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

2016 Building Technologies Office Peer Review

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Project Summary

Timeline:
Start date: August 1, 2015 (new project)
Planned end date: July 31, 2016

Key Milestones
1. Conduct Lab Tests; March 31, 2016
3. Secure Builder and Manufacturer Interest; July 31, 2016

Budget:
Total Project $ to Date: (thru Feb. 2016)
• DOE: $263,729
• Cost Share: $155,696

Total Project $:
• DOE: $600,085
• Cost Share: $220,845

Key Partners:
Best Practices Research Alliance

Project Outcomes:
• A simplified air delivery system for low-load homes with predictable performance from a manifold arrangement of small diameter ducts
• A straightforward, intuitive design method and companion guidance documents
• Justification and suggested language for needed code and standard changes
• Written commitment from at least one manufacturer partner to pursue product development and at least one builder partner to demonstrate the technology based on the project’s findings
Purpose and Objectives

Problem Statement:

• The residential HVAC market faces market challenges with low-load homes and HVAC systems
• Heating and cooling to each space is not optimally delivered from smaller-capacity equipment
• Traditional duct systems have a host of problems
• The issues can inhibit low-load homes from achieving broader high-performance goals, including comfort

Target Market and Audience:

• **Market**: new construction low-load homes
• **Audience**: Home builders, HVAC contractors and system designers, HVAC equipment manufacturers and component suppliers, and material suppliers
Purpose and Objectives

Impact of Project:

- The Plug-n-Play duct system could revolutionize ducted air distribution systems in the way manifolded PEX piping systems impacted plumbing distribution.
  - PEX costs 25% - 45% less, installed
  - Rapid claim to majority market share
- Plug-n-Play potential for significant cost savings vs. conventional systems, with performance benefits
  - More discrete room-by-room zoning opportunities
  - Improved comfort - energy is effectively used
  - Ease of design and installation
  - Alternative to current small-diameter 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
- Lower costs yield wider / deeper market penetration
Purpose and Objectives

Project Outputs:

• Characterized the pressure and airflow relationships for plastic small diameter rigid ducts and fittings
• Characterized the installed performance of the Plug-n-Play system
• Compared performance to traditional air distribution system approaches
• Defined range of application for the system in terms of home size, load, load density, and climate
• Analyzed cost and installation impacts
• Developed installation guidance
• Developed design methodology
• Secured interest from a builder and manufacturer
### 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 recent building 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 stimulate market demand for energy efficiency &amp; foster markets that value energy efficiency</td>
<td>Energy efficiency programs facilitate market demand for energy efficiency &amp; foster markets that value energy efficiency</td>
</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>Energy efficiency programs &amp; building professionals have access to resources &amp; model business practices to increase scale of energy efficiency investments</td>
<td>Homeowners are motivated to invest in more energy efficient homes spurred by increased value in the residential market.</td>
</tr>
<tr>
<td></td>
<td>Outreach to stakeholders on a national scale to increase adoption of energy efficiency solutions in common transactions.</td>
<td>Peer sharing via Better Building Residential Network</td>
<td>Targeted campaigns to propel adoption of low cost home upgrade improvements</td>
<td>Energy efficiency programs &amp; building professionals have access to resources &amp; model business practices to increase scale of energy efficiency investments</td>
<td>Industry stakeholders widely promote value of energy efficiency in products, services, &amp; typical market transactions with homeowners</td>
</tr>
<tr>
<td></td>
<td>Tool development &amp; demo of the value of energy efficiency in the market with market partners</td>
<td>Home Energy Score tool</td>
<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></td>
</tr>
<tr>
<td>Impact</td>
<td>40% savings in existing homes demo’d</td>
<td>Proved in 1 million existing homes &amp; 50K ZER new homes</td>
<td>Market Partnerships reach 90% of homes</td>
<td>Reduce the energy used for space conditioning &amp; water heating in single family homes by 40% by 2025 from 2010 levels</td>
<td>Reduce avg. EUI in all bldgs. 30% by 2030</td>
</tr>
<tr>
<td></td>
<td>60% savings in new homes demo’d</td>
<td>5% savings thru individual measures with partners</td>
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</table>

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Approach

Approach:

• Test pressure and airflow relationships for straight runs and fittings
• Install and evaluate a duct system in an unoccupied lab house
• Push industry for acceptance of plastic ducts
• Simulate performance to establish range of applications
• Evaluate installation processes in a mock-up
• Develop a simple design methodology
Approach

Key Issues:

- Duct systems are often not designed to have all runs accessible for maintenance, dampering
- Duct design, layout and installation suffer from shortfall of available skilled labor
- 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
- Plastic ducts are not presently accepted by the industry
Approach

Distinctive Characteristics:

- A home-run manifold of small diameter 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 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 low-load homes and emerging comfort systems, providing reliable design results
Progress and Accomplishments

Accomplishments:

- Characterized pressure/airflow relationships through Lab Testing.

