Designing Low Air Leakage Homes Insulated with Spray Polyurethane Foam

Spray polyurethane foam combines dual attributes of insulation and air barrier, making it a material of choice when a low blower door result is desired. Bayer MaterialScience is developing design solutions for congruent use of SPF with other building materials and components to create a high performance building envelope.

Jim Lambach – Manager, BMS Spray Insulation Technology & Technical Marketing
Bayer Companies

Science For A Better Life
Bayer MaterialScience

High-tech Polymers, Innovative Solutions

- Basic Chemicals: 27%
- Coatings, Adhesives, Sealants: 15%
- Polycarbonates: 2%
- Thermoplastic Polyurethanes: 51%
- Polyurethanes: 4%
Bayer MaterialScience

Participation in the Construction Segment

**Daylighting**
- windows, skylights
- single, multi-wall sheet
- diffuser sheet
- pultruded lineals
- encapsulated framing

**Sustainable Energy**
- photovoltaic, geothermal
- encapsulant film
- pultruded lineals
- water pillow tanks

**Insulation**
- roof, walls, floors
  - SPF insulation
  - SPF roofing
  - polyiso board
  - Refrigerators
  - Water heaters

**Artificial Illumination**
- LED lighting systems
- optics & lenses
- covers & housings
- diffuser film

**Smart Grid**
- charging stations, smart meters
- housings, covers
- displays
- plugs

**Indoor Environment Quality**
- efficient, low emission formulations
- coatings, adhesives, sealants
- OSB binders, SPF insulation
Focused on Implementing Sustainable Manufacturing Practices

<table>
<thead>
<tr>
<th>KEY ECOLOGICAL DATA</th>
<th>2008</th>
<th>2009</th>
</tr>
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<tbody>
<tr>
<td><strong>USE OF RESOURCES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy use (in petajoules)</td>
<td>82.8</td>
<td>77.3</td>
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<tr>
<td>Water use (in MM m³/day)</td>
<td>1.20</td>
<td>1.11</td>
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<tr>
<td><strong>EMISSIONS</strong></td>
<td></td>
<td></td>
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<tr>
<td>Direct greenhouse gas emissions (CO2 equiv. in MM tons)*</td>
<td>5.09</td>
<td>4.57</td>
</tr>
<tr>
<td>Indirect greenhouse gas emissions (CO2 equiv. in MM tons)*</td>
<td>3.57</td>
<td>3.53</td>
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<tr>
<td>VOC emissions (in kt p.a.)</td>
<td>3.16</td>
<td>2.59</td>
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<tr>
<td>Total phosphorus in wastewater (in kt p.a.)</td>
<td>0.78</td>
<td>0.74</td>
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<tr>
<td>TOC in wastewater (in kt p.a.)</td>
<td>1.59</td>
<td>1.35</td>
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<tr>
<td>Total nitrogen in wastewater (in kt p.a.)</td>
<td>0.67</td>
<td>0.64</td>
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<tr>
<td><strong>WASTE</strong></td>
<td></td>
<td></td>
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<tr>
<td>Hazardous waste generated (in kt p.a.)</td>
<td>365</td>
<td>375</td>
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<tr>
<td>Hazardous waste landfilled (in kt p.a.)</td>
<td>81</td>
<td>89</td>
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</table>

*Portfolio adjusted as per Greenhouse Gas Protocol
Committed to Developing Sustainable Building Technologies

Buildings are a Principal Source of Energy Consumption and GHG Emissions
DOE Hub Member

Greater Philadelphia Innovation Cluster for Energy Efficient Buildings

- Transform building industry from fragmented approaches to an integrated systems approach.
- Improve energy efficiency & operability & reduce carbon emissions of new & existing buildings.
- Stimulate private investment & quality job creation in the Greater Philadelphia region & beyond.

