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

# Building Science
## Require A Better Workforce

**SAM RASHKIN**
Chief Architect
Building Technologies Office

# Why Building Science Education



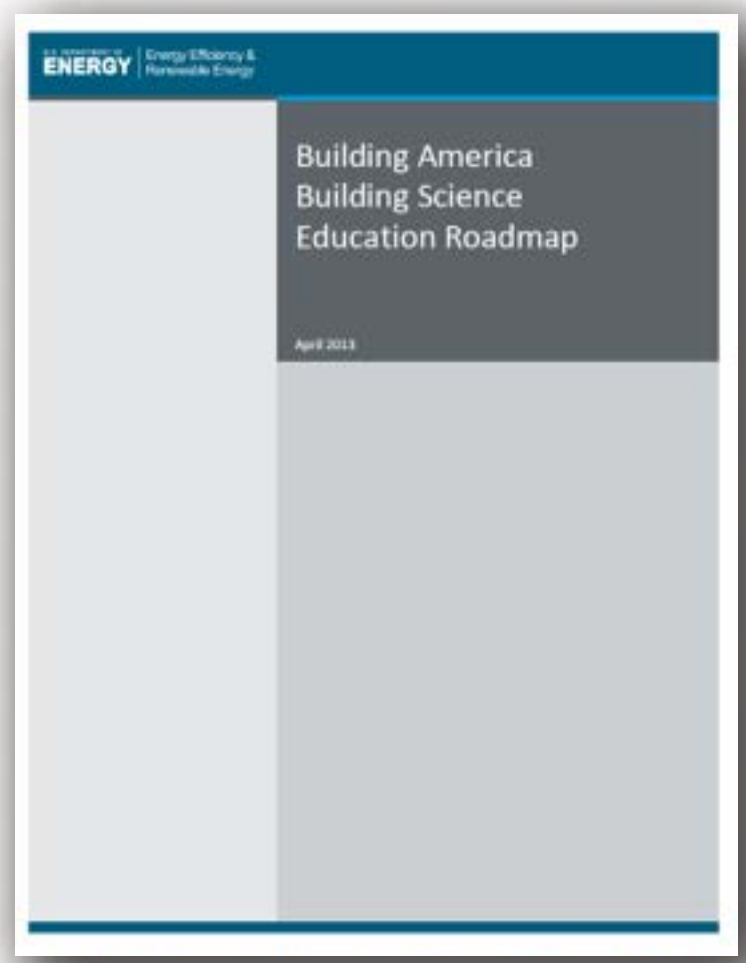
**Supply System:**
Workforce Competent in Building Science

**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**

# Building America Building Science Education Summit



# DOE Building Science Ed. Program

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

| | |
|---|---|
| Framework for Consistent Competency | DOE Guidelines for Building Science Education |
| Full Integration with Degree Programs | DOE '**Race to Zero**' Student Design Competition |
| Value Understood in the Market | Building Science Translator |

| Workforce Classifications | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1 High-School Ed.** | **2 Builder/ Remodel Pros** | **3 Program/ Project Manager** | **4 Transact. Process Pros** | **5 Design/ Construc. Pros** | **6 Building Science Pros** | **7 Home Energy Pros** | **8 Building Depart.** |
| Physics | Builder | Utllity | Realtor | A/E Degree | Forensics | Auditors | Code Offic. |
| | GC/Forem. | Energy Eff. | Appraiser | Lic. Arch. | QA Envel. | Perf Assess | |
| | Remodeler | Maint. Pro | Home Insp | Mech. Eng. | QA M&E | | |
| | Insulater | Facil. Man. | Insurers | Civil/Struc. | | | |
| | HVAC | | Lenders | Mat. Sci. | | | |
| | Plumber | | | Designers | | | |
| | Home Perf. | | | Landscape | | | |
| | | | | Const. Man | | | |

# Building Science Skills

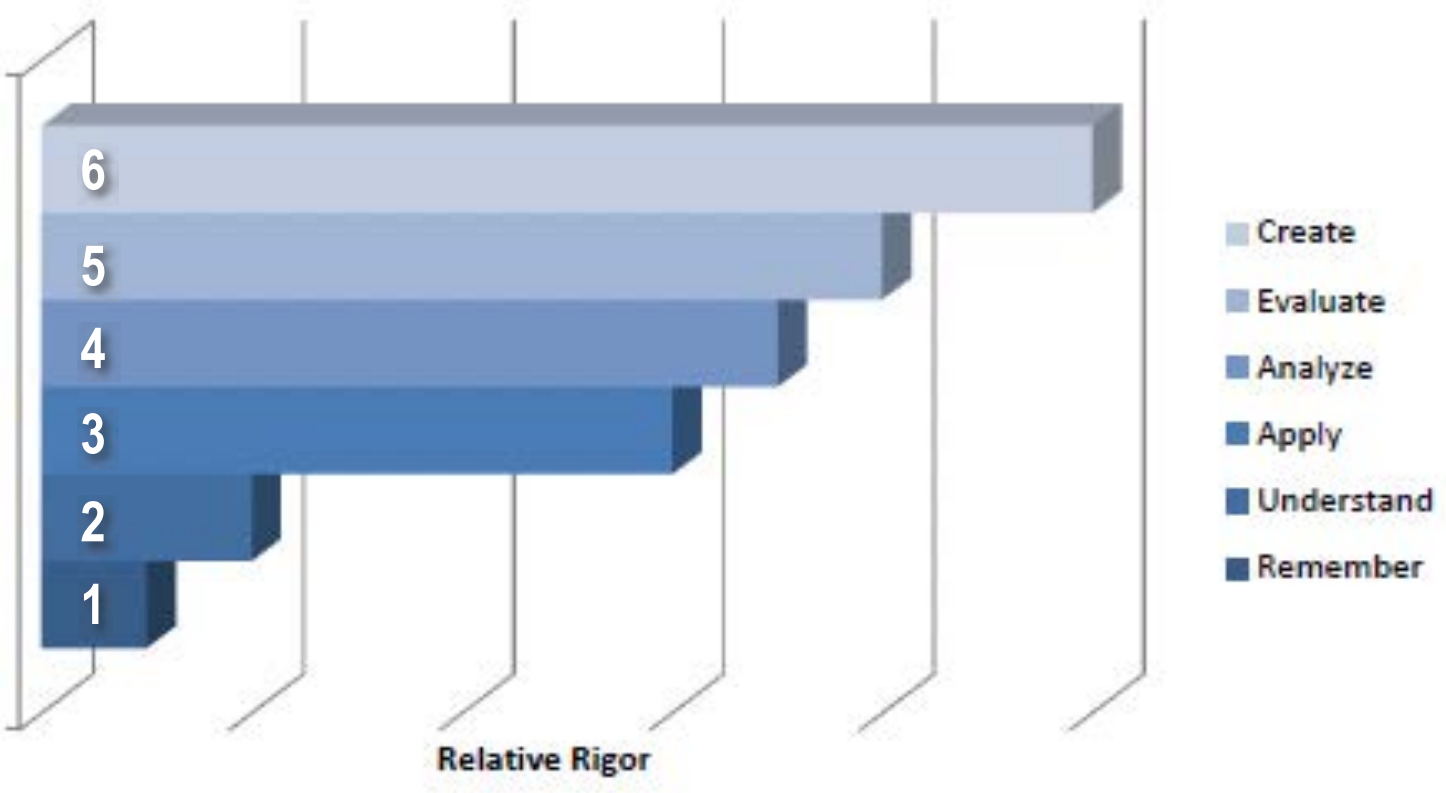
| 1<br>Integration of Whole-Bldg. Sys. | 2<br>Building Science Principles | 3<br>Operations & Maintenance | 4<br>Building Testing |
|---|---|---|---|
| 1.1 Performance | 2.1 Heat Transfer | 3.1 User Interface/Cont. | 4.1 Commissioning |
| 1.2 Life-Cycle Cost Eff. | 2.2 Material Selection | 3.2 Preventative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

Building Science Proficiency Based on Blooms Taxonomy

| | |
|---|---|
| 6 | **Create** (Design) |
| 5 | **Evaluate** (Synthesis) |
| 4 | **Analyze** (Analysis) |
| 3 | **Apply** (Application) |
| 2 | **Understand** (Comprehension) |
| 1 | **Remember** (Knowledge) |

