

# Design Options for Locating Ducts within Conditioned Space

U.S. DEPARTMENT OF  
**ENERGY** | Energy Efficiency &  
Renewable Energy



## DOE Challenge Home Technical Training

Bill Zoeller, RA  
Steven Winter Associates

## By designing, constructing, and verifying DOE Challenge Homes, you are:

- **in a select group**

Only the top one percent of builders in the country meets the extraordinary energy efficiency, comfort, health, safety, durability and quality levels associated with the DOE Challenge Home.

- **providing unprecedented value**

Your customers receive immediate energy savings of 40-50% easy to adapt to net-zero performance with a small renewable energy system.

- **differentiated from the competition**

About 12 in 13 homes sales nationwide are 'used' homes. In addition, the majority of new homes are constructed to minimum code. Based on a foundation of comprehensive home performance, including ENERGY STAR Qualified Home v.3 and the latest proven innovations from DOE Building America, DOE Challenge Home provides a path to constructing net-zero energy ready that none of your competition has.

# Training Purpose

For a home to qualify with DOE Challenge Home, ducts must be located within the home's thermal and air barrier boundary.

DOE Challenge Home recognizes several alternate compliance approaches, including locating ducts within insulated unvented attics, use of plenum truss systems, and encapsulating ducts with spray foam and burying them in insulation. Done right, these alternative approaches can be cost-effective to build and provide highly efficient distribution systems - - but getting them right means understanding the details.

This training will cover several possible approaches to locating ducts within the home's air and thermal barriers, and then dig into design considerations and details for the spray foam encapsulation approach.

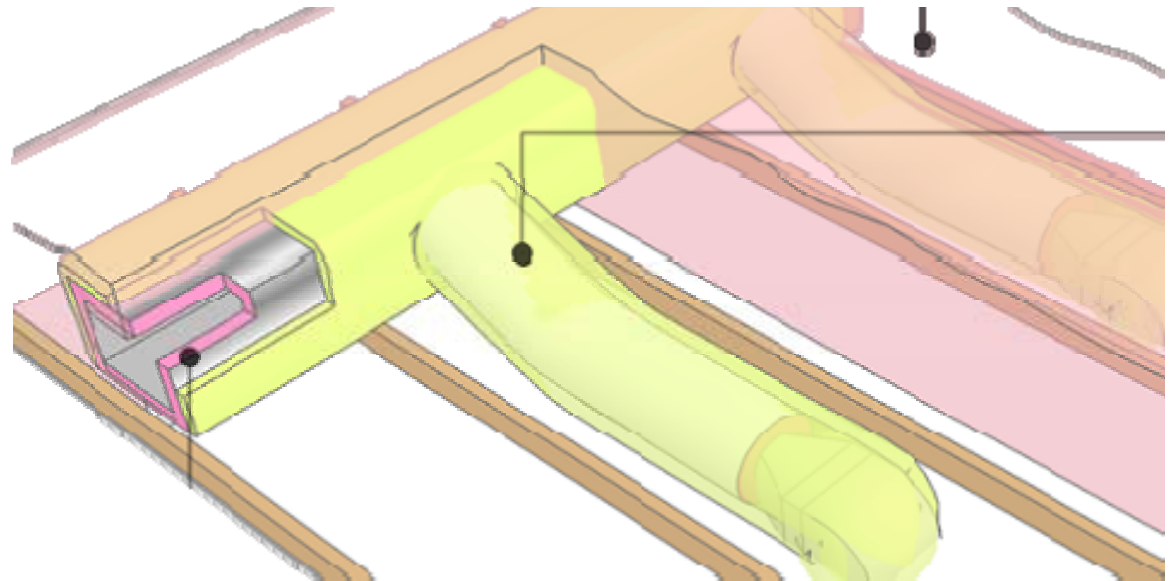
Trainees, including builders, raters, and contractors, will learn:

1. DOE Challenge Home requirements for duct system location.
2. Strategies for locating ducts within conditioned space in new residential construction.
3. Key design and installation details for encapsulating ducts within spray foam and then burying them with attic insulation.

