A “Plug and Play” Air Delivery System for Low Load Homes

2017 Building Technologies Office Peer Review
Project Summary

Timeline:
Start date: 08/01/2015
Planned end date: 01/31/2017

Key Milestones
1. Complete Cost Analysis, 01/31/2017
2. Develop Design Methodology, 01/31/2017
3. Secure Builder and Manuf Interest, 01/31/2017

Budget:
Total Project $ to Date:
• DOE: $600,085.00
• Cost Share: $220,845

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• DOE: $600,085.00
• Cost Share: $220,845

Key Partners:
Housing Innovation Alliance

Project Outcome: The Project Goal is to develop a simplified residential air delivery system that is a solution to air distribution and comfort delivery issues in low-load production-built homes.

Outcomes include the following:
• A straightforward, intuitive design method and companion guidance documents
• Justification and suggested language for needed code and standard changes
• Commitment from a manufacturer partner to pursue product development and a builder partner to demonstrate the technology based on the project’s findings
Purpose and Objectives

Problem Statement:

• The residential HVAC market is struggling to achieve effective HVAC system design, installation, and commissioning in lower-load homes

• Heating and cooling to each space is not optimally delivered from smaller-capacity equipment with traditional air distribution systems

• Traditional duct systems have a host of problems, including installation labor, leakage, constriction, and energy loss

• These issues can inhibit low-load homes from achieving broader industry performance goals, including energy efficiency and comfort

Target Market and Audience:

• Market: new construction low-load homes (0.01 quads/year) – 2012 IECC enclosure, 2,000-3,000 ft² “sweet spot”

• Audience: Home builders, HVAC contractors and system designers, HVAC equipment manufacturers and component suppliers, and material suppliers
Purpose and Objectives

Impact of Project: Project Outputs

- Characterize the performance parameters for plastic small diameter rigid ducts and fittings and other, off-the-shelf duct products
- Characterize the installed “comfort” (temperature) impact of Plug and Play system
- Define the range of application for the system in terms of home size, load, load density, and climate
- Analyze the cost and installation impacts
- Compare the performance and cost to traditional air distribution system approaches
- Develop installation guidance
- Develop a documented design methodology
- Secure interest from a builder and manufacturer
Purpose and Objectives

Impact of Project:

• Could revolutionize ducted air distribution like PEX piping impacted plumbing distribution
  – PEX costs 25% - 45% less, installed
  – Rapid claim to majority market share
• Potential for significant cost savings vs. conventional systems, with performance benefits
  – More discrete room-by-room zoning opportunities
  – Improved comfort - energy is effectively used
  – Simplified design and installation
  – Facilitates integration into conditioned space
• Alternative to all conventional and small diameter air distribution systems on the market
• Residential ductwork is a $1.2 Billion market annually
  – 10% new constr. market penetration in 5 years
  – 25% penetration in 10 years, plus retrofit market
• As costs decrease, market penetration increases
### Purpose and Objectives

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Activities / Partners</th>
<th>Outputs</th>
<th>Short Term Outcome</th>
<th>Mid-Term Outcome</th>
<th>Long Term Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrate &amp; integrate energy efficient technologies &amp; practices in representative homes</td>
<td>Competitive R&amp;D funding focused on demo, testing &amp; validation by Building America &amp; national lab researchers in field homes</td>
<td>Space conditioning, water heating &amp; IAQ focused Building America upgrade packages &amp; techniques for existing &amp; new homes across climates</td>
<td>Innovator building professionals equipped with validated energy saving solutions for integrating highly energy efficient tech or practices into homes</td>
<td>Leading building professionals improve or construct high performance homes above model energy codes</td>
<td>Industry standard orgs adopt technical specs to accelerate new tech &amp; practices in building energy codes</td>
</tr>
<tr>
<td>Prove energy saving solutions &amp; programmatic designs on a national scale with market partners</td>
<td>Resources development with national labs for building prof. &amp; service providers</td>
<td>Guidance for energy savings beyond energy codes &amp; industry standards for stakeholders</td>
<td>Industry standard orgs. &amp; voluntary programs equipped with validated technical specs &amp; guidelines to make homes highly efficient</td>
<td>Energy efficiency programs facilitate market demand for energy efficient &amp; better homes &amp; communities across climates</td>
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</tr>
<tr>
<td>Accelerate market adoption by increasing understanding of effective energy saving solutions</td>
<td>Support business model demo to upgrade or construct high perf. homes with market partners across climates</td>
<td>Best practice online Better Buildings &amp; Buildings America Solution Centers</td>
<td>Demonstrated home upgrades &amp; new construction in HPwES &amp; ZER Homes</td>
<td>Industry standard orgs. install proven energy saving solutions in the broader market</td>
<td>Industry stakeholders widely promote value of energy efficiency in products, services, &amp; typical market transactions with homeowners</td>
</tr>
<tr>
<td>Outreach to stakeholders on a national scale to increase adoption of energy efficiency solutions in common transactions.</td>
<td>Tool development &amp; demo of the value of energy efficiency in the market with market partners</td>
<td>Peer sharing via Better Building Residential Network</td>
<td>Targeted campaigns to propel adoption of low cost home upgrade improvements</td>
<td>Home Energy Score tool</td>
<td>Building professionals install proven energy saving solutions in the broader market</td>
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<td>Educational support to promote quality workforce</td>
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<td>Building science curriculum, student competitions &amp; workforce development</td>
<td>Wide array of industry stakeholders &amp; building professionals aware of strategies to increase energy efficiency</td>
<td>Industry stakeholders widely promote value of energy efficiency in products, services, &amp; typical market transactions with homeowners</td>
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</tbody>
</table>