# Proficiency Level Relative Rigor



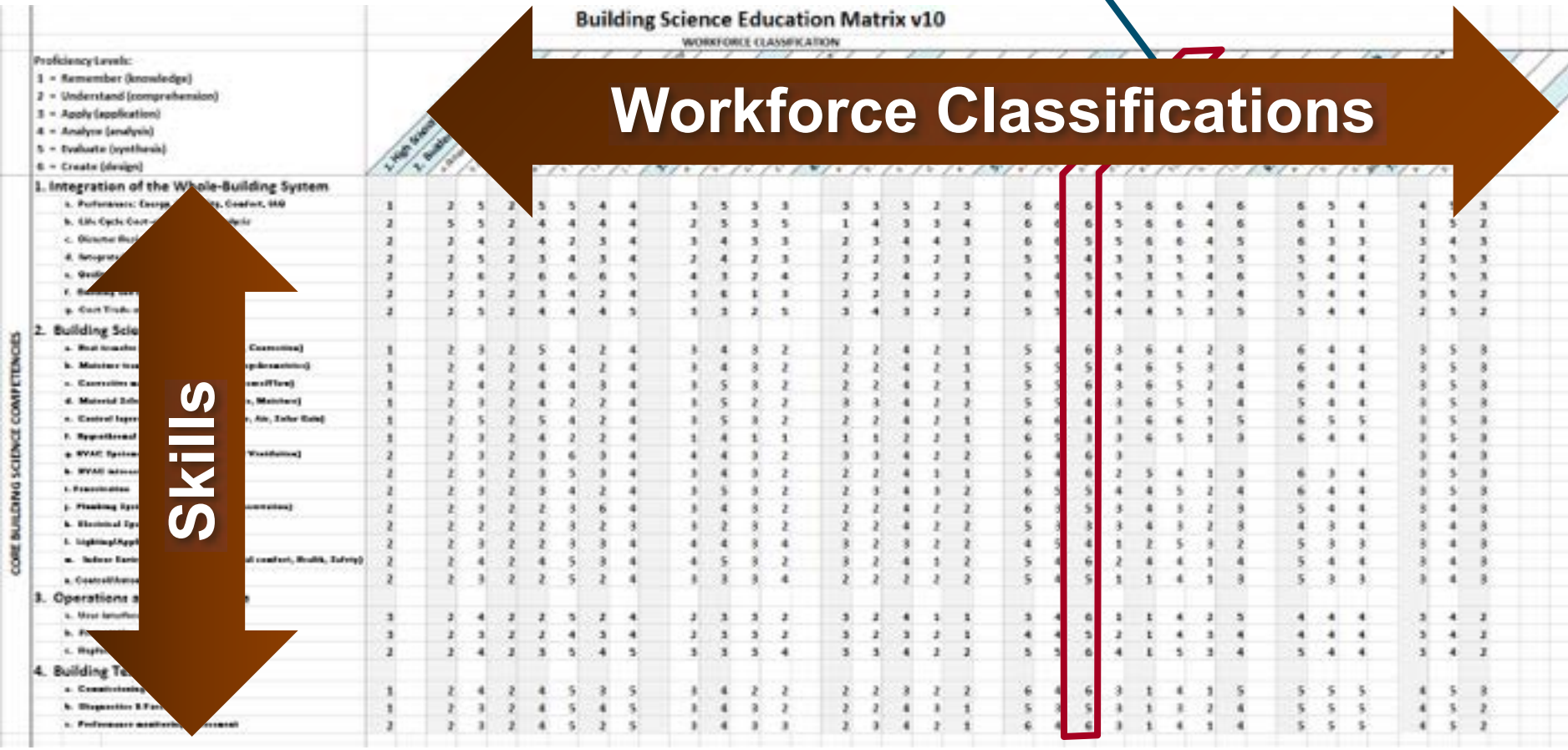


# Building Science Education Matrix



**Mechanical Engineer Guideline**

**Work in Progress**

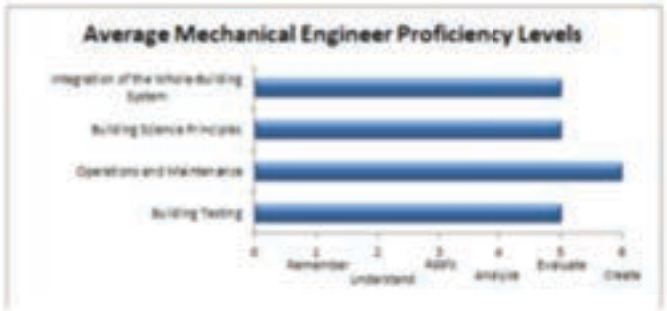


# Consistent Framework – Sample Guideline

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

## Building Science Education Guidelines for Mechanical Engineers

A summary of the proficiency levels[1] 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.




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

| Topic | Proficiency Level | Checkbox |
|---|---|---|
| **Integration of the whole-building system** | Average = 5 | |
| Simultaneous consideration of energy, durability, comfort and IAQ | 6 | ☐ |
| Annualized cash flow | 6 | ☐ |
| Building techniques related to natural and man-made disasters | 5 | ☐ |
| Integrated design and construction | 4 | ☐ |
| Quality management | 5 | ☐ |
| Building energy modeling | 3 | ☐ |
| Cost trade-off analysis (optimized first costs) | 4 | ☐ |

[1] The average level shown here is the whole number that best represents the combination of individual scores from each sub-category.

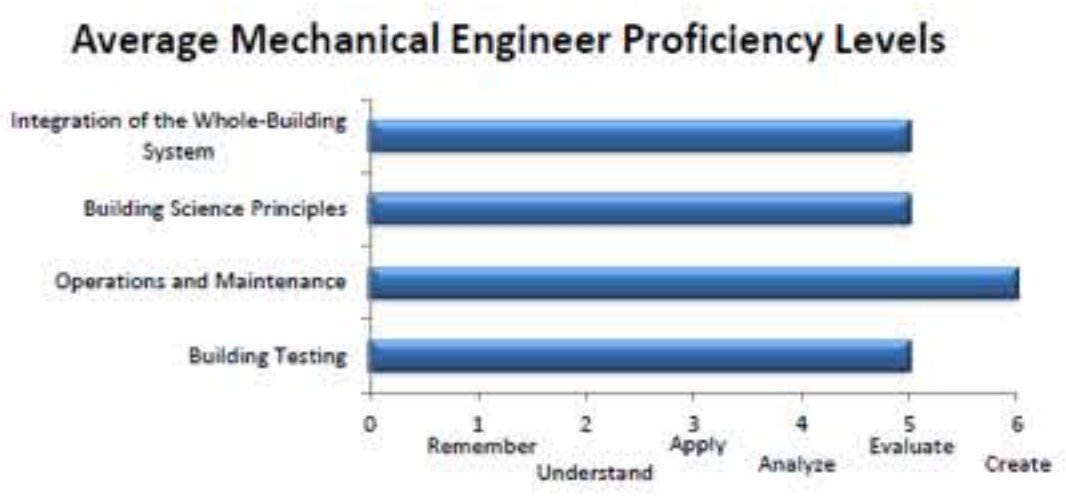
| Topic | Proficiency Level | Checkbox |
|---|---|---|
| **Building science principles related to the enclosure** | Average = 5 | |
| Heat transfer (convection, conduction and radiation) | 6 | ☐ |
| Moisture transport of liquid | 5 | ☐ |
| Convective air transport due to pressure differences | 6 | ☐ |
| Material selection (IAQ, thermal mass, moisture) | 4 | ☐ |
| Controls layers (heat, vapor, water, air and solar gain) | 4 | ☐ |
| Hygrothermal analysis | 3 | ☐ |
| HVAC systems (heating, cooling and ventilation) | 6 | ☐ |
| HVAC interactions with the enclosure | 6 | ☐ |
| Fenestration considerations | 5 | ☐ |
| Plumbing systems (heating, distribution, conservation) | 5 | ☐ |
| Electrical systems | 3 | ☐ |
| Lighting appliances and miscellaneous loads | 4 | ☐ |
| Indoor environmental quality (temperature uniformity and indoor pollutants) | 6 | ☐ |
| Control automation systems | 5 | ☐ |
| **Operations and maintenance** | Average = 6 | |
| User controls (ex: thermostat) | 6 | ☐ |
| Preventative maintenance (ex: cleaning air filters) | 5 | ☐ |
| Determination of appropriate replacement choices | 6 | ☐ |
| **Building testing and certification** | Average = 5 | |
| Commissioning | 6 | ☐ |
| Diagnostics and forensics | 5 | ☐ |
| Monitoring | 6 | ☐ |
| National codes and standards | 3 | ☐ |
| Certification programs | 3 | ☐ |

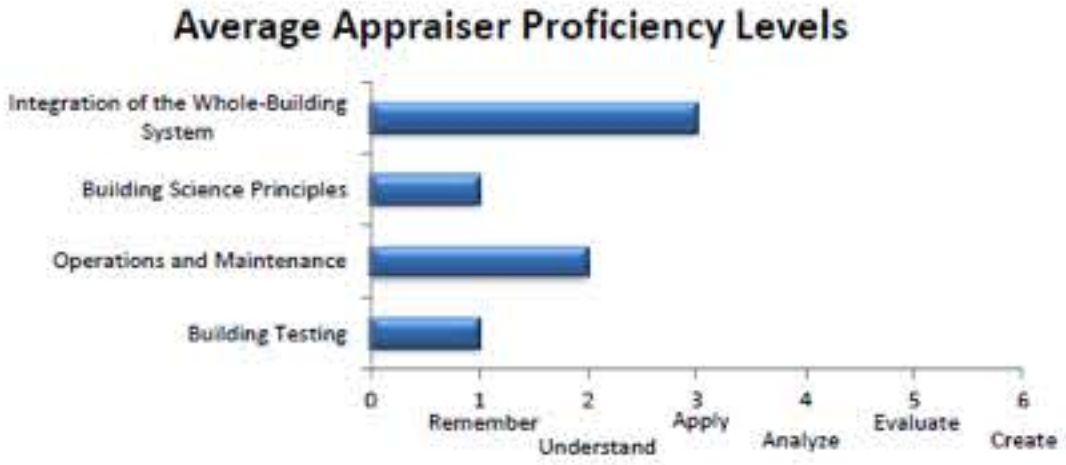
The _____ mechanical engineer certification body has incorporated all of the relevant information in the above checklist into their training materials.

Signature _____

# Sample Guideline Comparison





| Skills | | Proficiency | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 Integration of Whole-Building System | 1.1: Performance: Energy, Durability, Comfort, IAQ | | | | | | |
| | 1.2: Life-Cycle Cost-Effectiveness Analysis | | | | | | |
| | 1.3: Disaster Resistance/Resiliency | | | | | | |
| | 1.4: Integrated Design and Construction | | | | | | |
| | 1.5: Quality Management | | | | | | |
| | 1.6: Building and Energy Modeling | | | | | | |
| | 1.7: Cost Trade-Off Analysis | | | | | | |
| Bu | 2.1: Heat Transfer (Conduction, Radiation, Convection) | | | | | | |
| | 2.2: Moisture Transport (Liquid, Vapor, Pxychrometrics) | | | | | | |
| | 2.3: Convective Mass (air) Transport (Pressure/Flow) | | | | | | |
| | 2.4 Material Selection (IAQ, Thermal Mass, Moisture) | | | | | | |
| Op | | | | | | | |
| Bu | | | | | | | |

Content

**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

## 2. Building Science Principles - 2.1 Heat Transfer

# Database of Education Resources – BSE Solution Center Content

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

| Skills | | Proficiency | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| **1 Integration of Whole-Building System** | 1.1: Performance: Energy, Durability, Comfort, IAQ | | | | | | |
| | 1.2: Life-Cycle Cost-Effectiveness Analysis | | | | | | |
| | 1.3: Disaster Resistance/Resiliency | | | | | | |
| | 1.4: Integrated Design and Construction | | | | | | |
| | 1.5: Quality Management | | | | | | |
| | 1.6: Building and Energy Modeling | | | | | | |
| | 1.7: Cost Trade-Off Analysis | | | | | | |
| **2 Building Science Principles** | 2.1: Heat Transfer (Conduction, Radiation, Convection) | | | | | | |
| | 2.2: Moisture Transport (Liquid, Vapor, Pxychrometrics) | | | | | | |
| | 2.3: Convective Mass (air) Transport (Pressure/Flow) | | | | | | |
| | 2.4: Material Selection (IAQ, Thermal Mass, Moisture) | | | | | | |
| | 2.5: Control Layers (Thermal, Vapor, Water, Air, Solar Gain) | | | | | | |
| | 2.6: Hygrothermal Analysis | | | | | | |
| | 2.7: HVAC Systems (Heating, Cooling, and Ventilation) | | | | | | |
| | 2.8: HVAC Interactions with Enclosure | | | | | | |
| | 2.9: Fenestration | | | | | | |
| | 2.10: Plumbing Systems (Heating, Distribution, Conservation) | | | | | | |
| | 2.11: Electrical Ssytems | | | | | | |
| | 2.12: Lighting/Appliances and Miscellaneous Loads | | | | | | |
| | 2.13: Indoor Envir. Quality (Thermal Comfort, Health, Safety) | | | | | | |
| | 2.14: Control/Automation Systems | | | | | | |
| **3 Operation & Maint.** | 3.1: User Interface and Controls | | | | | | |
| | 3.2: Preventive Maiantenance | | | | | | |
| | 3.3: Replacement and Renovation | | | | | | |
| **4 Building Testing** | 4.1: Commissioning | | | | | | |
| | 4.2: Diagnostics and Forensics | | | | | | |
| | 4.3: Performance Monitoring/Assessment | | | | | | |

**Workforce-Specific Content Per Guideline: Mechanical Engineer**

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## 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.

