Building Science
Require A Better Workforce

SAM RASHKIN
Chief Architect
Building Technologies Office
Why Building Science Education

**Supply System:**
Workforce Competent in Building Science

**Product on Shelf:**
Better Buildings
  > Comfort
  > Health
  > Safety
  > Durability

**Market Demand:**
Consumers and Transaction Process That Value Better Buildings

**Building Science Big Prize:**
- $100’s B Savings
- Millions MMTCe
- 100,000’s of Jobs
- National Security
Planning a Supply System

Building America Building Science Education Summit

[Image of cover page of a report titled "Building America Building Science Education Roadmap"]
DOE Building Science Ed. Program

Framework for Consistent Competency

Full Integration with Degree Programs

Value Understood in the Market

DOE Guidelines for Building Science Education

DOE ‘Race to Zero’ Student Design Competition

Building Science Translator
## Workforce Classifications

<table>
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<td>Insurers</td>
<td>Civil/Struc.</td>
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<td>Landscape</td>
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<td>Const. Man</td>
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<td>1</td>
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<td>2</td>
<td>Building Science Principles</td>
<td>3</td>
<td>Operations &amp; Maintenance</td>
<td>4</td>
<td>Building Testing</td>
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<tr>
<td>1.1 Performance</td>
<td>2.1 Heat Transfer</td>
<td>3.1 User Interface/Cont.</td>
<td>4.1 Commissioning</td>
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<td>1.2 Life-Cycle Cost Eff.</td>
<td>2.2 Material Selection</td>
<td>3.2 Preventative Maint.</td>
<td>4.2 Diag. &amp; Forensics</td>
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<td>1.3 Disaster Resistance</td>
<td>2.3 Moisture Transport</td>
<td>3.3 Replacement/Renov.</td>
<td>4.3 Perf. Mon./Assess.</td>
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<td>1.4 Int. Design &amp; Const.</td>
<td>2.4 Control Layers</td>
<td>4.4 Ntl. Codes &amp; Stds</td>
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<tr>
<td>1.5 Quality Management</td>
<td>2.5 Convective Transprt.</td>
<td>4.5 Cert. Programs</td>
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<td>1.6 Bldg/Energy Model’g</td>
<td>2.6 Hygrothermal Anal.</td>
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<td>1.7 Cost Trade-Off Anal.</td>
<td>2.7 HVAC Systems</td>
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<td></td>
<td>2.8 HVAC Inter. w/Struc.</td>
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<td>2.9 Fenestration</td>
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<td></td>
<td>2.10 Plumbing Systems</td>
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<td></td>
<td>2.11 Electrical Systems</td>
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<td></td>
<td>2.12 Lgting &amp; Appliances</td>
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<td></td>
<td>2.13 Indoor Air Quality</td>
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<tr>
<td></td>
<td>2.14 Control/Automation</td>
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</tbody>
</table>
Consistent Framework – Proficiency Levels

Building Science Proficiency Based on Blooms Taxonomy

<table>
<thead>
<tr>
<th>Level</th>
<th>Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Remember (Knowledge)</td>
</tr>
<tr>
<td>2</td>
<td>Understand (Comprehension)</td>
</tr>
<tr>
<td>3</td>
<td>Apply (Application)</td>
</tr>
<tr>
<td>4</td>
<td>Analyze (Analysis)</td>
</tr>
<tr>
<td>5</td>
<td>Evaluate (Synthesis)</td>
</tr>
<tr>
<td>6</td>
<td>Create (Design)</td>
</tr>
</tbody>
</table>
Consistent Framework – Proficiency Level Relative Rigor

- 6: Create
- 5: Evaluate
- 4: Analyze
- 3: Apply
- 2: Understand
- 1: Remember
## Consistent Framework - Building Science Education Matrix

### Mechanical Engineer Guideline

### Work in Progress

### Workforce Classifications

### Skills

<table>
<thead>
<tr>
<th>Workforce Classifications</th>
<th>Proficiency Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Remember (knowledge)</td>
</tr>
<tr>
<td></td>
<td>2 = Understand (comprehension)</td>
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<td>5 = Evaluate (synthesis)</td>
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<td></td>
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</tbody>
</table>

### Table: Building Science Education Matrix v10

<table>
<thead>
<tr>
<th>Workforce Classifications</th>
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</tr>
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<tbody>
<tr>
<td></td>
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<td>5 = Evaluate (synthesis)</td>
</tr>
<tr>
<td></td>
<td>6 = Create (design)</td>
</tr>
</tbody>
</table>
# Consistent Framework – Sample Guideline

## Building Science Education Guidelines for Mechanical Engineers

A summary of the proficiency levels for the core competencies are displayed in the graphic below. For each core competency level described in this checklist, it is assumed that the organization or student is proficient in the level described, as well as all the cognitive levels below that level.

