Building America System Innovations:

Accelerating Innovation in Home Energy Savings

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Project Relevance
Building America Fills Market Need for a High-Performance Homes HUB of Innovation
U.S. Energy Consumption

- Residential: 22%
- Transportation: 28%
- Commercial: 19%
- Industrial: 31%

Building America Business Case
Residential Energy Use Significant
Housing Industry Economic Impact

Housing Sector Percent of GNP

Source: NAHB  data through Q1 2012

- Residential Construction: 5%
- Housing Services: 15%
- Combined: 20%
~$2,200: Average Annual Household Energy Bill

>113,000,000: DOE Housing Units in America

>$240 Billion: Amount spent on home utility bills per year.

>$120 Billion: Available to the economy

if we make our houses 50% more efficient (i.e., President SOTU address)
Building America Business Case
Housing Underinvests in R&D

R&D Investment as a % of Revenue

- Corporate America: 4%
- Housing Industry: 1%
Building America Business Case
Value Proposition

$2,200: Average Annual Household Energy Bill

$1,100  Annual Value of 50% Savings

<$20M: DOE Building America R&D Budget

~200M: U.S. Taxpayers

Annual Cost per Taxpayer less than:
Problem Statement: **Low industry R&D investments** and **System-level risks and barriers** slow the rate of energy innovation in the residential building sector.
Purpose & Objectives

Project Focus: Building America focuses on “whole house” system-level research required to resolve early market entry barriers to innovation.

BTO Portfolio Element

- Appliance, Equipment & Building Standards
- Emerging Technologies

Research to develop Integrated Residential System Innovations that deliver 50% Whole House Savings
Approach/Project Management
Building America Strategy:
Research to Market Transformation

Program Management
- Manage Impact
- Create Innovation Culture

Research
- Strategic
- Effective Systems

Product Development
- Customer focused Solution Center

Sales
- Customer based Market Delivery
Market Transformation Process

**Codes**
Drive ENERGY STAR spec

- MEC 1993
- IECC 2006
- IECC 2009
- IECC 2012

**ENERGY STAR**
Drives code changes, market

- ENERGY STAR v1
- ENERGY STAR v2
- ENERGY STAR v3
- ENERGY STAR v4

**Builders Challenge**
ENERGY STAR Next Gen Farm System

- Builders Challenge v1
- DOE Challenge Home
- DOE Challenge Home v2

**Building America**
Develop & demo Solutions

- Building America Phase 1
- Building America Phase 2
- Building America Phase 3
- Building America Phase 4
Market Transformation Results

ENERGY STAR Homes Growth leads IECC code adoption

% Energy Savings

2006 IECC Baseline

Residential Building Energy Codes


15% 30%

-30% -20% -10% 0% 10% 20% 30% 40% 50% 60%

ENERGY STAR Market Penetration

Baseline

2006 IECC

1. Efficiency
   - Thermal Enclosure ("Envelope")
   - Low-Load HVAC
   - Efficient Components

2. Performance
   - Comfort
   - Health
   - Durability
   - Renewable Readiness/Integration
   - Water Conservation
   - Disaster Resistance
Building America Goal

Goal:
High-Performance Zero Net-Energy Ready New & Existing Homes

ZNER New/Exist. Home

Minimum Code New Home

Energy Star Certified New Home

New Home

Typical Existing Home

Low Efficiency

High Efficiency

Low Performance

High Performance
Goal: High-Performance Zero Net-Energy Ready New & Existing Homes

Thermal Load

1970 - 1980
Thermal Load
1980 - 1990
Thermal Load
1990 - 2000
Thermal Load
2000 - 2010
Thermal Load
2010 - 2020
Thermal Load
2020 - 2030
Thermal Load

Resulting Research Priorities

Thermal Enclosure
Water Man.
Ventilat’n/IAQ
Low-Load HVAC

Eff. Comps./MEL’s
Durability
Infrastructure Development
Bldg. Integr. Renewables

Building America Technology Path

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

17 | Building Technologies Office
eere.energy.gov
System Research Goals

Impact of Project: *Whole house system innovations, leading to 50% energy savings in new and existing homes.*

![Bar chart showing energy savings](chart.png)
System Research Approach: Building America system research portfolio includes four key elements (project types):

1. System Performance Mapping → Whole House Models/System Interactions
2. Cost/Performance Analysis → Least Cost Path and Performance Gaps
3. Whole House Field Testing → Validated Energy and Non-Energy Benefits
The residential program is grounded on technology and systems research. This research is translated into implementation tools to make solutions accessible to practitioners. Finally, deployment initiatives promote speed and scale to successfully transform the market.
System Research Approach

Key Issues: Key system research issues include moisture management and cladding attachment in high R wall systems and development of low load HVAC and distribution systems for homes with 50% smaller loads than current homes.