## RECENTLY UPDATED

**AUGUST 17, 2015**
Disaster Resilience - Analysis

**AUGUST 17, 2015**
Cost Trade-Off Analysis - Knowledge

**AUGUST 17, 2015**
Commissioning - Understand

More Guides

## RECENTLY ADDED CONTENT

**AUGUST 17, 2015**
Removable Interior Storm Windows

**AUGUST 17, 2015**
Taped Insulating Sheathing Drainage Panes

**AUGUST 17, 2015**
Job Classification

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## 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

TRANSACTION PROFESSIONALS

CODE OFFICIALS

BUILDING SCIENCE PROFESSIONALS

PROGRAM MANAGERS

K-12 SCHOOLS

HOMEOWNERS

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## Mechanical Engineer Checklist

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

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Fenestration

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## 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
Fenestration
Plumbing Systems
Electrical Systems
Lighting, Appliance, and Miscellaneous Loads
Indoor Environmental Quality
Control/Automation systems

▶ Operations and Maintenance

▶ Building Testing and Certification

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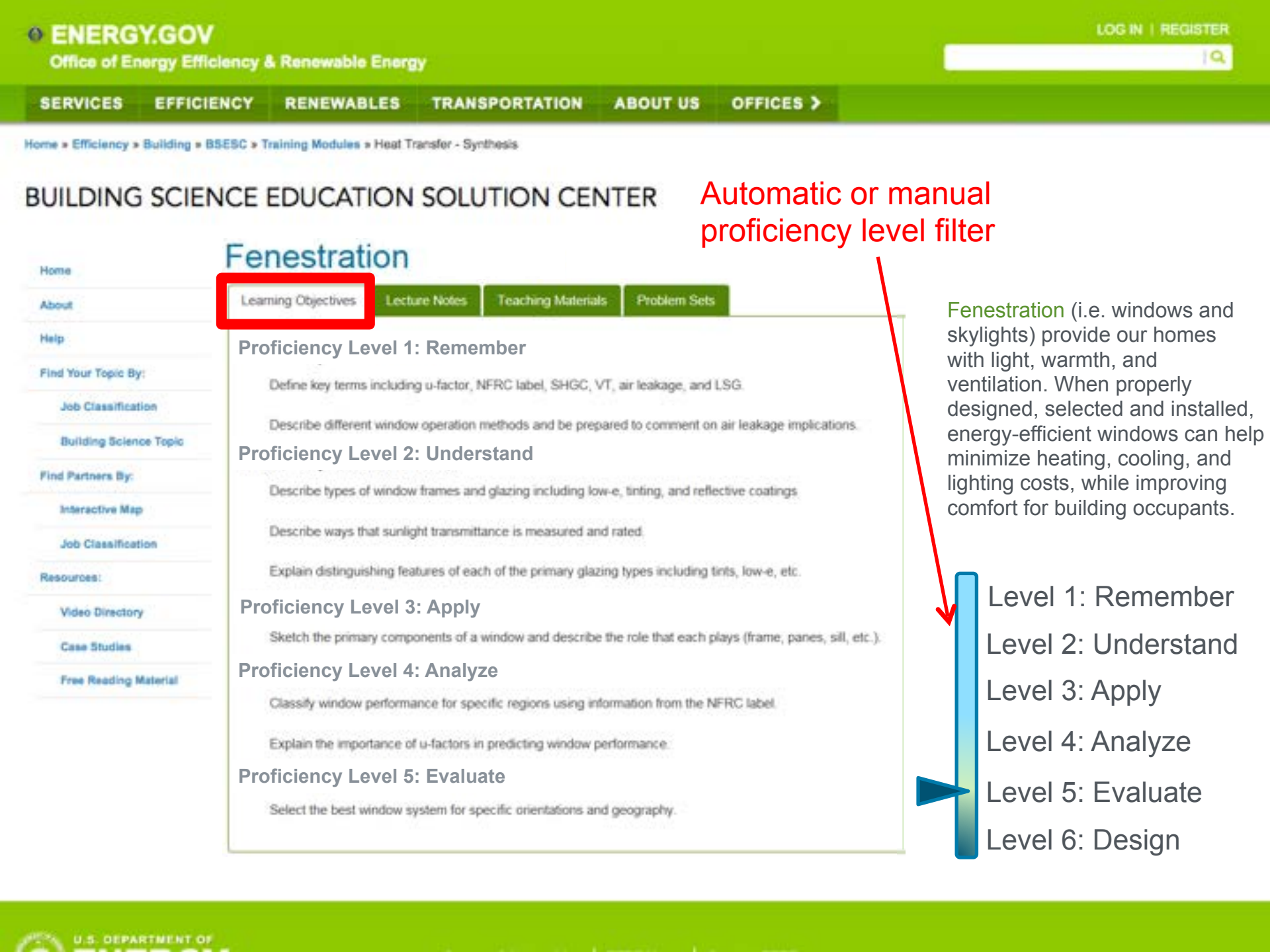
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Learning Objectives
Lecture Notes
Teaching Materials
Problem Sets
Proficiency Level 1: Remember
Define key terms including u-factor, NFRC label, SHGC, VT, air leakage, and LSG.
Describe different window operation methods and be prepared to comment on air leakage implications.
Proficiency Level 2: Understand
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.
Proficiency Level 3: Apply
Sketch the primary components of a window and describe the role that each plays (frame, panes, sill, etc.).
Proficiency Level 4: Analyze
Classify window performance for specific regions using information from the NFRC label.
Explain the importance of u-factors in predicting window performance.
Proficiency Level 5: Evaluate
Select the best window system for specific orientations and geography.
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.
Level 1: Remember
Level 2: Understand
Level 3: Apply
Level 4: Analyze
Level 5: Evaluate
Level 6: Design
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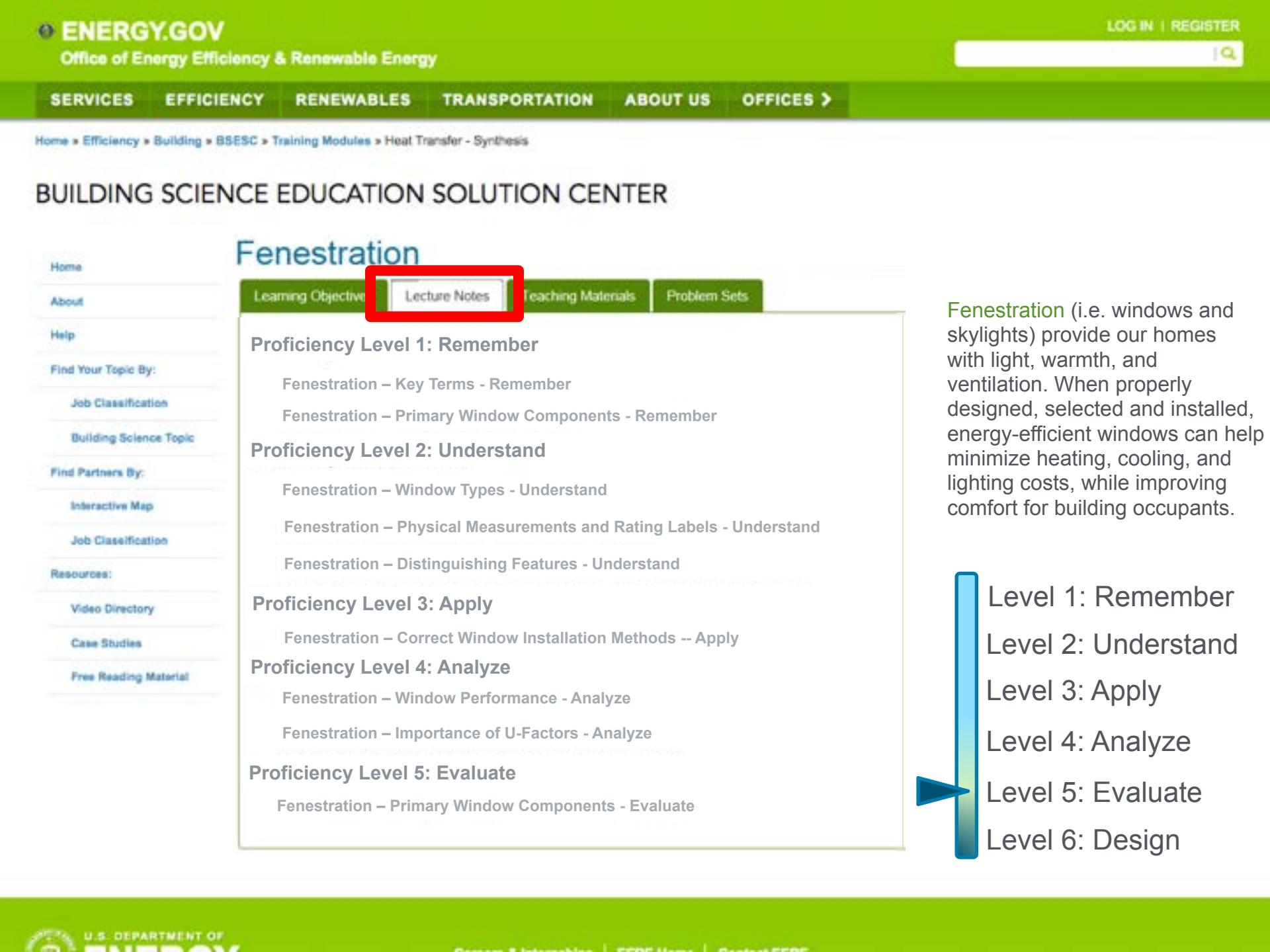