### Average Mechanical Engineer Proficiency Levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Remember</th>
<th>Understand</th>
<th>Apply</th>
<th>Analyze</th>
<th>Evaluate</th>
<th>Create</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

### As the entity responsible for managing home energy certifiers, a mechanical engineer should be proficient in the following categories:

#### Topic

- **Building science principles related to the enclosure**
  - Heat transfer (convection, conduction, and radiation)
  - Moisture transport of liquid
  - Convective air transport due to pressure differences
  - Material selection (IAQ, thermal mass, moisture)
  - Control layers (heat, vapor, water, air and solar gains)
  - Hygrothermal analysis
  - HVAC systems (heating, cooling, and ventilation)
  - HVAC interactions with the enclosure
  - Fenestration considerations
  - Plumbing systems (heating, distribution, conservation)
  - Electrical systems
  - Lighting: appliances and miscellaneous loads
  - Indoor environmental quality (temperature uniformity and indoor pollutants)
  - Control/automation systems

#### Proficiency Level

- **Building testing and certification**
  - Commissioning
  - Diagnostics and forensics
  - Monitoring
  - National codes and standards
  - Certification programs

### The ___________________ mechanical engineer certification body has incorporated all of the relevant information in the above checklist into their training materials.

**Signature**
Consistent Framework – Sample Guideline Comparison

Average Mechanical Engineer Proficiency Levels

Integration of the Whole-Building System
Building Science Principles
Operations and Maintenance
Building Testing

Average Appraiser Proficiency Levels

Integration of the Whole-Building System
Building Science Principles
Operations and Maintenance
Building Testing
2. Building Science Principles - 2.1 Heat Transfer

Level 1: Identify and state the units for: heat flux, heat rate, thermal conductivity, temperature gradient, emissivity, heat transfer coefficient.

Level 2: Define key terms including conduction, convection, radiation, energy, steady state.

Level 3: Calculate heat transport, conductivity, area or temperature difference through a solid using Fourier’s law.

Level 4: Draw a heat transfer diagram that shows each mode of heat transfer in context with the geometry.

Level 5: Determine the mode of heat transfer most important or likely to occur in a system if given information about the substances/processes involved.

Level 6: Design an integrated hybrid thermal envelope.
**Skills**

<table>
<thead>
<tr>
<th>Integration of Whole-Building System</th>
<th>Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Integration of Whole-Building System</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>1.1: Performance: Energy, Durability, Comfort, IAQ</td>
<td>Workforce-Specific Content Per Guideline: Mechanical Engineer</td>
</tr>
<tr>
<td>1.2: Life-Cycle Cost-Effectiveness Analysis</td>
<td></td>
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<tr>
<td>1.3: Disaster Resistance/Resiliency</td>
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<tr>
<td>1.4: Integrated Design and Construction</td>
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<tr>
<td>1.5: Quality Management</td>
<td></td>
</tr>
<tr>
<td>1.6: Building and Energy Modeling</td>
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<tr>
<td>1.7: Cost Trade-Off Analysis</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Building Science Principles</th>
<th>Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Building Science Principles</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>2.1: Heat Transfer (Conduction, Radiation, Convection)</td>
<td></td>
</tr>
<tr>
<td>2.2: Moisture Transport (Liquid, Vapor, Psychrometrics)</td>
<td></td>
</tr>
<tr>
<td>2.3: Convective Mass (air) Transport (Pressure/Flow)</td>
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<tr>
<td>2.4: Material Selection (IAQ, Thermal Mass, Moisture)</td>
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</tr>
<tr>
<td>2.5: Control Layers (Thermal, Vapor, Water, Air, Solar Gain)</td>
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<tr>
<td>2.6: Hygrothermal Analysis</td>
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<tr>
<td>2.7: HVAC Systems (Heating, Cooling, and Ventilation)</td>
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<tr>
<td>2.8: HVAC Interactions with Enclosure</td>
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<tr>
<td>2.9: Fenestration</td>
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<tr>
<td>2.10: Plumbing Systems (Heating, Distribution, Conservation)</td>
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<td>2.11: Electrical Systems</td>
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<tr>
<td>2.12: Lighting/Appliances and Miscellaneous Loads</td>
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<tr>
<td>2.13: Indoor Envir. Quality (Thermal Comfort, Health, Safety)</td>
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<tr>
<td>2.14: Control/Automation Systems</td>
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<table>
<thead>
<tr>
<th>Operation &amp; Maint.</th>
<th>Proficiency</th>
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</thead>
<tbody>
<tr>
<td>3. Operation &amp; Maint.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>3.1: User Interface and Controls</td>
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<tr>
<td>3.2: Preventive Maintenance</td>
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<tr>
<td>3.3: Replacement and Renovation</td>
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<table>
<thead>
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<td>4. Building Testing</td>
<td>1 2 3</td>
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<tr>
<td>4.1: Commissioning</td>
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<tr>
<td>4.2: Diagnostics and Forensics</td>
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<tr>
<td>4.3: Performance Monitoring/Assessment</td>
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</tbody>
</table>
Job Classification