Vapor Retarder Definitions

The 2009 IRC R601.3 gives the following definitions and examples for vapor retarder classes:

<table>
<thead>
<tr>
<th>Class</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>( \leq 0.1 \text{ perm} )</td>
<td>Sheet polyethylene, sheet metal, non-perforated aluminum foil, foil-faced insulation sheathing</td>
</tr>
<tr>
<td>II</td>
<td>( &gt; 0.1 ) to ( &lt; 1.0 \text{ perm} )</td>
<td>Kraft-faced fiberglass batts or low-perm paint, unfaced expanded polystyrene, fiber-faced polyisocyanurate</td>
</tr>
<tr>
<td>III</td>
<td>( &gt; 1.0 \text{ perms} )</td>
<td>Latex or enamel paint</td>
</tr>
</tbody>
</table>
Distinctive Characteristics: Using a system approach, Building America analyzes tradeoffs to maximize incremental value & minimize incremental cost.

Phoenix, 2500 ft², 2-story, $9000 first cost increase.

Systems approach out-performs single measure approach
Building America Project Portfolio: 2012 funded projects...

by Sector
- 58% Retrofit
- 29% New
- 13% Both

by Climate
- 33% Cold
- 19% Hot/Dry
- 19% Marine
- 5% Humid
- 6% Mixed
- 5% None

by House Type
- 50% HUD
- 29% MF
- 18% SF
- 3% All

by Scale
- 64% Test Communities
- 24% Test Houses
- 12% Individual Measures
Targeted Innovation Gaps - 2013

- Unspecified Innovation / Admin
- Research Tools
- Building Science Solutions
- Assured Health and Safety
- Energy Efficient Components
- High-Performance Home Solutions
- New Homes Whole-House Packages
- Whole-House Program Support
- Existing Homes Whole-House Packages
- Informing Codes/Standards Process
- Informing Transaction Process
- Educating Professionals
- High-Performance Home Metrics

FY13 Project Proposals ($000)

Unfunded or underfunded innovation areas
World Class Building Systems Research

Building America Solution Center
BASC.energy.gov

At Your Fingertips!

http://www1.eere.energy.gov/buildings/residential/ba_solution_center.html
**Project Plan & Schedule**

*Project original initiation date: 1/1/2010*

*Project planned completion, 30% savings: 12/31/2014*

*Project planned completion, 50% savings: 12/31/2020*

<table>
<thead>
<tr>
<th>Task / Event</th>
<th>FY2012</th>
<th>FY2013</th>
<th>FY2014</th>
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<tbody>
<tr>
<td><strong>Project Name: Building America Research</strong></td>
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<tr>
<td>2012 Planning Meeting: 2013 R&amp;D Milestones</td>
<td>Q1 (Oct-Dec)</td>
<td>Q4 (Jul-Sep)</td>
<td>Q2 (Jan-Mar)</td>
</tr>
<tr>
<td>2012 Technical Update Meeting: 2012 Innovations</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
<td>Q3 (Apr-Jun)</td>
</tr>
<tr>
<td>2012 Annual Report</td>
<td>Q3 (Apr-Jun)</td>
<td>Q1 (Oct-Dec)</td>
<td>Q1 (Oct-Dec)</td>
</tr>
<tr>
<td>2013 Stakeholder Meeting: Solutions for Existing Homes</td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q2 (Jan-Mar)</td>
</tr>
<tr>
<td>2013 Project Plan: FOA Schedule and Critical Innovations plan for 50% Savings</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
<td>Q3 (Apr-Jun)</td>
</tr>
<tr>
<td><strong>Future Plans</strong></td>
<td></td>
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<tr>
<td>Complete performance specifications for 30% homes</td>
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<tr>
<td>Complete high R enclosure system guidance for 30% homes</td>
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<tr>
<td>Complete low load HVAC system guidance for 30% homes</td>
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<tr>
<td>Complete technology pathways report for 50% homes</td>
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**Legend**

- Work completed
- Active Task
- Milestones & Deliverables (Original Plan)
- Milestones & Deliverables (Actual)

**Team Re-competition/Strategy Updates**

- 2010
- 2015
- 2020
Project Budget

Variances: None

Cost to Date: Expenditures are on track with annual spending plan: 50% costed at 50% point.