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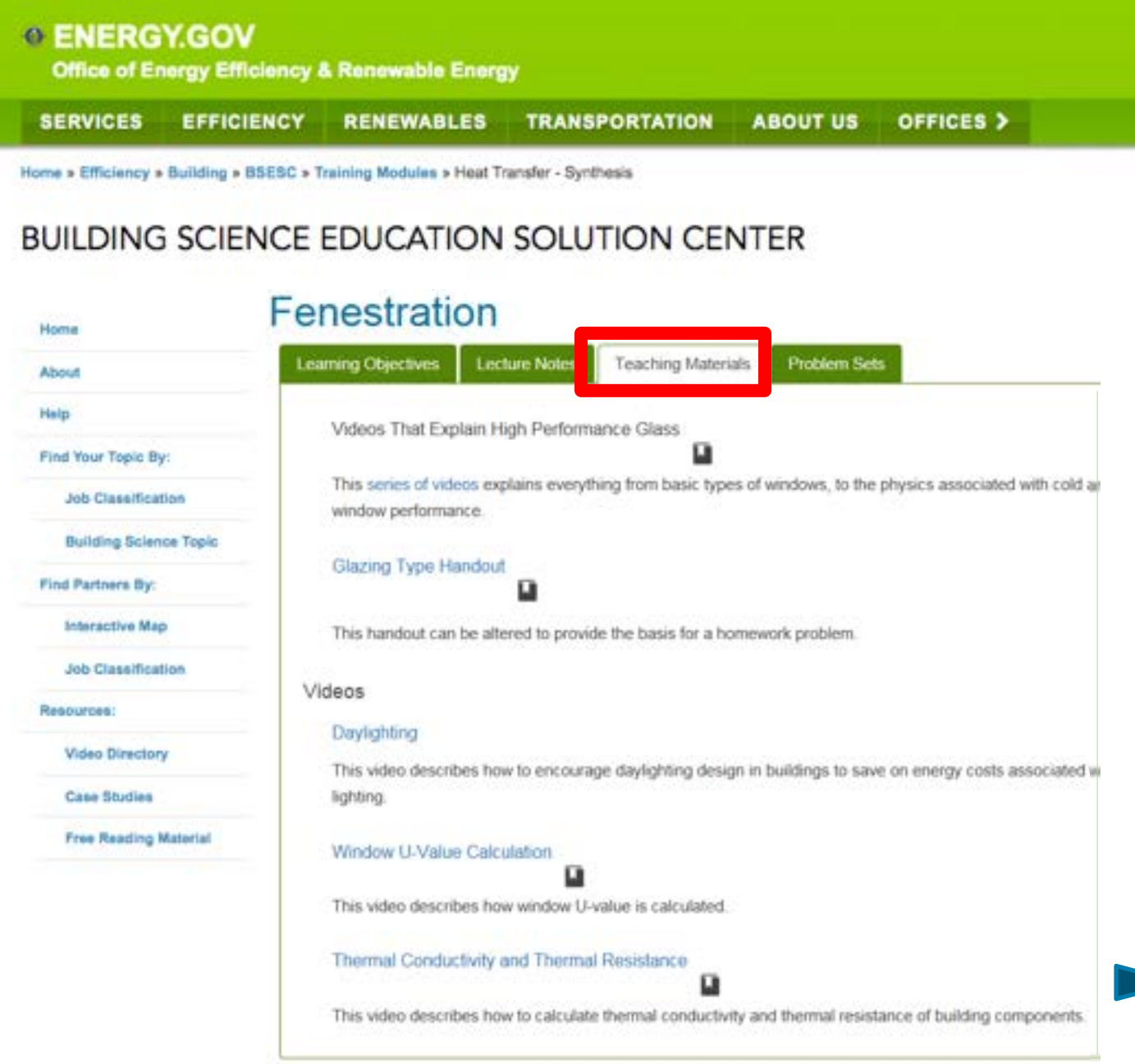


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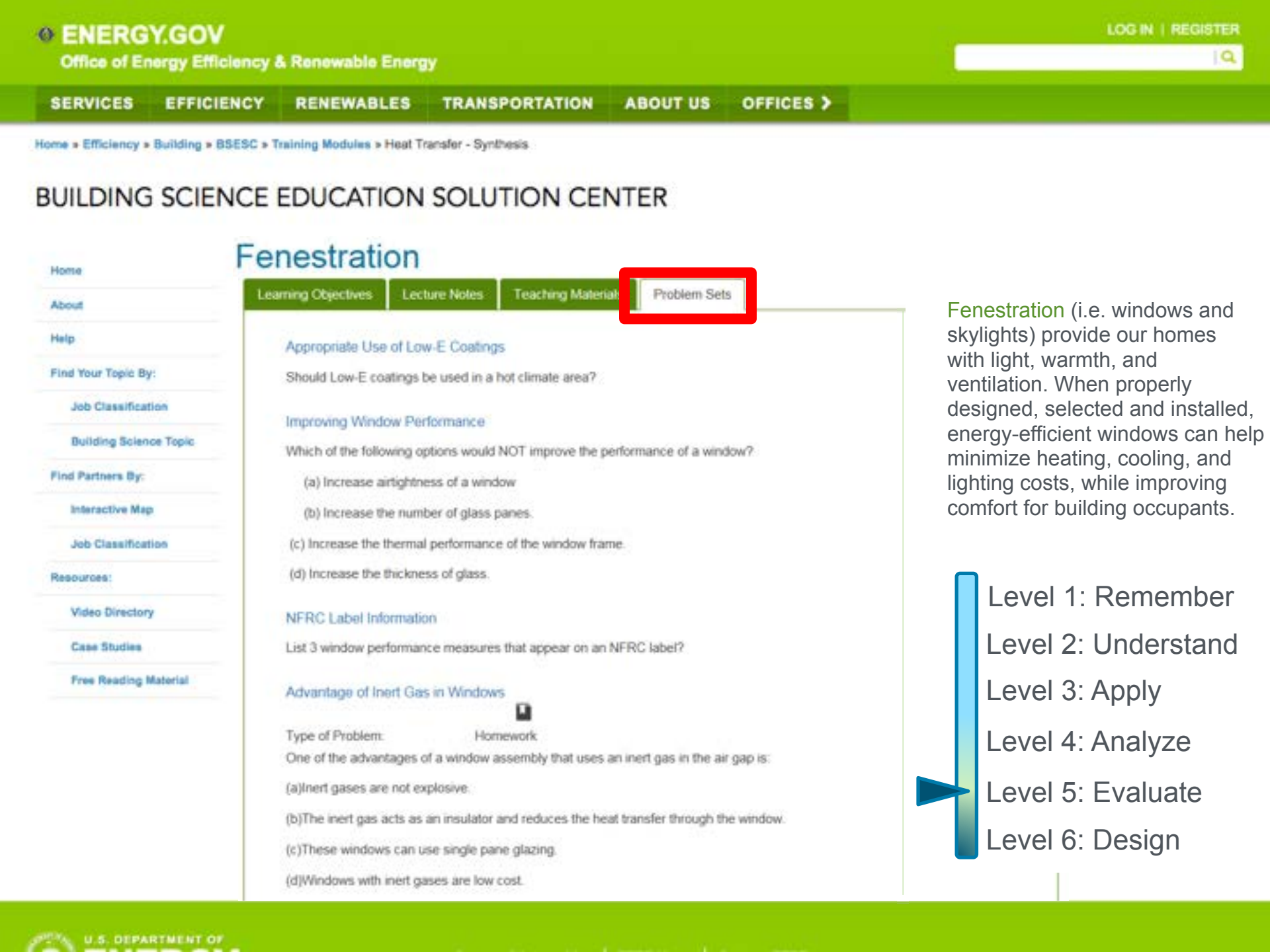


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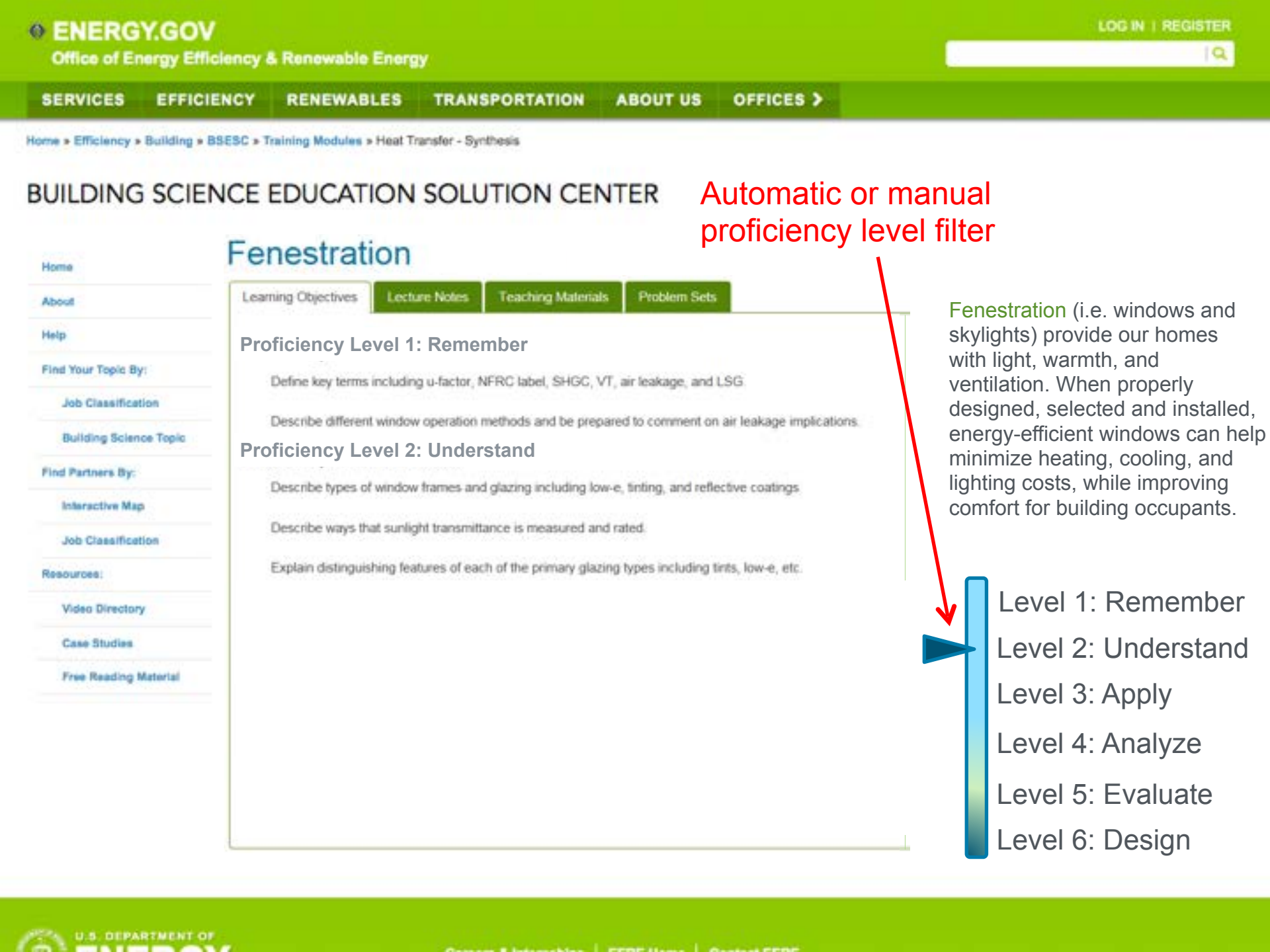
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## Partners A-Z