**Impact**:
- 40% savings in existing homes demo’d
- 60% savings in new homes demo’d
- 10% savings thru individual measures

**Proved in**:
- 1 million existing homes & 50K ZER new homes

**Market Partnerships reach**:
- 90% of homes
- 5% savings thru individual measures with partners

**Reduce the energy used for space conditioning & water heating in single family homes by 40% by 2025 from 2010 levels**

**U.S. Department of Energy**

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**Energy Efficiency & Renewable Energy**
Approach

**Approach:**

- Use benchtop tests, mock ups, lab house tests, and performance simulation to do the following:
  - Develop a new “Plug and Play” design methodology (NO BALANCING DAMPERS)
  - Define its application parameters
  - Evaluate installation, constructability, and cost
  - Test this design against a conventional system
- Engage the market
Key Issues: Conventional Duct Systems

• Difficult to access all duct runs for maintenance and dampering

• Current labor pool is unwilling, unskilled, or unavailable to practice good duct design and installation

• Traditional duct systems are often:
  – Oversized for low loads
  – Leaky, requiring secondary sealing
  – Routed though unconditioned space
  – Not well-integrated into home
  – Dirt collectors

• Comfort and performance suffers

• Too many SKUs
Approach

Distinctive Characteristics:

• A home-run manifold of small diameter (2-3 inch) ducts to work with small-capacity equipment to deliver predictable performance for low-load homes

• Intended to use off-the-shelf products as a kit-of-parts with fewer SKU’s to install a simplified duct system with less error/waste than conventional systems

• Conventionally-skilled tradespersons and home designers will have a quick, efficient and credible method for designing an air delivery system that responds to the unique qualities of lower-load homes and emerging comfort systems, providing reliable design results.
Progress and Accomplishments

Accomplishments:

• Completed a design methodology
  – Using ACCA Manual J loads and airflows
  – Based on plastic ducts but completed analysis of alternate duct materials
  – Evaluated range of applications for Plug and Play duct system
• Simulation
  – Created a detailed multi-zone model using Energy Plus Airflow Network
  – Calibrated model to unoccupied lab home data
  – Evaluated “comfort” performance of Plug and Play duct system compared to traditional systems
• Compared installation material & labor costs to traditional duct system
• Engaged Codes community around use of plastic ducts
Progress and Accomplishments

Market Impact:
- Ongoing engagement with homebuilders – interest to demonstrate or pilot the technology when available
- Engaging potential commercialization partners
- Pursuing code approval of plastic ducts while exploring the use of existing, off-the-shelf duct materials
- Defining target house types and climate zones
- Developing cost comparisons and value story
- Engaging Standards organizations
Progress and Accomplishments

Awards/Recognition: None

Lessons Learned:

• All homes could use 3.0” flexible ductwork.
• 2.5” smooth ductwork provides sufficient airflow for a 2200 sq. ft. home in climate zones 2-5.
• Smaller homes (<1200 sq. ft.) or very low load homes built (i.e. Passive House) can use 2.0” smooth ductwork.
• A simplified design method is possible with proper load calculations and uniform duct diameters & materials.
Progress and Accomplishments

Lessons Learned:

• Plug and Play achieves equal or better thermal uniformity in homes than a traditional duct system.
  – Exception when large disparity between heating and cooling loads and airflow needs in the house

• The EnergyPlus Airflow Network is a powerful tool to simulate the dynamic effects of air delivery systems
Progress and Accomplishments

Lessons Learned:

• The Plug and Play duct system is cost competitive to traditional duct systems, installed