## Design Options for Locating Ducts within Conditioned Space



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# Mandatory Requirements



**Exhibit 1: DOE Challenge Home Mandatory Requirements for All Labeled Homes**

Area of Improvement	Mandatory Requirements
<b>1. ENERGY STAR for Homes Baseline</b>	<input type="checkbox"/> Certified under ENERGY STAR Qualified Homes Version 3 <sup>5</sup>
<b>2. Envelope<sup>6</sup></b>	<input type="checkbox"/> Fenestration shall meet or exceed latest ENERGY STAR requirements <sup>7, 8</sup> <input type="checkbox"/> Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels <sup>9</sup>
<b>3. Duct System</b>	<input type="checkbox"/> Ducts located within the home's thermal and air barrier boundary <sup>10</sup>
<b>4. Water Efficiency</b>	<input type="checkbox"/> Hot water delivery systems shall meet efficient design requirements <sup>11</sup>
<b>5. Lighting &amp; Appliances<sup>12</sup></b>	<input type="checkbox"/> All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. <input type="checkbox"/> 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets <input type="checkbox"/> All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified
<b>6. Indoor Air Quality</b>	<input type="checkbox"/> EPA Indoor airPLUS Verification Checklist and Construction Specifications <sup>13</sup>
<b>7. Renewable Ready<sup>14</sup></b>	<input type="checkbox"/> EPA Renewable Energy Ready Home Solar Electric Checklist and Specifications <sup>15</sup> <input type="checkbox"/> EPA Renewable Energy Ready Home Solar Thermal Checklist and Specifications <sup>16</sup>

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# Mandatory Requirements



- Up to 10' of total duct length is permitted to be outside of the home's thermal and air barrier boundary.
- Ducts are located in an unvented attic, regardless of whether this space is conditioned with a supply register
- **Ducts are located in a vented attic with all of the following characteristics: minimum R-8 duct insulation with an additional minimum 1.5" of closed-cell spray foam insulation encapsulating the ducts; total duct leakage  $\leq$  3 CFM25 per 100 ft<sup>2</sup> of conditioned floor area; and ductwork buried under at least 2" of blown-in insulation**

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# Mandatory Requirements

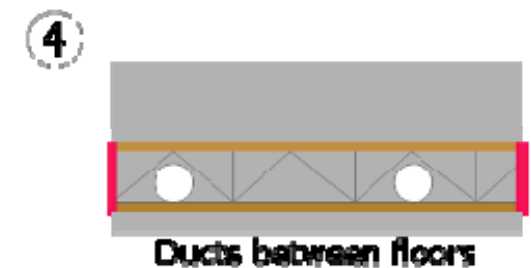
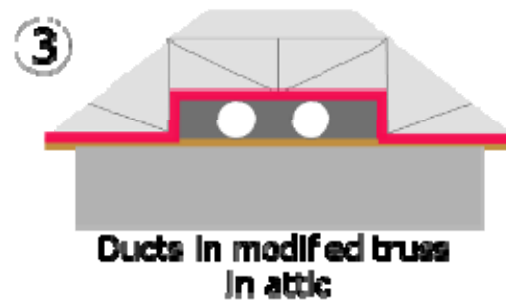
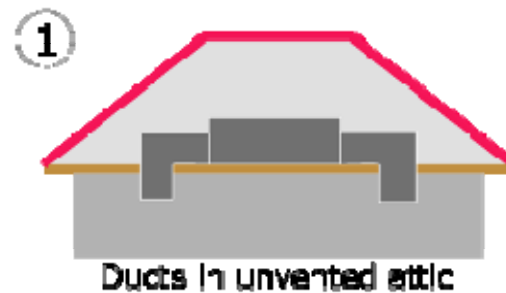


- Jump ducts which do not directly deliver conditioned air from the HVAC unit may be located in attics if all joints, including boot-to-drywall, are fully air sealed with mastic
- Ducts are located within an unvented crawl space
- Ducts are located in a basement which is within the home's thermal boundary
- Ductless HVAC system is used