### Cold Climate Housing Program - University of Minnesola

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.

BUILDING TYPE
Residential (6)
Both (4)
Commercial (4)

JOB CLASSIFICATION
Material Science Engineers (2)
Mechanical Engineers (2)
Appraisers (1)
Builders/Remodelers (1)
Civil and Structural Engineers (1)

PARTNERSHIP LEVEL
Silver (4)

# Collective Impact Progress

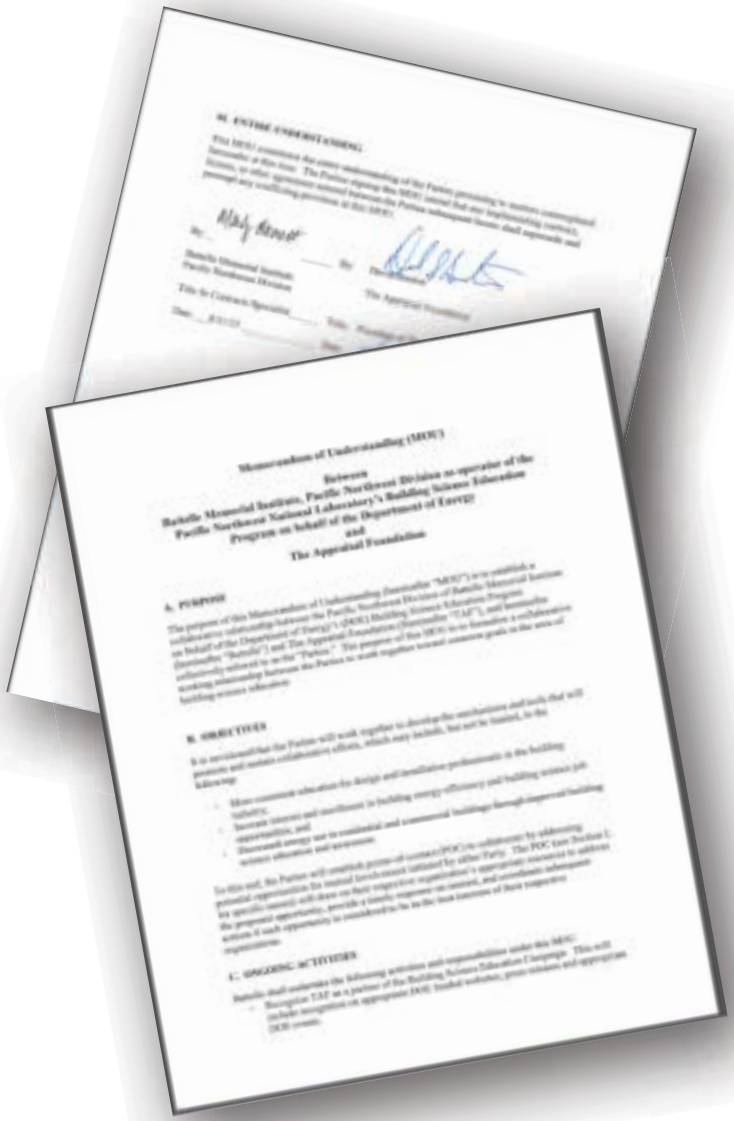


## MOU's Signed

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

## MOU's in Progress

- Virginia Tech
- RESNET
- AIA



# Actions for a National Platform



- Become Partner and Align with Guidelines
- Recruit Partners
- Provide Solution Center Content
- Engage Stakeholders

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# 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

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

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

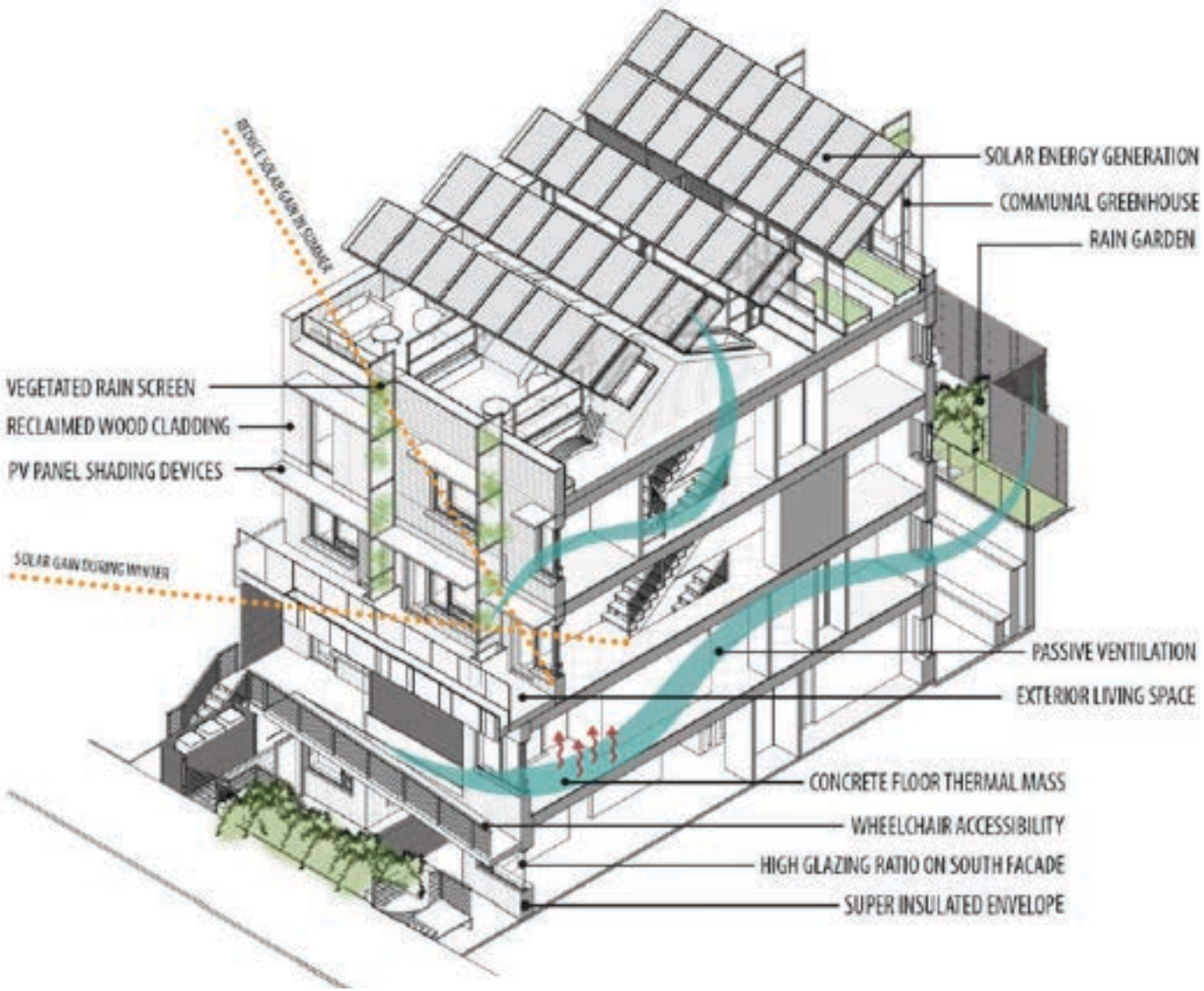
Figure 39. Water Barrier

# Building Science: Design Integration




# Creative Solutions





# Race to Zero Experience



*"This required me to work with industry professionals and to design with a different mindset than usual school projects."*