Additional Funding: Cost share from industry partners averages 20% of total project cost including building materials and labor for test houses and in kind.

<table>
<thead>
<tr>
<th></th>
<th>FY2010</th>
<th>FY2011</th>
<th>FY2012</th>
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<tbody>
<tr>
<td>DOE</td>
<td>$30 million</td>
<td>$20 million</td>
<td>$15 million</td>
</tr>
<tr>
<td>Cost-share</td>
<td>$6 million</td>
<td>$4 million</td>
<td>$3 million</td>
</tr>
</tbody>
</table>

10 industry teams, 4 universities, 4 national laboratories
Progress and Accomplishments
Accomplishments and Progress: Proven Innovations

Proven Innovations:

1. Advanced Techs. & Practices
   - 1.1: Building Science Solutions
   - 1.2: Eff. Components
   - 1.3: Assured Health, Safety, & Durability

2. House-as-a-System Business Case
   - 2.1: New Homes w/Whole-House Packages
   - 2.2: Existing Homes w/Whole-House Pkgs.
   - 2.3: Program Support

3. Effective Guidance & Tools
   - 3.1: High-Performance Home Solutions
   - 3.2: High-Performance Home Metrics
   - 3.3: Research Tools

4. Infrastructure Development
   - 4.1: Educating Professionals
   - 4.2: Recognize Value in Transaction Proc.
   - 4.3: Informing Code/Standards Process

Gaps:

- 2.2: Existing Homes w/Whole-House Pkgs.
Accomplishments and Progress: Proven Innovations

32 Top Innovation Profiles:

BUILDING AMERICA TOP INNOVATIONS ‘HALL OF FAME’ PROFILE


In response to increasing code requirements and improving construction practice, IECC released a third-generation guideline (ENERGY STAR for Homes 3.0) that took effect on July 1, 2012. Homes built to ENERGY STAR for Homes Version 3.0 are approximately 15% more efficient than those built to the 2009 IECC. More importantly, these latest specifications ensure comprehensive building design with detailed checklists substantially informed by Building America research. In addition, DOE is working with EPA by making the vast expertise of Building America research teams available for ongoing guidance on the wide array of technical issues and questions required to maintain these specifications.

In October 2010, DOE began developing the 2012 specifications for the DO Challenge Home in coordination with EPA. The goal was to finally align the old Building America (DOE) and ENERGY STAR for Homes models to ensure a unified federal government and process for promoting advanced building science.

The project is an opportunity to "prove-out" building science measures targeted for the next new homes specifications while providing an opportunity to "streamline" technologies and best practices successfully established in their building America research program (DOE 2010).

REFERENCES


Innovations in building science — The U.S. Department of Energy Building America’s office has two energy and materials science programs:

Building America's Office for Homes Support

Building America, DOE Challenge Home, and ENERGY STAR for Homes are examples of "good government" programs working together as a system, creating a highly effective market transformation process that stimulates a cascade of new innovations.

Building America - Office for Homes Support

Building America’s Office for Homes Support (EERE) provides technical support to communities, organizations, and homeowners in the use of energy efficient strategies and program support.
Since 1995, Building America Innovations have resulted in approximately 0.32-0.80 quads of cumulative energy savings for U.S. homeowners and continue to grow each year (new construction market impacts only).

These energy savings correspond to a cumulative utility cost savings of approximately $6.3-$15.8 Billion.*

* Based on 1990-2015 estimates from 2011Building Energy Data Book, Table 2.3.1
“Builders do not have the technical resources to evaluate manufacturer’s claims. Building America is the only source of independent research on new technologies. Adoption of BA research has provided real benefits to our customers.”