Click on the image above to find content organized by job classification. Examples include mechanical engineer, appraiser, home performance contractor, code official and many more!

READ MORE

The Building Science Education Solution Center provides complete, accurate training material and curriculum for a full range of building-related professions. New to the BSE Solution Center? Visit our webinar for detailed information and a tour of the BSE Solution Center.

As a community-driven tool, we welcome your comments on how to continuously improve the Solution Center. Educators and professors should register to unlock assessment questions and practice problems.
Job Classifications

Click on the component for a list of corresponding component subcategories. Select on subcategory to display a list of related Guides.

- DESIGN & CONSTRUCTION PROFESSIONALS
  - Architect
  - Mechanical Engineer
  - Civil Engineer
  - Landscape Architect
  - Material Science Engineer
BUILDING SCIENCE EDUCATION SOLUTION CENTER

Mechanical Engineer Checklist

- Building Science Principles
- Integration of the Whole-Building System
- Operations and Maintenance
- Building Testing and Certification
MECHANICAL ENGINEER CHECKLIST

- Building Science Principles
- Integration of the Whole-Building System
  - Heat Transfer
  - Moisture Transport
  - Convection Mass (air) Transport
  - Material Selection
  - Control Layers
  - Hygrothermal Analysis
  - HVAC Systems
  - HVAC Interactions with the Enclosure
- Plumbing Systems
- Electrical Systems
  - Lighting, Appliance, and Miscellaneous Loads
  - Indoor Environmental Quality
  - Control/Automation systems
- Operations and Maintenance
- Building Testing and Certification
Fenestration (i.e. windows and skylights) provide our homes with light, warmth, and ventilation. When properly designed, selected and installed, energy-efficient windows can help minimize heating, cooling, and lighting costs, while improving comfort for building occupants.

<table>
<thead>
<tr>
<th>Proficiency Level</th>
<th>Learning Objectives</th>
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</thead>
<tbody>
<tr>
<td>Level 1: Remember</td>
<td>Define key terms including u-factor, NFRC label, SHGC, VT, air leakage, and LSG. Describe different window operation methods and be prepared to comment on air leakage implications.</td>
</tr>
<tr>
<td>Level 2: Understand</td>
<td>Describe types of window frames and glazing including low-e, tinting, and reflective coatings. Describe ways that sunlight transmittance is measured and rated. Explain distinguishing features of each of the primary glazing types including tints, low-e, etc.</td>
</tr>
<tr>
<td>Level 3: Apply</td>
<td>Sketch the primary components of a window and describe the role that each plays (frame, panes, sill, etc.).</td>
</tr>
<tr>
<td>Level 4: Analyze</td>
<td>Classify window performance for specific regions using information from the NFRC label. Explain the importance of u-factors in predicting window performance.</td>
</tr>
<tr>
<td>Level 5: Evaluate</td>
<td>Select the best window system for specific orientations and geography.</td>
</tr>
<tr>
<td>Level 6: Design</td>
<td></td>
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Level 1: Remember
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Level 3: Apply
Level 4: Analyze
Level 5: Evaluate
Level 6: Design
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BUILDING SCIENCE EDUCATION SOLUTION CENTER

Job Classifications

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- Design & Construction Professionals
  - Architect
  - Mechanical Engineer
  - Civil Engineer
  - Landscape Architect
  - Material Science Engineer
Landscape Architect Checklist

- Building Science Principles
- Integration of the Whole-Building System
  - Heat Transfer
  - Moisture Transport
  - Convection Mass (air) Transport
  - Material Selection
  - Control Layers
  - Hygrothermal Analysis
  - HVAC Systems
  - HVAC Interactions with the Enclosure
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Cold Climate Housing Program - University of Minnesota
The Cold Climate Housing Program (CCH) is an information and education program that promotes the idea of the "house as a system."