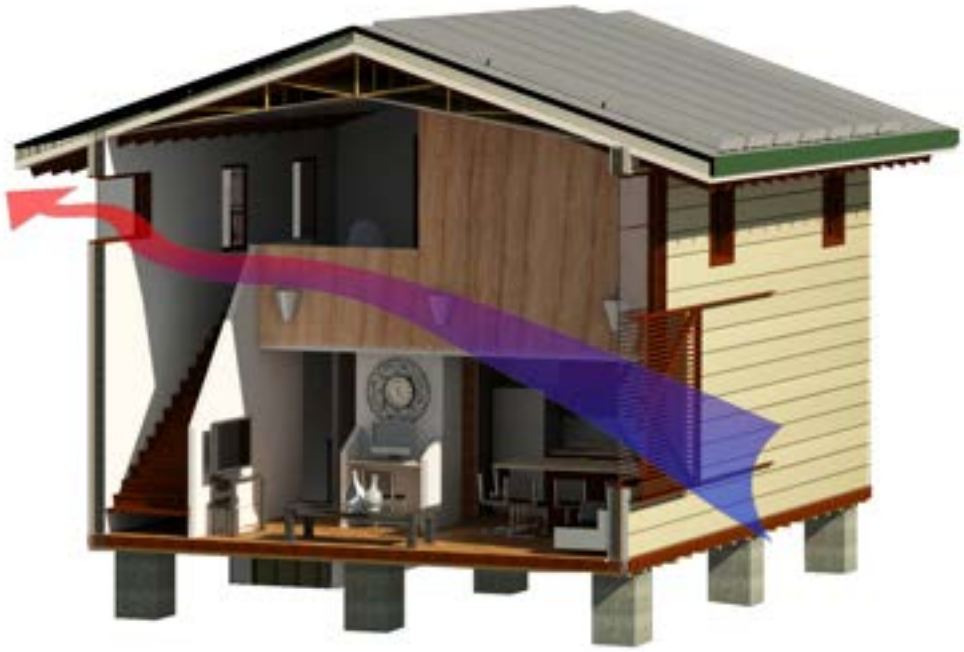
2016 Race to Zero Participant

# Race to Zero Experience



*"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



# Race to Zero Experience



*"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."*

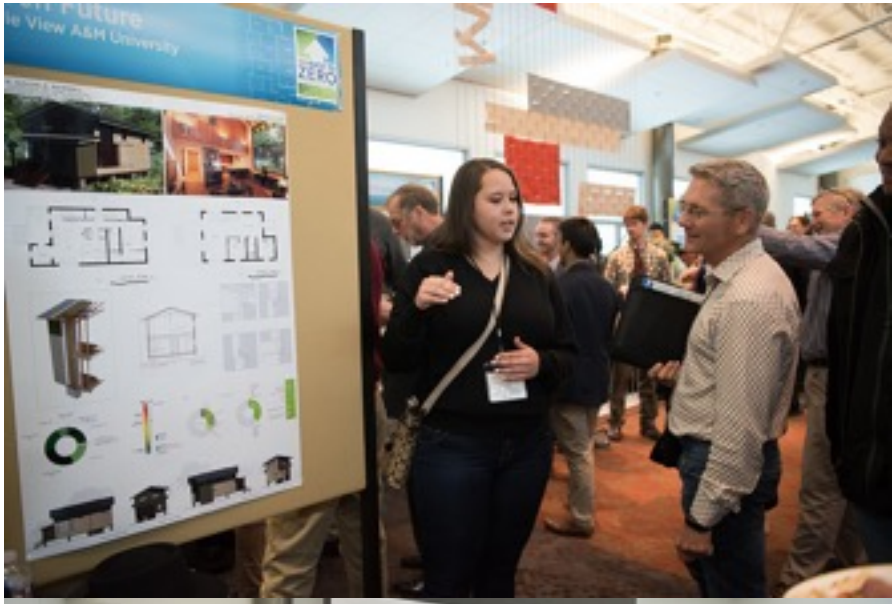
2016 Race to Zero Participant

# Race to Zero Experience

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

*"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



# Actions



- Recruit University Teams
- Serve as Juror
- Participate in Career Connections
- Promote Event
- Become a Sponsor

# DOE Building Science Ed. Program

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

| | |
|---|---|
| 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 |

# Power Words:

**It's really difficult to sell an…**

Energy **Audit**

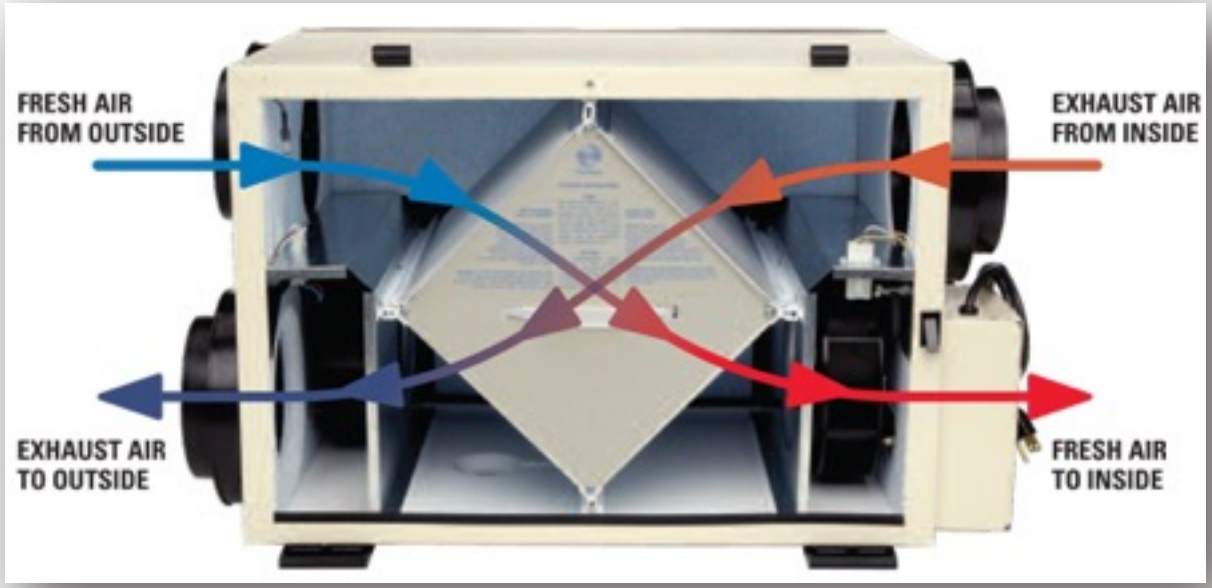
# Power Words:

**It's much easier to sell an…**

Energy Check-up

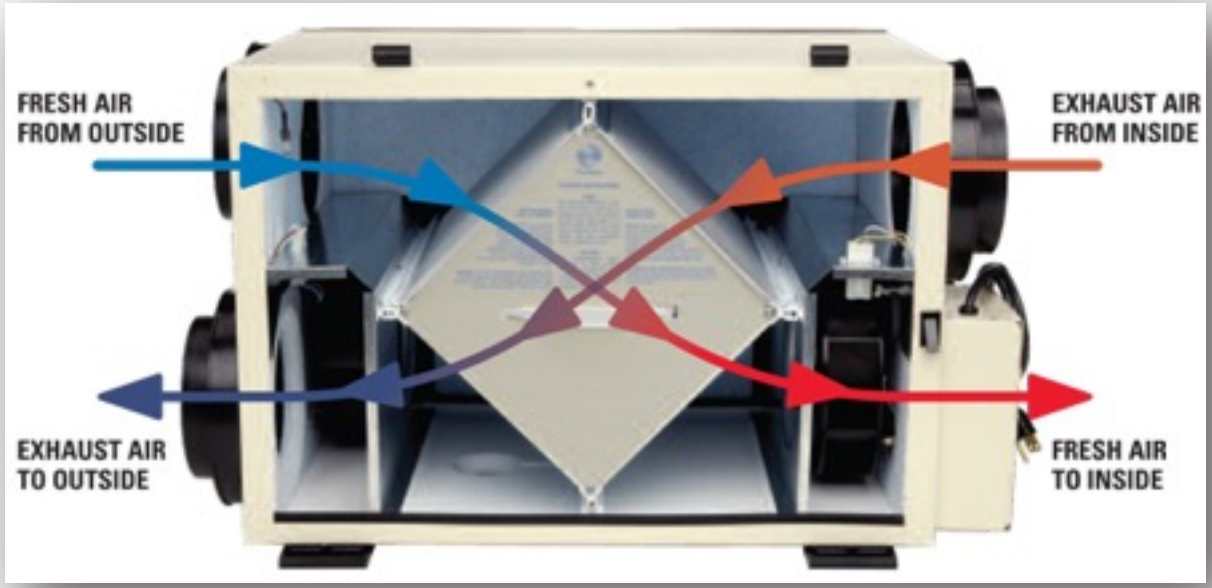
## It's really difficult to sell a…

# Ventilation System



## It's much easier to sell a…

# Fresh-Air System



# Building Science Translator

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

'Race to Zero' | Guidelines | **Translator**

**Building America Building Science Translator – Page 1a**

| Building Science Measure | New Building Science Terminology | Alternate Terms | | | | | |
|---|---|---|---|---|---|---|---|
| | | Lives Better | | Works Better | | Lasts Better | |
| | | Engineered Comfort | Healthful Environment | Ultra-Efficient | Advanced Technology | Quality Built | Enhanced Durability |
| High-Performance Thermal Enclosure | High-Performance Thermal Enclosure | Enhanced Comfort Enclosure | Moisture Managed Enclosure | High-Efficiency Enclosure | Advanced Enclosure Technology | Professionally-Installed Thermal Enclosure | Low-Maintenance Enclosure |
| High-Performance Window System | High-Performance Window System | Enhanced Comfort Window System | Quiet Window System | High-Efficiency or Ultra-Efficient Window System | Advanced Window System Technology | Professionally-Installed Window System | Enhanced Durability Window System |
| High-R Window | High-Efficiency Window | Enhanced Comfort Window | Quiet Window | High-Efficiency or Ultra-Efficient Window | Advanced Window Technology | | Sun Protection Window |
| Window | Professionally-Installed Window | Installation | Window Installation | Window Installation | Installation | Installed Window | Window Installation |
| High-Performance Insulation System | High-Performance Insulation System | Enhanced Comfort Insulation System | Enhanced Quiet Insulation System | High-Efficiency or Ultra-Efficient Insulation System | Advanced Insulation System | Professionally-Installed Insulation System | Next-Gen Insulation System |
| High-R Insulation | High-Efficiency or Ultra-Efficient Insulation | Enhanced Comfort Insulation | Enhanced Quiet Insulation | High-Efficiency or Ultra-Efficient Insulation | Advanced Insulation Technology | | |
| High-R Wall Insulation | High-Efficiency or Ultra-Efficient Wall Insulation | Enhanced Comfort Wall Insulation | Enhanced Quiet Wall Insulation | High-Efficiency or Ultra-Efficient Wall Insulation | Advanced Wall Insulation | | |
| High-R Floor Insulation | High-Efficiency or Ultra-Efficient Floor Insulation | Enhanced Comfort Floor Insulation | Enhanced Quiet Floor Insulation | High-Efficiency or Ultra-Efficient Floor Insulation | Advanced Floor Insulation | | |
| High-R Attic Insulation | High-Efficiency or Ultra-Efficient Attic Insulation | Enhanced Comfort Attic Insulation | Enhanced Quiet Ceiling Insulation | High-Efficiency or Ultra-Efficient Attic Insulation | Advanced Attic Insulation | | |
| High-R Foundation Insulation | High-Efficiency or Ultra-Efficient Foundation Insulation | Enhanced Comfort Foundation Insulation | Enhanced Quiet Foundation Insulation | High-Efficiency or Ultra-Efficient Foundation Insulation | Advanced Foundation Insulation | | |
| Insulation Quality Installation | Premium-Installed Insulation | Enhanced Comfort Insulation Installation | Enhanced Quiet Insulation Installation | Energy Saving Insulation Installation | Advanced Insulation Installation Practices | Professionally-Installed Insulation | Moisture Control Insulation Installation |
| Fully Aligned Air Barriers | Whole-House Draft Barrier | Whole-House Draft Barrier | Air Contaminant Barrier | Energy Saving Air Barrier | Advanced Air Barrier Technology | Professionally-Installed Draft Barrier | Moisture Control Air Barrier |