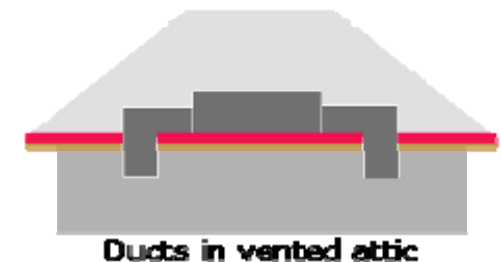
# Current Options



- Ductwork thermal losses can range from 10-45%
- Multiple Interior duct options exist, but may be impractical, expensive, not work well in all climates, or increase envelope loads



— Insulation





# Ducts in Unvented Attic



- HVAC design flexibility
- Minimal design integration
- Usually more expensive
- May increase enclosure loads

IRC Sections R806.4 Unvented Attic Assemblies,  
and R316 FOAM PLASTIC control these assemblies

# Ducts in Dropped Soffit



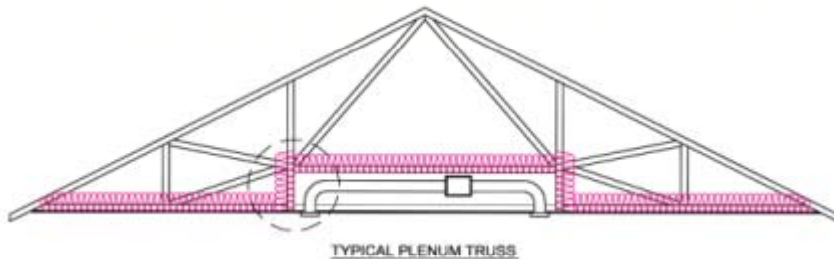
- Requires high-level of architectural integration
- Low-cost in simple plans
- Longer “throws” may be required based on plan.

# Floor Truss Integrated Ducts



- Offers simple installation and design flexibility
- Very cost-effective
- Conducive to floor registers which don't work well for cooling
- High wall registers increase performance, cost, and complexity

