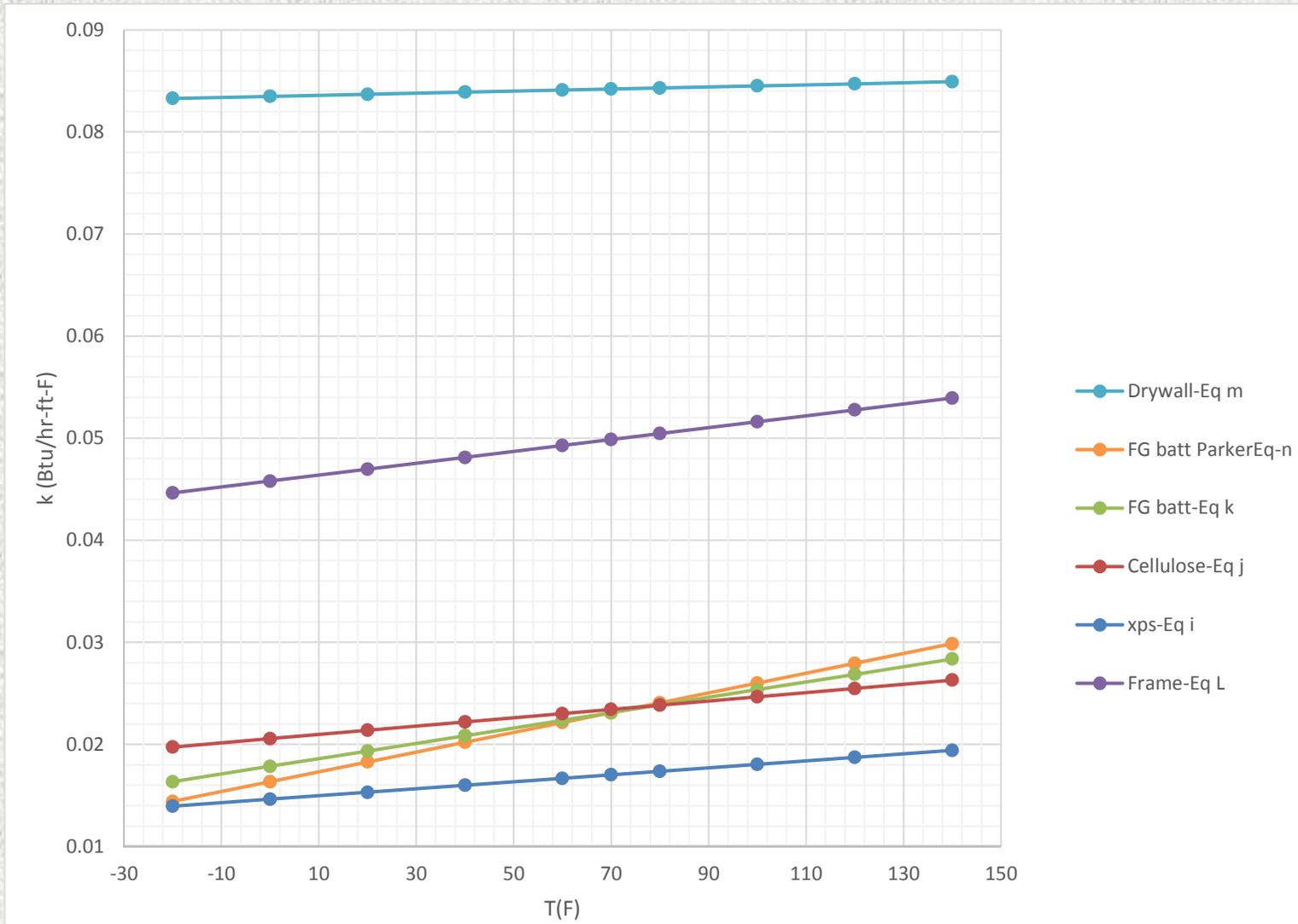
Observations and findings

- Done correctly attic temperature within a few degrees of directly conditioned space
- No documented moisture issues in California

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Impact of Temperature on Conductivity



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Cost-Effectiveness Results

Based on HPA package with R-13 Below Roof Deck + R-38 at Ceiling

Climate Zone	Benefit: TDV Energy Cost Savings + Other Cost Savings (2013 PV\$)	Cost: Total Incremental Cost (2013 PV\$)	Change in Lifecycle Cost (2013 PV\$)	Benefit to Cost Ratio
1	\$1,129	\$ 589	\$ (540)	1.9
2	\$1,011	\$ 831	\$ (180)	1.2
3	\$478	\$ 831	\$ 353	0.6
4	\$1,063	\$ 831	\$ (232)	1.3
5	\$421	\$ 831	\$ 410	0.5
6	\$518	\$ 831	\$ 314	0.6
7	\$198	\$ 831	\$ 633	0.2
8	\$1,295	\$ 831	\$ (464)	1.6
9	\$2,174	\$ 831	\$ (1,343)	2.6
10	\$2,023	\$ 831	\$ (1,192)	2.4
11	\$2,956	\$ 589	\$ (2,367)	5.0
12	\$2,290	\$ 589	\$ (1,701)	3.9
13	\$3,503	\$ 589	\$ (2,914)	5.9
14	\$2,497	\$ 670	\$ (1,828)	3.7
15	\$4,600	\$ 589	\$ (4,011)	7.8
16	\$2,270	\$ 670	\$ (1,601)	3.4

Note: A negative change in LCC means measure is cost effective

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Alternative Compliance Options

Alternative Compliance Options Savings Compared to 2013 TDV

Case 1	Proposed Prescriptive HPA - R13 Below Deck + No RB
Case 2	Vented Attic - R6 Above Deck
Case 3	Sealed Attic - Insulation below deck + No RB + No WHF + Ducts in attic

Climate	Case 1	Case 2	Case 3
01	6%	5%	10%
02	7%	7%	7%
04	8%	8%	8%
08	13%	13%	0%
09	14%	14%	6%
10	12%	13%	6%
11	10%	10%	10%
12	12%	12%	7%
13	12%	12%	12%
14	9%	9%	10%
15	11%	10%	13%
16	8%	7%	11%
Average	10%	9%	9%

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Questions?

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Comments by Email

The Energy Commission encourages comments by email.

- Comments should be in a downloadable, searchable format such as Microsoft Word or Adobe Acrobat
- Include your name and any organization name
- Include the docket number 14-BSTD-01 and indicate *2016 Building Standards Update* in the subject line

Send comments to:
docket@energy.ca.gov

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