# BASC Sales Tool



# World-Class Expert Guidance…

Building America Solution Center

BASC.energy.gov

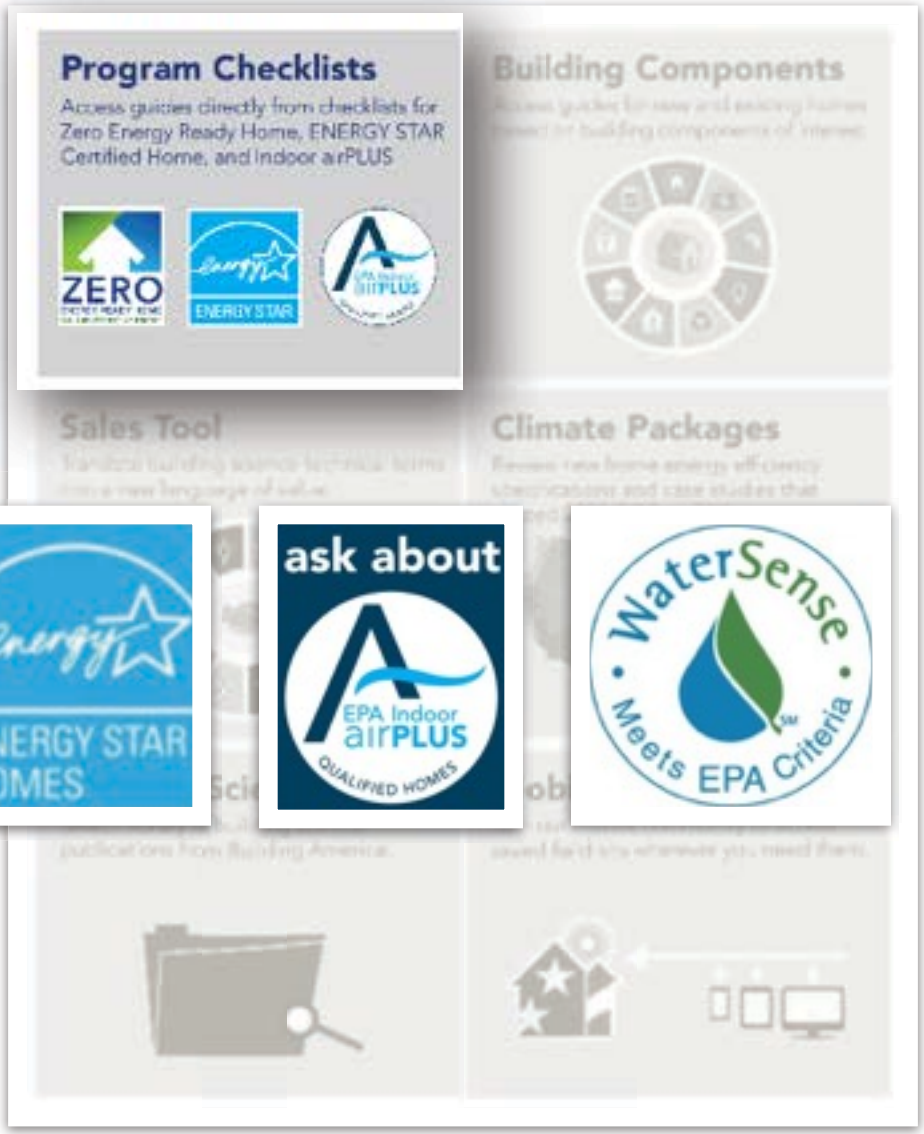
…At Your Fingertips

# BASC Simple Interface



# BASC Guides






ZERO ENERGY READY HOME U.S. DEPARTMENT OF ENERGY

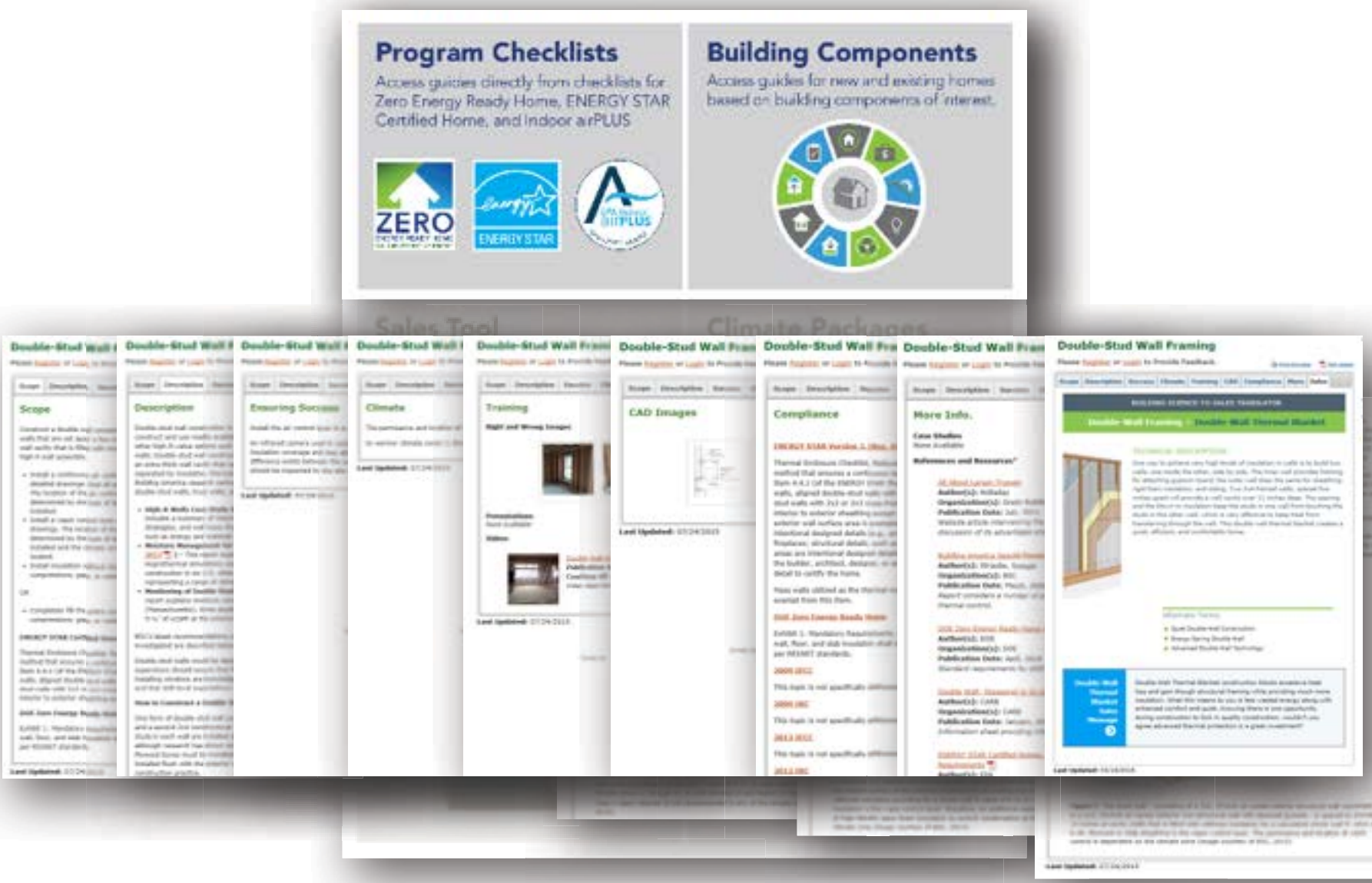
ENERGY STAR HOMES

ask about EPA Indoor airPLUS QUALIFIED HOMES

WaterSense Meets EPA Criteria

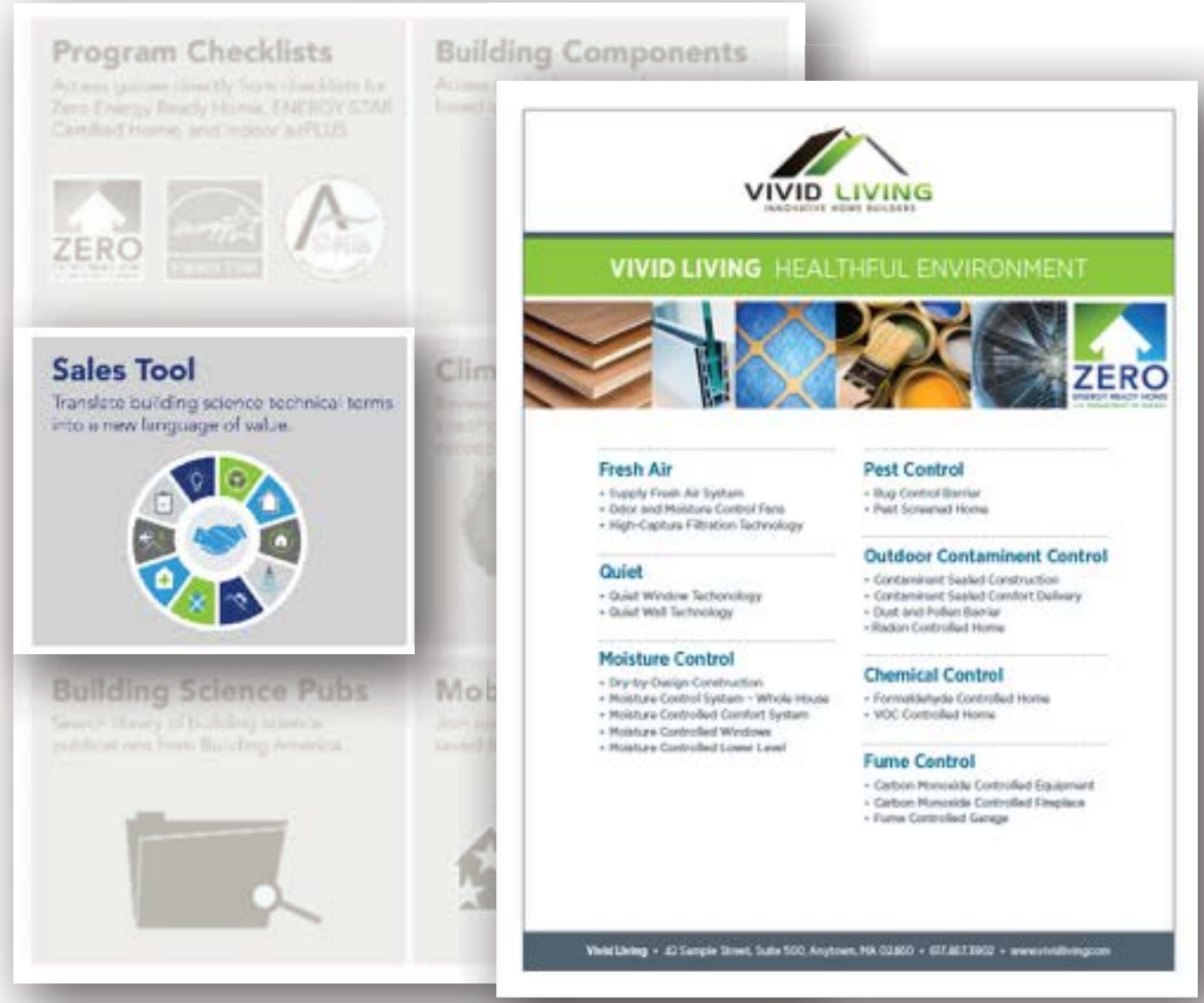
# BASC Guides




Program Checklists
Access guides directly from checklists for Zero Energy Ready Home, ENERGY STAR Certified Home, and Indoor airPLUS
ZERO
ENERGY STAR
Building Components
Access guides for new and existing homes based on building components of interest.
Double-Stud Wall Framing
Scope
Description
Climate