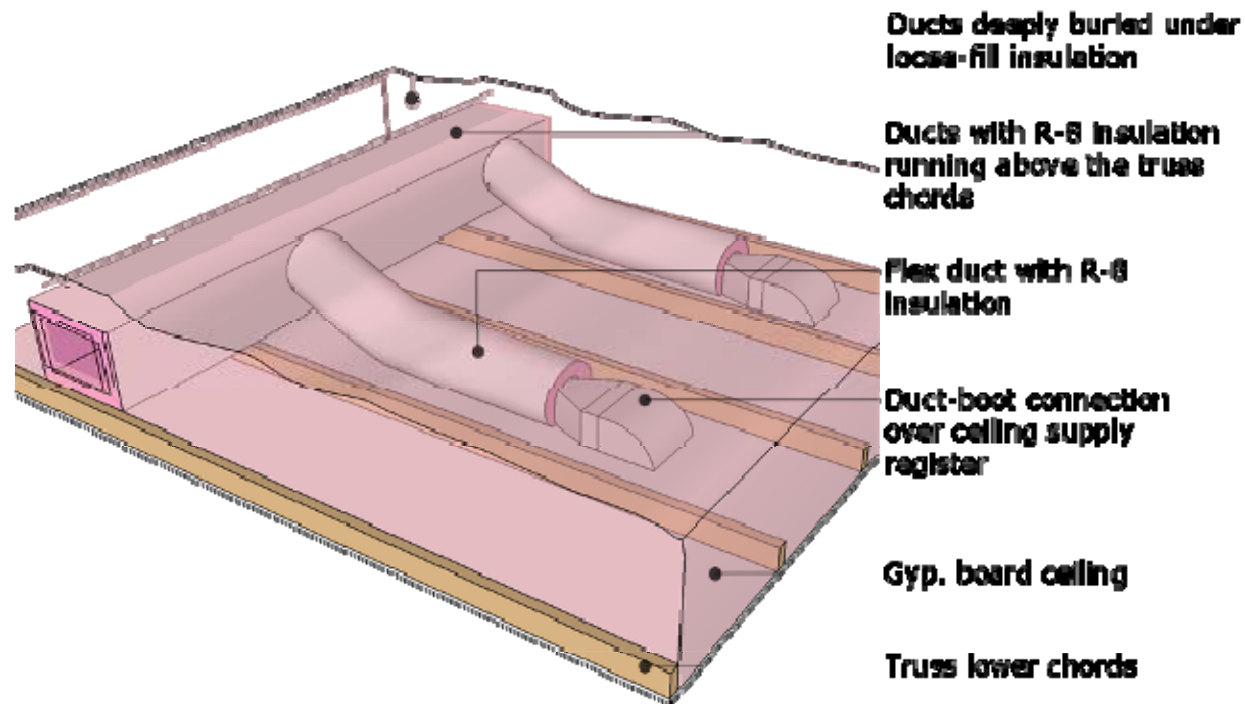
# Ducts in Modified Truss



- Works well in narrow plans
- Moderate cost-increase
- Sealing the air-barrier is critical
- design integration required