**Strategic Focus**

Full-spectrum retrofit of existing average size commercial & multi-family residential buildings.
GPIC: Greater Philadelphia Innovation Cluster for Energy Efficient Buildings

DOE HUB Members
- Penn State (lead)
- Bayer Materials Science
- Ben Franklin Technology Partners of SE PA
- Carnegie Mellon University
- Collegiate Consortium
- Delaware Valley Industrial Resource Center
- Drexel University
- IBM Corporation
- Lawrence Livermore National Laboratory
- Morgan State University
- New Jersey Institute of Technology
- Philadelphia Industrial Development Corporation
- PPG Industries
- Princeton University
- Purdue University
- Rutgers University
- Turner Construction
- United Technologies Corporation
- University of Pennsylvania
- University of Pittsburgh
- Virginia Tech
- Wharton Small Business Development Center

GPIC Stakeholder Groups
- Local STEM Community
- Apprenticeship Programs
- Secondary Schools
- Career and Technical Institutes
- One-Stop Career Centers
- Workforce Investment Boards
- Community Organizations
- Local and State Agencies
- Economic Development Agencies
- Philanthropic Foundations
- Venture Capitalists
- Banks and Financial Institutions
- Publicly and Privately Held Businesses
- Industry Associations
- Labor Organizations

GPIC Partners
- Industry Partners
  - Air Products and Chemicals
  - ALSTOM Power
  - Ametek
  - Armstrong World Industries
  - Boeing Company
  - C.B. Richards
  - CertainTeed Corporation
  - Construction Specialties
  - Deloitte Services LP
  - Dow Chemical Company
  - DuPont Building Innovations
  - Flad Architects
  - HOK
  - Horton Lees Brogden Lighting Design
  - Johns Manville
  - Lafarge
  - Lam Partners
  - Larson Design Group
  - Linc Lighting and Electrical
  - Lockheed Martin
  - PECO
  - Pfizer Global Engineering
  - PIM Interconnection
  - Pittsburgh Corning
  - Rose Companies
  - Saint-Gobain
  - Sauco, Inc.
  - Schneider Electric
  - Siemens
  - Thornton-Tomasetti Group
  - URS Corporation
  - Vivid Energy
  - Weber Murphy Fox, Inc.

Community and Economic Development Partners
- Economy League of Greater Philadelphia
- Citizens for Pennsylvania's Future
- Select Greater Philadelphia
- University City Science Center

Government Partners
- Commonwealth of Pennsylvania
- Delaware Valley Regional Planning Commission
- City of Philadelphia
- Naval Surface Warfare Center Carderock Division
- New Jersey Economic Development Authority

Labor organizations
- National Roofing Contractors Association
- Penn Del-Jersey Chapter of NECA

International Partners
- Lund University, Sweden
- Tsinghua University, China
EcoCommercial™
Building Network

We’re building a collaborative network that brings together innovative products and services to make sustainable, environmentally-friendly, and profitable building solutions possible.

Customized Concepts
- Innovative product & service solutions
- Energy-based concept implementation
- Material & technology solutions

Analytical Consulting
- Analytical tools
- Energy & ecology metrics
- Certification assistance

Financial Consulting
- Target value design
- Cost assessment & efficiency
- Financing & funding processes
Introduction of the High Performance Residential Program

- Whole house energy solution built on the unique insulation and air sealing performance of spray polyurethane foam.
- Comprehensive, cost effective approach to producing energy efficient, healthy, and comfortable homes.
- Standards and Guidelines used during design phase overlay the builder’s performance targets within a high performance framework.
Builder Listening Events

Industry Input Prior to Launch

• Conducted one-on-one meetings with cross-section of builders.
  – Purpose: Gather input on cost and value of program. Learn more about challenges to implementation and support needed.
  – Senior management involvement in ~70% of interviews.
  – Nearly 80% of are building some type of energy efficient product.

• General builder interviews also conducted through the Alliance.
  – Purpose: Determine business challenges. Identify topics of interest and help needed.
Builder Listening Events – Bayer

Key Feedback

• Value in SPF solution exists, but buyers need to be educated on “cost of ownership”.

• Providing help in the design process is important.

• Need better process and communications with trade contractors.
  – Need standardized installation times for SPF.
  – Need to better understand direct costs for installation.
  – Education needed on building science fundamentals with SPF.
  – Concerns over availability of skilled labor and scheduling.