Training
CAD Images
Compliance
More Info.

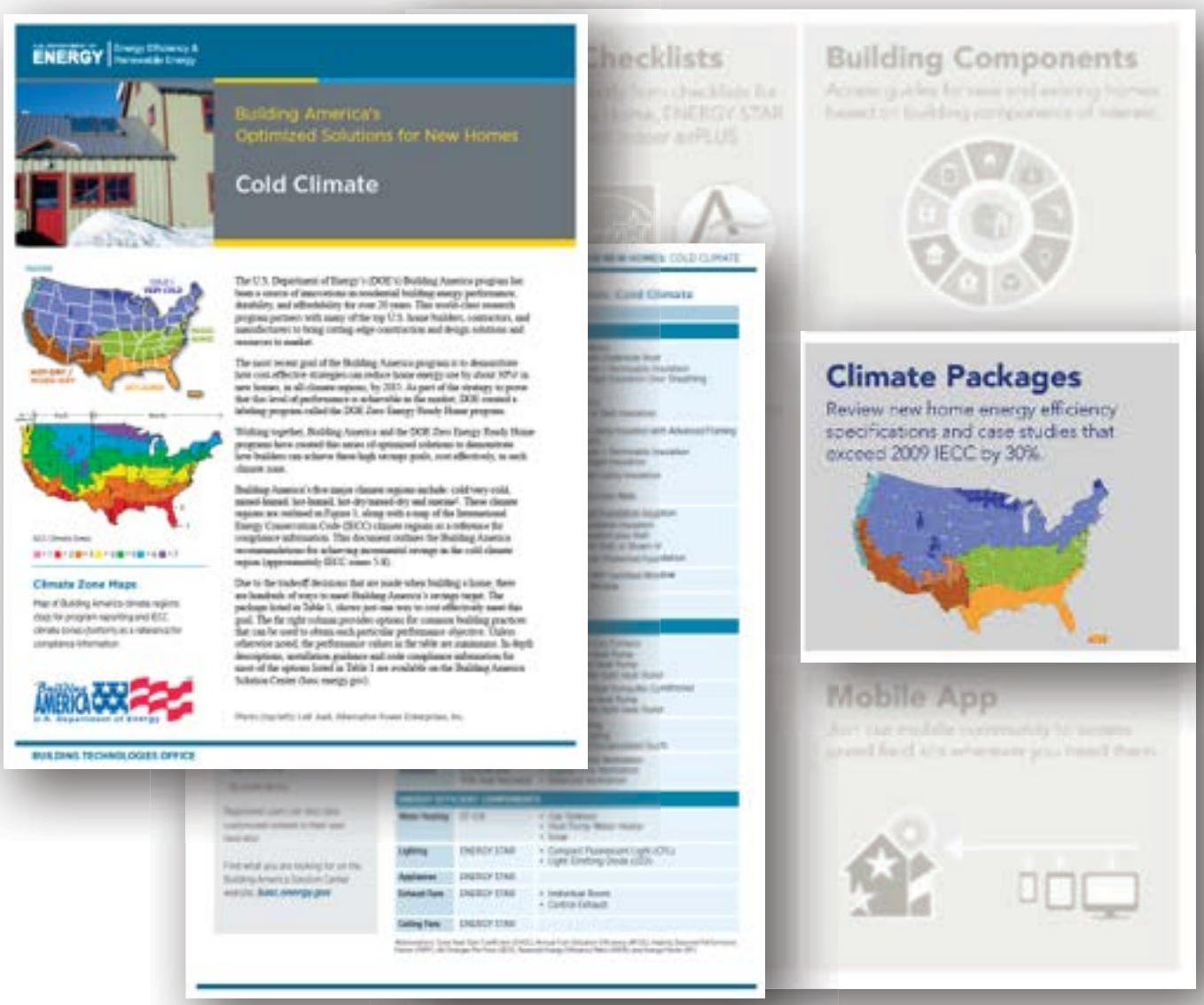
# BASC Sales Tool





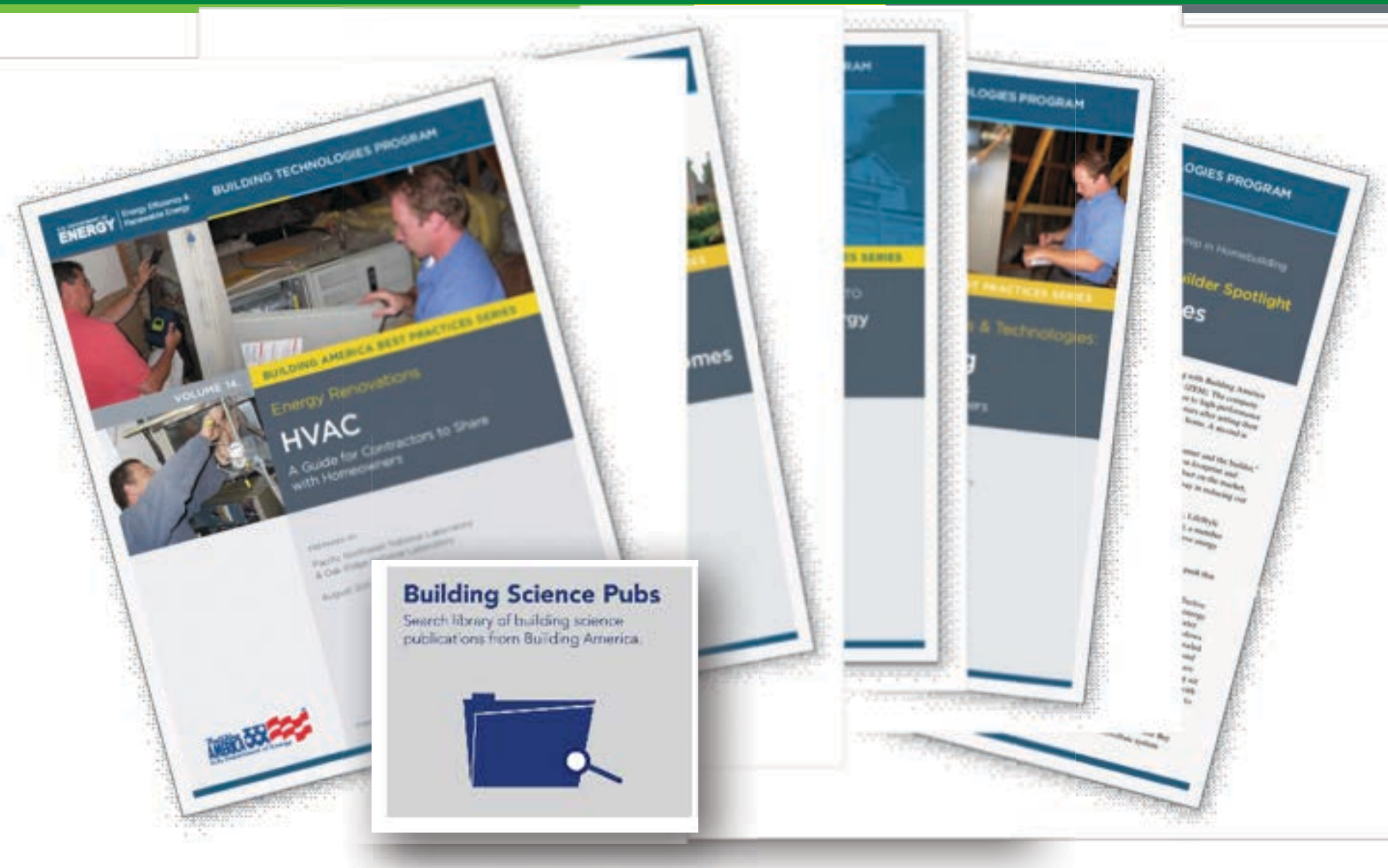
# BASC ZERH Climate Packages





# BASC Building Science Publications





# BASC Mobile Application



# Snapshot of BASC Content



- 209+ full guides
- 1,500+ images
- 115+ CAD drawings
- 270+ proven performance case studies
- 500+ peer-reviewed references
- 80+ Videos

# Actions



- Register as a User
- Provide Feedback
  - Errors
  - Improvements
  - Additional Content
- Use as Sales Tool
  - Power Words
  - Customized Point-of-Sale
  - Reference Binders
  - Sales Training
- Use for Training
  - 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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