# What Are Buried Ducts?



- Low cost, high-performance duct strategy
- Very high R-values



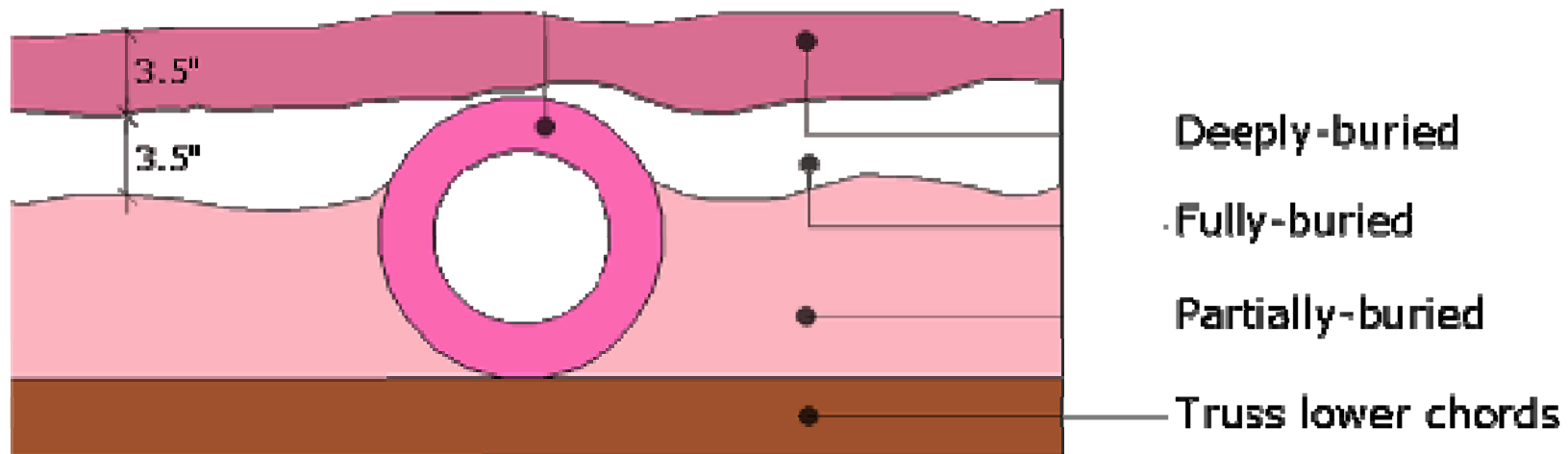
# Buried/Encapsulated Duct Categories



- Buried Ducts
- Buried and Encapsulated Ducts
- Encapsulated Ducts

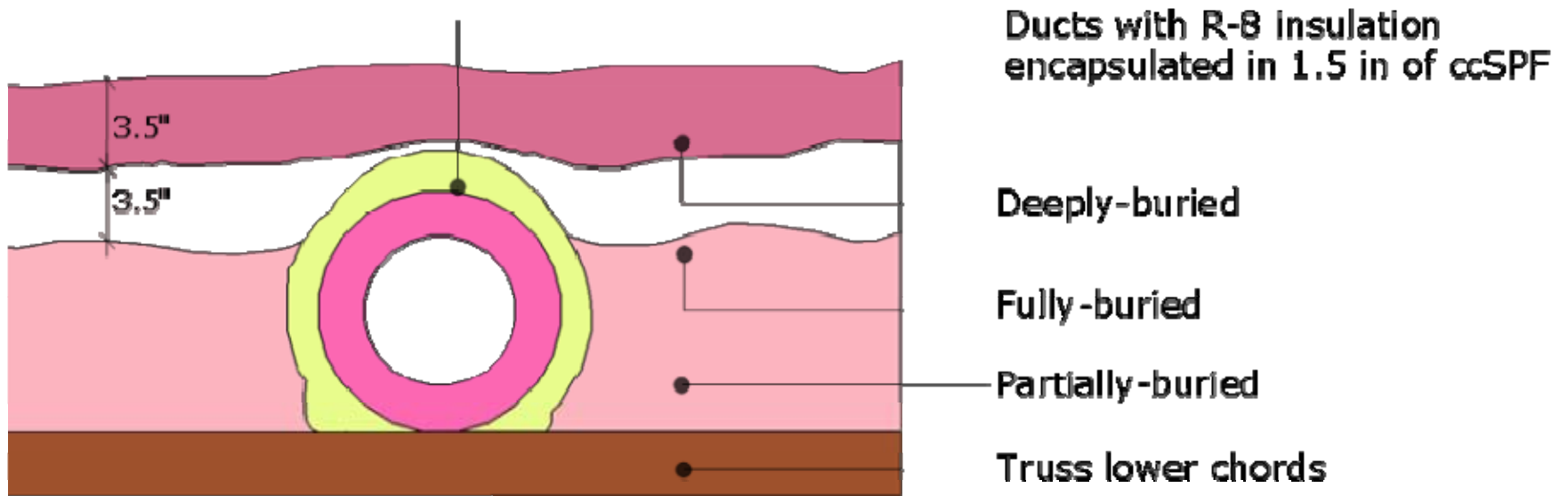


# Buried Duct Classification



## Buried Duct Schematic (Dry Climate Only)

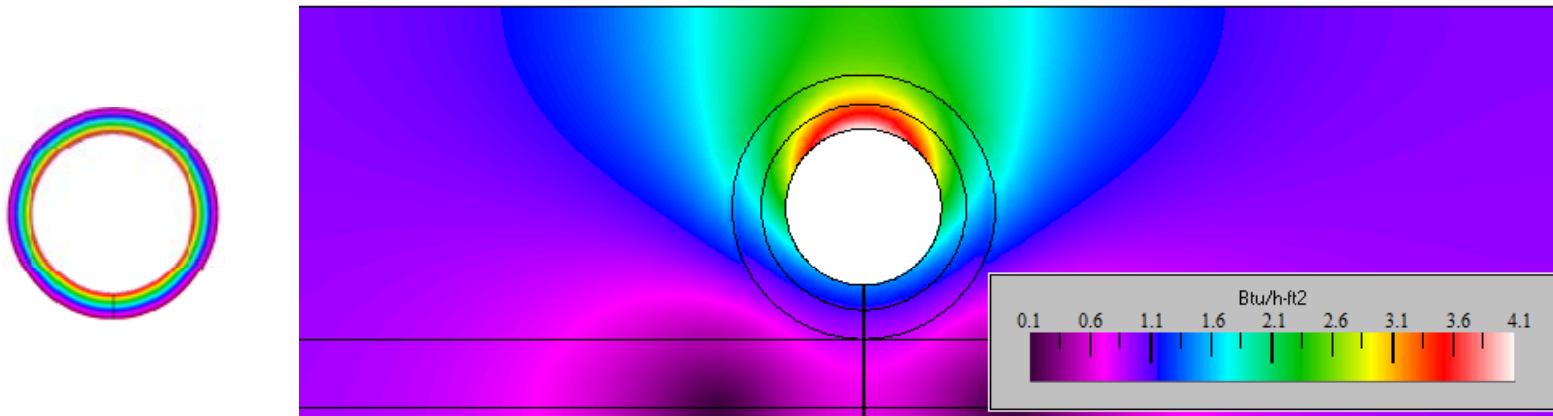
# Buried Duct Classification



## Buried & Encapsulated Duct Schematic (All Climates)

# Effective R-values

- R-value metrics:
  - ▣ Nominal – listed values for duct insulation
  - ▣ Effective – heat loss/gain from duct to attic
- Buried duct effective R-values calculated using FEA