Business Processes and Approach are as Important as Technology to Achieve Higher Standard
Builder Listening Events – Alliance

Key Feedback

- Builders still need help understanding how to look at whole house design as performance targets continue to change (ENERGY STAR, codes).

- The process of engaging internal and external teams, implementing new standards, and managing change is an even bigger challenge.

- **Bottom line:** It has to be cost-effective. Homebuyers need to understand the value.

Business Processes and Approach are as Important as Technology to Achieve Higher Standard
The building enclosure of all homes in the program will utilize Spray Polyurethane Foam Insulation.

All homes are REQUIRED to have their heating and cooling system right-sized

All homes are REQUIRED to have ventilation that meets ASHRAE 62.2

All homes are REQUIRED to have ENERGY STAR equipment and be combustion fuel safe.

All homes are RECOMMENDED to be risk free of all water intrusion issues.

The Standards & Guidelines are adapted from Building America’s Builders Challenge and ENERGY STAR.

Several unique additions are focused on building science considerations for homes with very low air leakage.
• Energy Modeling with RESNET® Approved Software
• EnergySmart Home ScaleSM Used for Reporting
• No Specific HERS Target … Builder Defines
• Builder Optional Energy Usage Guarantee
Utilization of Spray Polyurethane Foam is Required by the Program

Multi-Functional Material in the Energy Efficiency Toolkit

Expands to fill and seal any shape

Adheres to most substrates

Class I installation in architecturally complex thermal envelope

oc and cc-SPF are air-impermeable

cc-SPF high R-value per inch and functions as a vapor retarder

Applications:

- walls - between studs or c.i.
- under roof deck or attic floor
- Basement and crawlspace ceiling or walls
- base and sill plates, etc.

50 Production Homes Sealed with SPF and Caulking

Average
1.09 AExch\text{50}
0.07 AExch\text{nat}

Whole House Air Exchanges at 50 Pa
Standards and Guidelines

Building Enclosure

Thermal and Moisture Management

WALLS

- Two Options:
  1. SPF-only application
  2. Hybrid with blown-in fiberglass or cellulose

- Specified insulation minimums by climate zone for SPF-only

- Climate zone specific calculation tool confirms that dew point is located within the SPF for hybrid solutions

- Unvented crawlspaces recommended

- Sill and band joists, floors over garages, and cantilever floors must be SPF-only

**Thermal Enclosure and Moisture Management**

**REQUIREMENT / SPECIFICATION**

1. Complete the High Performance Residential Program Insulation and Air Barrier Checklist for the home. A link to this checklist is listed on the High Performance Residential Program™ http://www.bayer.com/…

2. Builder must keep signed copy of the Insulation and Air Barrier Checklist in builder’s project records. Either builder or third-party verifier may complete the checklist.

3. Third-party verifier must confirm that a signed Insulation and Air Barrier Checklist has been completed.

**Option 1**

**Table 1. Minimum Amount of Spray Foam Required Based on Compliance with IECC 2009 Energy Cost Performance Path**

Other insulation packages must be designed by the Bayer representative to ensure IEECC 2009 Code Compliance

<table>
<thead>
<tr>
<th>System/Climate Zone</th>
<th>CZ 1</th>
<th>CZ 2</th>
<th>CZ 3</th>
<th>CZ 4 Except Marine</th>
<th>CZ 5 and Marine 4</th>
<th>CZ 6</th>
<th>CZ 7</th>
<th>CZ 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior Wall Cavity</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
</tr>
<tr>
<td>Band Joist Cavity</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
<td>OC – Min 3 inches CC – Min 2 inches</td>
</tr>
<tr>
<td>Class II Vapor Retarder</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>REQUIRED for Open Cell Foam</td>
<td>REQUIRED for Open Cell Foam</td>
<td>REQUIRED for Open Cell Foam</td>
</tr>
</tbody>
</table>
WINDOWS

Window performance very similar to ENERGY STAR, except for the introduction of the condensation resistance (CR) rating.