![Graph of Pressure Drop Per Foot, 2” Diam. PVC](image)
Progress and Accomplishments

Accomplishments:

• Modeling
  – Creating a detailed multi-zone Energy Plus model simulating the duct system using Energy Plus airflow network objects
  – Evaluate comfort performance of Plug-n-Play duct system
  – Compare performance of Plug-n-Play ducts against traditional systems
  – Evaluate range of application for Plug-n-Play ducts
  – Test design methodology

• Several builders, manufacturers and material suppliers have expressed interest in the system and collaboration to demonstrate / develop
Accomplishments:

- Field Data collection is underway showing performance results.
- Several draft Design Methodologies are being evaluated.

### Thermostat Temperatures

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<tr>
<th>Time</th>
<th>Thermostat (Open)</th>
<th>Thermostat (Closed)</th>
<th>Thermostat (Closed + Ins)</th>
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### Data Table

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<th>Elbows</th>
<th>ACCE Manual J</th>
<th>Actual CFM</th>
<th>DM1 CFM</th>
<th>DM1 Runs</th>
<th>DM2 CFM</th>
<th>DM2 Runs</th>
<th>DM3 CFM</th>
<th>DM3 Runs</th>
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<td>Kitchen</td>
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<td>267</td>
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</table>
Progress and Accomplishments

Market Impact:

- Multiple builders, manufacturers, and material suppliers have expressed interest
- Dissemination of knowledge has been though Alliance venues
- Design methodology work is accelerated
- To ensure / accelerate impacts:
  - Investigating semi-rigid materials to ease installation
  - Defining the preferred material properties (mass, friction, R-value) to deliver comfort
  - Modeling activities to determine market impact range
  - Engaging code community
- Actual impacts forthcoming
Awards/Recognition: None

Lessons Learned:

• Several installation challenges encountered, even with 2-2.5-in. diam. ducts

• Conditioned energy lost in “transit” through uninsulated ducts greatly impacts room supply air temperature

• A reasonable door undercut provides sufficient return air path with reduced airflow volumes

• Zone dampers are beneficial
Project Integration and Collaboration

Project Integration:
Innovation Pathway

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

Partners, Subcontractors, and Collaborators:
Best Practices Research 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

Three alternative material manufacturers have been engaged toward material and product development
Project Integration and Collaboration

Communications:
Best Practices Research Alliance
• Tech Summit and Annual Meeting
• Webinar, Surveys, Builder forums

ASHRAE
• Annual Meeting
• Winter Meeting
• Committee activities

RESNET
• Annual Conference

Pennsylvania Housing Research Center
• Housing Day
• 3rd Biennial Res. Design & Construction Conf.
Next Steps and Future Plans

Next Steps:

• Utilize modeling to compare simulated performance of Plug-N-Play system to conventional duct systems and evaluate application ranges, i.e. size of home, climate; load density
• Perform a time and motion study to compare installation costs and issues of this system against those for conventional systems
• Pursue Builder and Manufacturer willing to demonstration / development

Future Intentions:

• Develop companion components: dampers, plenum/manifold, diffusers
REFERENCE SLIDES
Project Budget

Project Budget: $820,930: $600,085 Federal + $220,845 Cost Share

Variances: To date there have been no variances from the original planned budget

Cost to Date: $263,729 or 44% of Federal Funding utilized through February 2016
$419,425 or 51% of total budget utilized through February 2016

Additional Funding: None.

<table>
<thead>
<tr>
<th>Budget History</th>
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<tbody>
<tr>
<td>DOE</td>
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# Project Plan and Schedule

## Project Schedule

<table>
<thead>
<tr>
<th>Task</th>
<th>Q1 (Oct-Dec)</th>
<th>Q2 (Jan-Mar)</th>
<th>Q3 (Apr-Jun)</th>
<th>Q4 (Jul-Sep)</th>
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<tbody>
<tr>
<td>FY2015</td>
<td>FY2016</td>
<td>FY2017</td>
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<tr>
<td>Completed Work</td>
<td>Active Task (in progress work)</td>
<td>Milestone/Deliverable (Originally Planned)</td>
<td>Milestone/Deliverable (Actual)</td>
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<tr>
<td>Scheduled Project Start / End</td>
<td>Delay in project startup</td>
<td>Delay in project startup</td>
<td>Delay in project startup</td>
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</tbody>
</table>

## Current/Future Work

- **Q2 Milestone:** Conduct Lab Tests
- **Q3 Milestone:** Complete Cost Analysis
- **Q4 Milestone:** Performance Simulation Analysis
- **Q4 Milestone:** Propose Design Methodology to Standards Groups
- **Q4 Milestone:** Secure Manufacturer Interest
- **Q4 Milestone:** Secure Builder Interest
- **Q4 Deliverable:** Final Report