Heat flux magnitude through a hung duct, and an encapsulated and fully-buried 8-in diameter duct

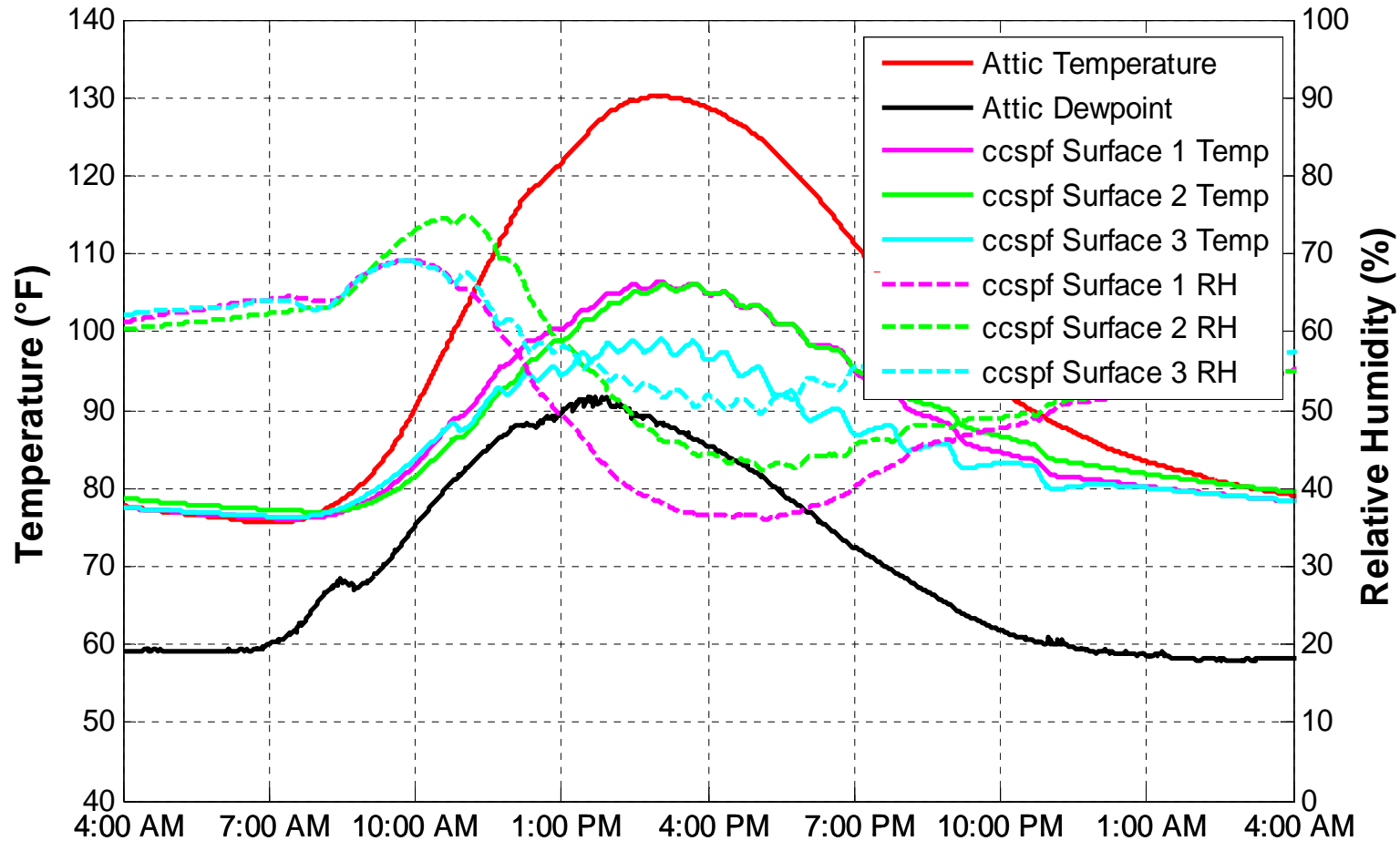
# Effective R-values



Duct Configuration	R-4.2 Ducts	R-6 Ducts	R-8 Ducts
Traditional hung ducts	4.6	5.9	7.2
Hung ducts encapsulated in 1.5" of ccSPF	11.3	12.0	12.7
Partially-buried	8.1	10.2	12.3
Fully-buried	12.0	14.1	16.2
Deeply-buried	20.7	22.1	23.5
Encapsulated in 1.5" of ccSPF and partially-buried	18.4	19.7	21.0
Encapsulated in 1.5" of ccSPF and fully-buried	22.6	23.8	25.0
Encapsulated in 1.5" of ccSPF and deeply-buried	29.6	30.3	31.1