Building America Industry Partner (Top 10 Builder)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Cost/Performance Analysis, System Performance Maps and Field Studies</td>
<td>Validation of delivered system energy savings and non-energy* costs and benefits</td>
</tr>
<tr>
<td>Performance Feedback to Research Partners</td>
<td>Increased system reliability and performance</td>
</tr>
<tr>
<td></td>
<td>Reduced system risks and costs</td>
</tr>
<tr>
<td>Knowledge Outreach: Technical support for codes and standards, development of supply chains, performance rating, and building science education</td>
<td>Accelerated market delivery of buildings as systems</td>
</tr>
</tbody>
</table>
Accomplishments and Progress

Progress on Goals: The project is on track to produce validated energy systems that deliver 30% energy savings by 2015 and 50% energy savings by 2020.
Example: Duct System Innovation

Ducts in Conditioned Space:
Building America provided proven solutions for locating ducts in conditioned space that are being adopted by builders across the country.

• ~8 – 15% savings on air conditioning bills
• 1,000’s of homes
Example: Duct System Innovation

Ducts in Conditioned Space:
Building America developed and demonstrated 6 different cost-effective solutions for locating ducts inside conditioned space. All are being adopted by builders across the country.
Example: Duct System Innovation

Figure 20. Ductwork well-sealed to sheetrock with ccSPF

Figure 21. Rigid insulation inserted under ductwork to serve as a substrate and provide insulating value

Figure 22. Varying thickness of ccSPF and interference from cross bracing

Figure 23. Varying application thicknesses shown on rectangular (left) and round (right) ducts
Phased Deep Energy Retrofits: Building America is currently investigating strategies for phased whole house retrofits to achieve deep energy savings (>50%).

• Parker residence achieved “Net Positive” in 2012, through incremental cost effective retrofits
Example: WH Retrofit System Innovation

Source Energy & Retrofit History for Parker Family
Electricity and Natural Gas
Cocoa Beach, 1989 - 2011

- Source Energy
- 12-month moving average

- R19 Ceiling & Tile Floor
- Seal Ducts
- WH Fan & New Frig
- New WH
- PV Pool Pump
- White Roof
- New AC
- Solar DHW & Gas
- Add Freeze
- +500 ft² Remodel
- Add 2nd Frig
- ES Ceiling Fans
- Remove Freezer
- Energy Feedback
- ES Dishwasher 4.4 kW
- & WHF PV
- HIEFF Windows
- Wall Ins.
- & Mini-split
- Add 0.33 kW
- PV
- ES Kitchen Fridg

Zero Energy Objective
Awards/Recognition: Annual innovation awards were initiated in 2012 and 32 innovations were awarded. 10-20 additional innovation awards are expected each year.

http://www1.eere.energy.gov/buildings/residential/ba_innovations.html
Collaborations, Tech Transfer, and Market Impact
Project Integration, Collaboration & Market Impact

Partners, Subcontractors, and Collaborators:

http://www1.eere.energy.gov/buildings/residential/ba_research.html

National Labs: NREL, PNNL, ORNL, PNNL
Deployment Program Partnerships:

- **DOE Challenge Home & Energy Star:** All new construction projects
- **Home Performance w/Energy Star:** 13 Projects (BSC, FSEC, IBACOS, NAHBRC, PARR)
- **Better Buildings Neighborhood Partnership grantees:** 3 projects (FSEC)
- **Better Buildings Challenge:** 6 projects (IBACOS)
- **Home Energy Score Pilots:** 5 projects (DEG, FSEC, IBACOS)
- **Weatherization Assistance Program:** 3 projects (DEG, UMN)
Technology Transfer, Deployment, Market Impact: Building science knowledge is integrated into real world projects and the Building America Solution Center

What Is SheaXero?
SheaXero is a state-of-the-art package, available for a limited time at no extra cost, which combines a solar power system with energy-efficient features to eliminate your electric bill.

No bills. No gimmicks. No kidding.
Next Steps and Future Plans
Next Steps and Future Plans:

- Future research will focus on developing the innovations required to deliver 50% savings and enable net zero energy ready homes at community-scale.
- A FOA will be issued by DOE in October, 2014 to select the industry research teams for 2015-2020.
Next Steps and Future Plans

Public Records and Census Data
- Floor Area, Bedrooms, Foundation Type, Year Built

Monthly Bills
- High-Interval Meter Data
- Data for Automated Calibration and/or Inverse Modeling

Satellite Imagery
- Footprint, Orientation & Shading

Drive-By Infrared Thermographic Imagery
- Thermal Properties & Geometry

Data-Driven, Physics-Based Simulation and Optimization Software

Community scale optimization

Community scale energy savings potential

Targeted deployment at scale