<table>
<thead>
<tr>
<th>Duct System</th>
<th>Hours</th>
<th>Labor Cost @ $33.35 hr.</th>
<th>Material Cost</th>
<th>SKU’S</th>
<th>Length of duct</th>
<th>Cost of ductwork system</th>
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</thead>
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<tr>
<td>Traditional</td>
<td>18 (including 6 hr bulkhead)</td>
<td>589</td>
<td>487</td>
<td>6</td>
<td>35’ trunk + 50’ flex</td>
<td>$ 1,076</td>
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<tr>
<td>2.5” PVC</td>
<td>10 (including 6 hr bulkhead)</td>
<td>330</td>
<td>686</td>
<td>6</td>
<td>210’</td>
<td>$ 1,017</td>
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<td>2” PVC</td>
<td>6</td>
<td>195</td>
<td>440</td>
<td>6</td>
<td>250’</td>
<td>$ 635</td>
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</table>

Notes:
• PVC costs were off-the-shelf pricing
• Time and motion study was conducted in a 1,200 ft² 2-story townhome
• 2.5” PVC is used only for furnace combustion pipes so off-the-shelf prices are escalated
• Schedule 40 pipe is not required for air distribution; schedule 10 to 15 would be more adequate which could reduce the material costs by half
Progress and Accomplishments

Lessons Learned:

• Code acceptance of plastic duct materials hinge on their function as a pathway between discrete zones (rooms) in a home
  – An automatic shutoff at the furnace could be a solution
  – Shutoff dampers between rooms is another option
  – Ultimately, a plastic meeting UL 181 Class 1 requirements for flame spread and smoke is ideal
Project Integration and Collaboration

Project Integration:

• Innovation Pathway
  - Model for collaboration to discover, define, demonstrate and deliver innovative solutions with economic and stakeholder value

• Builder Engagement
  - Connect with builder clients and partners to socialize the technology concept and project outcomes

• Manufacturer Engagement
  - Explore commercialization partnerships

• National Lab Engagement
  - Critical collaboration on development of simulation aspects (i.e. EnergyPlus Airflow Network)

• Industry Codes & Standards Organizations
  - ASHRAE, ICC
Partners, Subcontractors, and Collaborators:

Housing Innovation Alliance (a.k.a. “Alliance”)

- 75+ homebuilder members
- Represent 200,000 housing units annually
- A dozen innovative building industry product suppliers and manufacturers
- Collaborative homebuilding solutions
- Multi-venue feedback loop

Alliance partnership provides ongoing venue for communication of project outputs, socialization among Top 100 homebuilders, manufacturer engagement, and opportunities for product demonstration and a path to market.
Project Integration and Collaboration

Communications:
• Housing Innovation Alliance
• ASHRAE
• Pennsylvania Housing Research Center
• U.S. Department of Energy

Next Steps:
• Complete final project report and peer reviews
• Close out project documentation

Future Opportunities:
• Secure commercialization partner to develop technology and deliver to market
• Develop companion components: dampers, plenum/manifold, diffusers
• Develop design & commissioning standards
• Demonstrate product technology in field test homes and pilot projects
• Explore retrofit market integration
REFERENCE SLIDES
Project Budget: $820,930: $600,085 Federal + $220,845 Cost Share

Variances: A no-cost time extension was granted in June 2016 to extend the project timeline from July 31, 2016 to January 31, 2017.

Cost to Date: 100% of project budget expended through January 31, 2017.

Additional Funding: None

## Budget History

<table>
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<tr>
<th>Aug. 1, 2015 – FY 2016 (past) THRU 9/30/16</th>
<th>FY 2017 (current)</th>
<th>FY 2018 (planned)</th>
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<tbody>
<tr>
<td>DOE</td>
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<td>$529,866.77</td>
<td>$220,845.00</td>
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## Project Plan and Schedule

### Project Schedule

**Project Start:** August 1, 2015  
**Project End:** January 31, 2017

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<th>Task</th>
<th>FY2015</th>
<th>FY2016</th>
<th>FY2017</th>
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<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
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<td>Q4 (Jul-Sep)</td>
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### Past Work

- **Q4 Milestone:** Conduct Lab Tests  
- **Q5 Milestone:** Complete Cost Analysis  
- **Q5 Milestone:** Performance Simulation Analysis  
- **Q4 Milestone:** Propose Design Methodology to Standards Groups  
- **Q3 Milestone:** Secure Manufacturer Interest  
- **Q5 Milestone:** Secure Builder Interest  
- **Q6 Milestone:** Final Report

- **Project start delay**
- **Milestone delays due to NCTE**