# Condensation Potential



# Performance Comparison

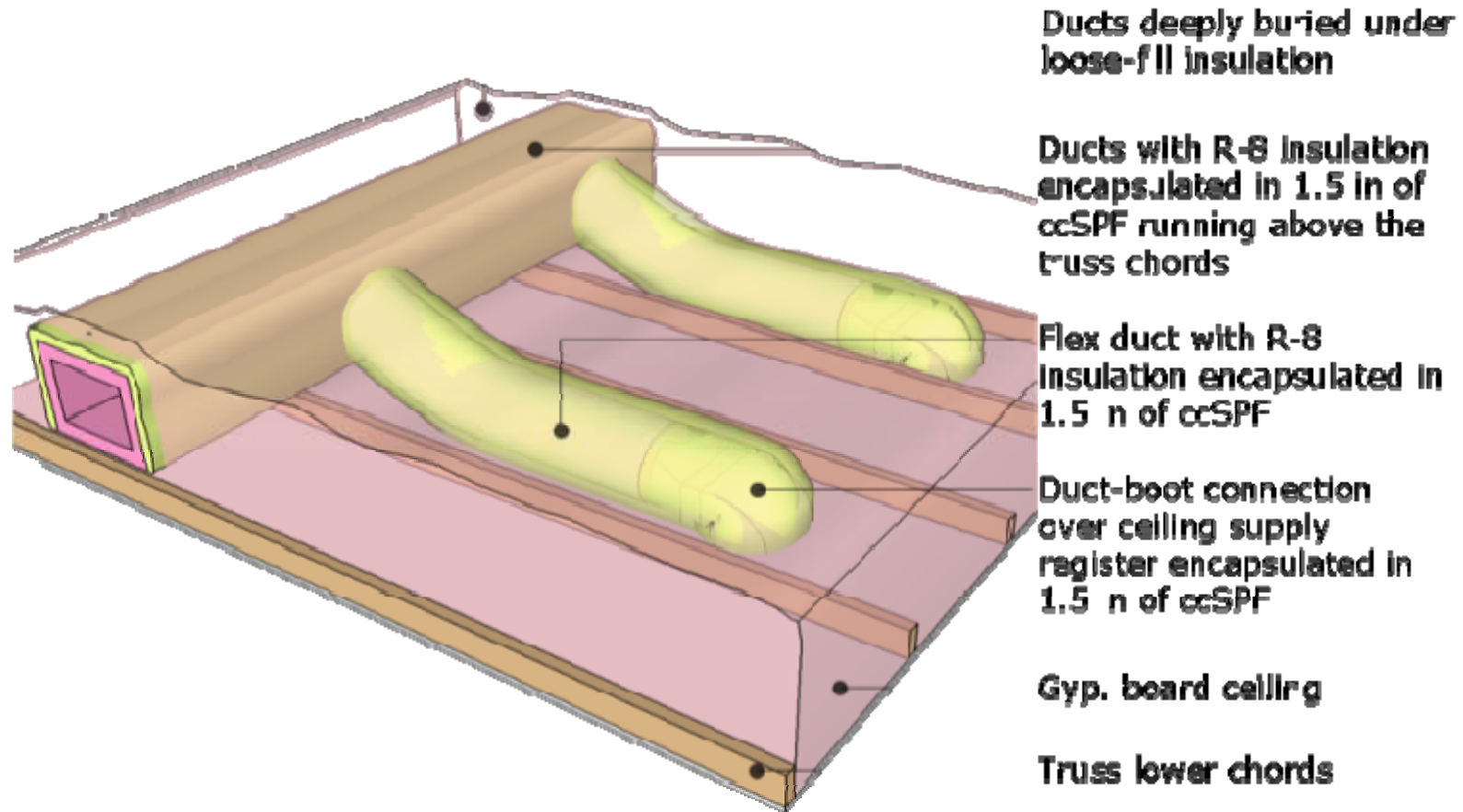


	Roof slope			
	4:12	6:12	8:12	10:12
<b>Benchmark<sup>1</sup></b>	0.0%	0.0%	0.0%	0.0%
<b>Improved benchmark<sup>1,2</sup></b>	9.2%	9.2%	9.2%	9.2%
<b>Partially-buried (R-33)</b>	10.4%	10.4%	10.4%	10.5%
<b>Fully-buried (R-42)</b>	11.6%	11.7%	11.7%	11.7%
<b>Deeply-buried (R-51)</b>	13.2%	13.4%	13.4%	13.4%
<b>Unvented<sup>1</sup></b>	13.7%	13.3%	12.7%	12.2%
<b>Encapsulated<sup>1</sup></b>	11.9%	11.9%	12.0%	12.0%
<b>Partially-buried &amp; encapsulated (R-37)</b>	12.9%	13.0%	13.0%	13.0%
<b>Fully-buried &amp; encapsulated (R-46)</b>	14.2%	14.3%	14.4%	14.4%
<b>Deeply-buried &amp; encapsulated (R-54)</b>	15.3%	15.5%	15.5%	15.6%
<b>Interior ducts<sup>1</sup></b>	15.4%	15.5%	15.5%	15.5%

<sup>1</sup> Benchmark ceiling or roof deck insulation is R-38 in Zone 5B. Ceiling insulation R-values for buried ducts may be higher than the benchmark.

<sup>2</sup> Improved Benchmark includes IECC 2012 requirements for infiltration (3 ACH50) and duct sealing (4 cfm per 100 sq ft conditioned living space).

# BEDs Implementation



# Install Low-Profile, Compact Duct Design



■ Before ceiling drywall



■ After ceiling drywall

# Mastic seal ducts, and test



- **Test total duct leakage** to assure performance levels are met (total leakage  $\leq 3$  cfm25 per 100 ft<sup>2</sup> of conditioned space)



# Apply 1.5" minimum ccSPF



- ccSPF applied prior to ceiling gypsum board

# Apply 1.5" minimum ccSPF



- ccSPF applied after ceiling gypsum board

# Install Loose-fill insulation



- Insulation must be ASTM classified as “mineral-fiber”, and must cover the ccSPF by a minimum of 1.5” (cellulose doesn’t qualify)
- Some foams are exempt from this requirement (more in a moment)

# Code Compliance



- 2009 IRC requires that spray foam insulation applied to the exterior of ductwork (Section M1601.3) in attics (Section R316.5.3) meet several requirements
  - Flame spread index less than 25
  - Smoke-developed index less than 450
  - No attic storage or occupancy
  - Spray foam protected by ignition barrier (1.5” mineral fiber)
    - ▣ Or meets R316.6 (no ignition barrier required)



# Builder Resources

- Code-related considerations:
  - ▣ IRC Sections R807.1, M1601.3, R316.5.3, R316.6
  - ▣ DOE Challenge Home
  - ▣ Title 24 of California Code of Regulations
- Technical References:
  - ▣ Multiple research reports since 2000
  - ▣ Upcoming BA Technical Report
  - ▣ Upcoming BA Measure Guideline

[www.buildingamerica.gov](http://www.buildingamerica.gov)



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1. Join DOE Challenge Home:
  - [www.buildings.energy.gov/challenge](http://www.buildings.energy.gov/challenge)
2. Release of Updated Rating Software – NOV 2012
3. DOE Challenge Home Awards program
4. DOE Challenge Home trainings
  - Additional Technical Trainings
  - Multiple RESNET Conference Sessions
  - Net-Zero Ready Home Trainings with Partners (various markets)

# Thank You

Questions?



**For More Information:**

[www.buildings.energy.gov/challenge](http://www.buildings.energy.gov/challenge)

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