Dr. Heather Dillon
Heather Dillon is a professor at the University of Portland, in Portland, OR. She teaches building science to undergraduate mechanical engineering students.

Guardian Industries Corporation

Shiley School of Engineering - University of Portland
The University of Portland is a thriving community of over 5,000 students, faculty and staff located on a bluff overlooking the booming metropolitan city of Portland, Oregon.

The Appraisal Foundation
The Appraisal Foundation (Foundation) is the nation’s foremost authority on the valuation profession.

The Energy and Environmental Building Alliance
The Energy & Environmental Building Alliance (EEBA) provides an invaluable platform for insight, collaboration and education.
MOU’s Signed

- The Appraisal Foundation
- University of Portland
- University of Minnesota
- EEBA

MOU’s in Progress

- Virginia Tech
- RESNET
- AIA
• Become Partner and Align with Guidelines
• Recruit Partners
• Provide Solution Center Content
• Engage Stakeholders
DOE Building Science Ed. Program

Framework for Consistent Competency

Professional Degree Program Integration

Value Understood in the Market

DOE Guidelines for Building Science Education

DOE ‘Race to Zero’ Student Design Competition

Building Science Translator
Race to Zero (RTZ) Vision

**Inspire** and develop the next generation of building science professionals

**Advance** and enhance building science curriculum at universities
RTZ Overview

- Annual Competition (Starting 2014)
- Collaborative Teams
- Market Ready Solutions (Design + Cost)
- Building Science Training
- Comprehensive Integrated Design
- Expert Juror Presentations
- Easily Integrated in Existing Course
- NREL Two-Day Event
- Career Connections
RTZ 2016 Team Distribution

- 301 Students
- 25 Universities
- 31 Teams
Race to Zero 2016 Grand Winner

Urban Single-Family Contest

Prairie View A&M University
RTZ 2016 Grand Winner Design

Affordable zero ready home for a historically significant, low income neighborhood.
Building Science: Control Layers

Figure 37. Thermal Barrier
Figure 38. Vapor Barrier
Figure 39. Water Barrier
Creative Solutions
“This required me to work with industry professionals and to design with a different mindset than usual school projects.”

2016 Race to Zero Participant
“I had almost zero knowledge in everything I had to do for this project. Learning the material in class then getting to apply it in a real world application was amazingly helpful…”

2016 Race to Zero Participant
“I am going to be looking for a job in building science/high-performance building. I found out that this is exactly what I want to do because of the Race to Zero.”

2016 Race to Zero Participant
“This competition is a great opportunity to go beyond regular materials and resources that are introduced in the typical classroom.”

2016 Race to Zero Participant
Recruit University Teams
Serve as Juror
Participate in Career Connections
Promote Event
Become a Sponsor
DOE Building Science Ed. Program

Framework for Consistent Competency

DOE Guidelines for Building Science Education

Professional Degree Program Integration

DOE ‘Race to Zero’ Student Design Competition

Value Understood in the Market

Building Science Translator
It’s really difficult to sell an... Energy Audit
Power Words:

It’s much easier to sell an…

Energy Check-up
It’s really difficult to sell a Ventilation System.
Power Words:

It’s much easier to sell a…

Fresh-Air System
<table>
<thead>
<tr>
<th>Building Science Measure</th>
<th>New Building Science Terminology</th>
<th>Alternate Terms</th>
<th>Quality Built</th>
<th>Enhanced Durability</th>
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<tr>
<td>High-Performance Thermal Enclosure</td>
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<td>Enhanced Comfort Enclosure</td>
<td>High-Efficiency Enclosure</td>
<td>Low-Maintenance Enclosure</td>
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<td>High-Performance Window System</td>
<td>High-Performance Window System</td>
<td>Enhanced Comfort Window System</td>
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<td>Enhanced Durability Window System</td>
</tr>
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<td>High-R Window</td>
<td>High-Efficiency Window</td>
<td>Enhanced Comfort Window System</td>
<td>High-Efficiency Window System</td>
<td>Enhanced Durability Window System</td>
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<td>Insulated Window</td>
<td>Professionally-Installed Window</td>
<td>Enhanced Comfort Window System</td>
<td>High-Efficiency Window System</td>
<td>Enhanced Durability Window System</td>
</tr>
<tr>
<td>High-Performance Insulation System</td>
<td>High-Performance Insulation System</td>
<td>Enhanced Quiet Insulation System</td>
<td>Advanced Insulation System</td>
<td>Next-Gen Insulation System</td>
</tr>
<tr>
<td>High-R Insulation</td>
<td>High-Efficiency or Ultra-Efficient Insulation</td>
<td>Enhanced Quiet Insulation System</td>
<td>Advanced Insulation Technology</td>
<td>Enhanced Durability</td>
</tr>
<tr>
<td>High-R Wall Insulation</td>
<td>High-Efficiency or Ultra-Efficient Wall Insulation</td>
<td>Enhanced Quiet Wall Insulation</td>
<td>Advanced Wall Insulation</td>
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<td>High-R Floor Insulation</td>
<td>High-Efficiency or Ultra-Efficient Floor Insulation</td>
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<td>Advanced Floor Insulation</td>
<td>Enhanced Durability</td>
</tr>
<tr>
<td>High-R Attic Insulation</td>
<td>High-Efficiency or Ultra-Efficient Attic Insulation</td>
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</tr>
<tr>
<td>High-R Foundation Insulation</td>
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</tr>
<tr>
<td>Insulation Quality Installation</td>
<td>Premium-Installed Insulation</td>
<td>Enhanced Quiet Insulation System</td>
<td>Advanced Insulation Installation</td>
<td>Enhanced Durability</td>
</tr>
<tr>
<td>Fully Aligned Air Barriers</td>
<td>Whole-House Draft Barrier</td>
<td>Enhanced Quiet Insulation System</td>
<td>Energy Saving Installation</td>
<td>Moisture Control Air Barrier</td>
</tr>
<tr>
<td><strong>Race to Zero</strong></td>
<td><strong>Guidelines</strong></td>
<td><strong>Translator</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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Fresh Air
- Supply Fresh Air System
- Odor and Moisture Control Fans
- High-Density Filtration Technology

Quiet
- Quiet Window Technology
- Quiet Wall Technology

Moisture Control
- Dry-by-Design Construction
- Moisture Control System - Whole House
- Moisture Controlled Comfort System
- Moisture Controlled Windows
- Moisture Controlled Lower Level

Pest Control
- Bug Control Barrier
- Pest Screened Home

Outdoor Contaminant Control
- Contaminant Snailed Construction
- Contaminant Snailed Comfort Delivery
- Dust and Pollen Barrier
- Radon Controlled Home

Chemical Control
- Formaldehyde Controlled Home
- VOC Controlled Home

Fume Control
- Carbon Monoxide Controlled Equipment
- Carbon Monoxide Controlled Fireplace
- Fume Controlled Garage
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BASC Guides

Program Checklists
Access guides directly from checklists for Zero Energy Ready Home, ENERGY STAR Certified Home, and indoor airPLUS

Building Components
Access guides for new and existing homes (new or building components of interest)

Sales Tool
Mantras building science technical terms into a new language of value

Climate Packages
Review new home energy efficiency specifications and case studies that provide hotspots for savings

Existing Homes

ZERO ENERGY READY HOME
J. S. DEPARTMENT OF ENERGY

ENERGY STAR HOMES

ask about
EPA Indoor airPLUS QUALIFIED HOMES

WaterSense
Meets EPA Criteria

Existing Homes
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Double-Stud Wall Framing
- Thermal Insulation
- R-value
- Materials
- Construction

Double-Stud Wall Framing
- CAD Images
- Compliance
- More Info

Climate Packages
- Training
- Tools
- Case Studies

Scope
- Description
- Ensuring Occupancy

Sizing and Scaling
- Description
- Compliance

Climate
- Description
- Compliance

Compliance
- Description
- Compliance
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BASC Mobile Application

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Certified Home, and indoor air

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Project site #1
East Lake Project field kit
Twin Peak Site

Mobile App
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saved field kits wherever you need them.
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  - University Classes
  - Building Science
  - Presentations
  - Field Crews
• Use for Precedence
  - Code Officials
  - Decision-Makers
• Use for Reference
• Spread the Word
Thank you!

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Samuel.rashkin@ee.doe.gov