The CR rating reduces the risk of selecting a poor performing window in a cold winter environment when condensation can occur.
Standards and Guidelines

Heating & Cooling

Air Handler and Ductwork Location and Duct Leakage

DUCTWORK

All ductwork inside the thermal boundary

Tight ductwork ensures that all conditioned air is being retained in the house and the demand in each room is being satisfied with a correct amount of air.

Air Handler and Ductwork Location and Duct Leakage

REQUIREMENT / SPECIFICATION

1. Air handler equipment and all duct work shall be located within the conditioned envelope of the house. Total measured duct leakage must be ≤ 6% of conditioned space floor area when measured at 25 Pascal’s using duct pressurization methods.

2. Duct boots sealed to floor, wall, or ceiling using caulk, foam, mastic tape, or mastic paste.
VENTILATION

Balanced ventilation approach insures the amount of fresh air introduced into the home is equivalent to the amount of stale air being removed.

The balanced ventilation system can also be installed independently from the main HVAC air handler.

Whole Building Mechanical Ventilation

**REQUIREMENT / SPECIFICATION**

1. Design and install a mechanical system(s) compliant with ASHRAE 62.2 to provide outside air to the indoor environment through a balanced ventilation system or a central dehumidification ventilation system.

2. Equip outside air intakes for ventilation with filters and shutoff dampers.

Option A ERV or HRV, streams of air are not mixing in the distribution box.

Option B Distribution box, streams of air are mixing in the distribution box.
DEHUMIDIFICATION

A climate zone specific humidity analysis tool estimates number of days when indoor humidity exceeds 60%.

If humidity cannot be controlled supplemental dehumidification is recommended - typically needed in warm humid regions of climate zones 1, 2 and 3.

Dehumidification

REQUIREMENT / SPECIFICATION

1. Install equipment with sufficient latent capacity to maintain indoor relative humidity at or below 60% in Climate Zones 1, 2, 3 and 4, as defined by the 2009 IECC Figure 301.1.
DIRECT VENT FURNACES

Direct venting eliminates potential back drafting concerns.

**Fireplaces**

**REQUIREMENT / SPECIFICATION**

1. Direct vent fireplaces or Electric fireplaces requires no additional ventilation requirements.

2. Atmospherically vented fireplaces must follow the ventilation requirements.
   a. Wood burning fireplaces or B-vented fireplaces are allowed only if they have combustion air from outside to the firebox & the firebox is equipped with gasketed doors.
   b. Wood burning and B-vent fireplaces are only permitted to have a combustion air duct from the outdoors supplied by a rigid sheet metal duct to the firebox.
   c. All wood burning fireplaces or B-vented fireplaces require a fresh air make up air duct supplied to the home by a 6" duct with a barometric damper. Note: if kitchen ventilation requires dedicated makeup air to the home than this requirement does not apply.

Barometric Damper for make up air

B-Vent Gas Fireplace

Direct Vent Gas Fireplace
High Performance Contractor Network

- Health and Safety Training, Occupancy Guidelines, SPF Application Techniques
- Quality Manual/Checklists
- Building Science Education
- Prepared to Support High Volume Builders
- One-Day-Complete for Typical Size Home
Roadmap for Production Builders

Your High-Performance Road Map

1. Planning & Development
   - High-performance
     - Strategic Planning
     - High-Performance Change Management Process
     - Builder Performance Target

2. Design & Specification
   - Customized whole-house solutions
     - Standards & Guidelines Achievement
     - SPF System Specification
     - Home Energy Performance Modeling
     - HVAC Design Optimization

3. Construction
   - One day, complete!
     - Builder Team Training
     - Certified Quality Contractor Program
     - Home Performance Testing

4. Marketing & Sales
   - Home buyer value creation
     - Marketing Collateral
     - Sales Team Training

5. Customer Care
   - Guaranteed advantage
     - Buyer Limited Heating/Cooling Guarantee®
     - Homeowner Guide
     - Energy Meter

*Limited guarantees subject to participation in the Home Performance High Performance Residential Program and compliance with the terms and conditions of the guarantee. Call us for more details.
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