A "Plug and Play" Air Delivery System for Low Load Homes

2017 Building Technologies Office Peer Review





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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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- 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:

- <u>Market</u>: new construction low-load homes (0.01 quads/year)
 2012 IECC enclosure, 2,000-3,000 ft² "sweet spot"
- <u>Audience</u>: Home builders, HVAC contractors and system designers, HVAC equipment manufacturers and component suppliers, and material suppliers

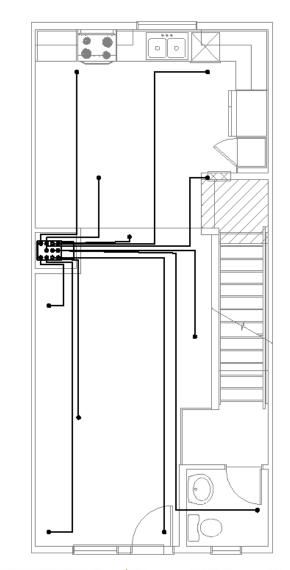




Purpose and Objectives

Impact of Project: Project Outputs

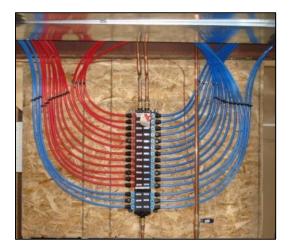
- Characterize the performance parameters for plastic small diameter rigid ducts and fittings and other, off-the-shelf duct products
- Characterize the installed "comfort" (temperature) impact of Plug and Play system
- Define the range of application for the system in terms of home size, load, load density, 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

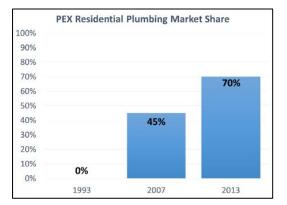




Impact of Project:

- 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





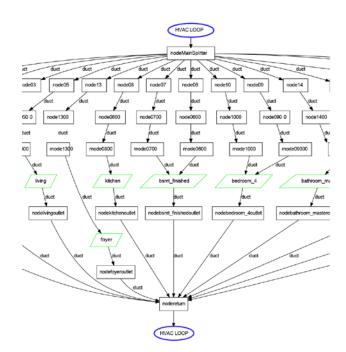


Purpose and Objectives

Objectives Activities / Partners Demonstrate & integrate energy efficient technologies & practices in	& America upgrade packages & techniques for existing & new homes across climates	Short Term Outcome Innovator building professionals equipped with validated energy saving solutions for integrating highly energy efficient tech or practices	Mid-Term Outcome Leading building professionals improve or construct high performance homes above model energy codes	Long Term Outcome The building industry regularly constructs high performance
representative homes Resources development national labs for building & service providers Prove energy saving solutions & building to upgrade or construct h	prof. codes (and structure structure) stakeholders demo Best practice online Better Buildings & Buildings America	Industry standard orgs. & voluntary programs equipped with validated technical specs & guidelines to make homes	Industry standard orgs adopt technical specs to accelerate new tech & practices in building energy codes	homes that are ready for renewable energy systems or significantly improves the
programmatic designs on a national scale with market partners Outreach to stakeholders national scale to increase adoption of energy efficie	Demonstrated home upgrades & new construction in HPwES & ZER Homes	highly efficient Energy efficiency programs & building professionals of veraccess to esources & no fel	Energy efficiency programs facilitate market demand for energy efficiency & forter markets that value energy efficiency Building professionals install	energy efficiency of existing homes across climates. Homeowners are motivated to
Accelerate market adoption by increasing understanding of effective energy efficient in the market with market partners	Targeted campaigns to propel adoption of low cost home upgrade improvements	business practices to increase scale of energy efficiency investments Wide array of industry stakeholders & building	proven energy saving solutions in the broader market Industry stakeholders widely promote value of energy efficiency in products,	invest in more energy efficient homes spurred by increased value in the residential
effective energy saving solutions Educational support to promote quality workforce	workionce development	professionals aware of strategies to increase energy efficiency	services, & typical market transactions with homeowners	market.
40% savings in existing homes demo'd 60% savings in new homes demo'd 10% savings thru individual measures	Proved in 1Market Partnershipmillion existing90% of homeshomes & 50K5% savings thru indZER new homesmeasures with partnership	ividual single famil ners 2025 from 2 U.S. D		Reduce avg. EUI in all bldgs. 30% by 2030 y Efficiency &

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



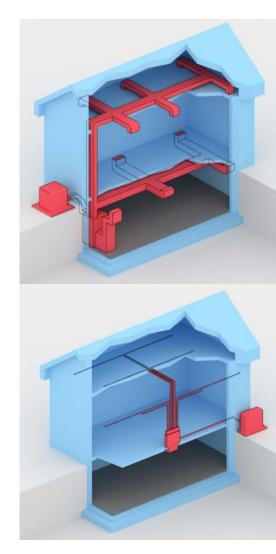




Approach

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 smallcapacity 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.





Accomplishments:

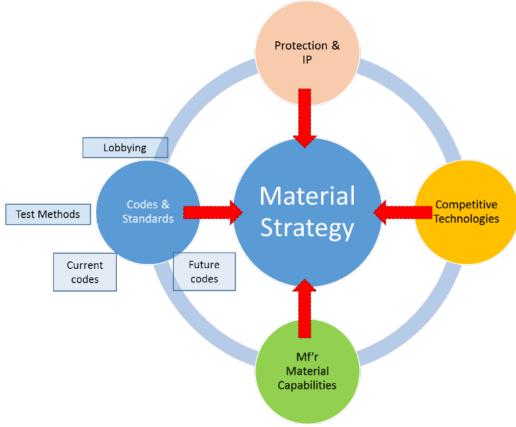
- Completed a design methodology
 - Using ACCA Manual J loads and airflows
 - Based on plastic ducts but completed analysis of alternate duct materials
 - Evaluated range of applications for Plug and Play duct system
- Simulation
 - Created a detailed multi-zone model using Energy Plus Airflow Network
 - 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

	Plug-and-Play H	Iome Run Manif	old Design Tool				
	V 0.1						
	Project						
	·						
	Nominal CFM	26	(based on 30' L, 60 Pa)				
	Available Pressure	0.35	in. wc. (from manual S)	(minus o.1	" for manifo	old)	
	Heating factor		Btuh / CFM				
	Cooling factor	0.0268	Btuh / CFM				
#	Room	Htg Load (Btuh)	Clg Load (Btuh)	CEM	Len (ft.)	Elb	Ducts
1			2316		29	5	2
2			2310	55 15	12	3	1
3		2025	1500	-	15	4	2
4		-	620	18	22	3	1
5		12-	4486	150	16	3	5
6		>					
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
	Total:	12319	9142	285	94	18	11
	Select Material						
	2" PVC						
	F1 - 6						
	EL of 90	2					
	Pipe Diameter	2.0					
	Conflictence all Disc	CT44 (D-1091)0(11)					
	Coefficients 2" PVC C	CFM = (Pa/C*L)^(1/n) 0.01146					
	n						
	п	1./0239					



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





Awards/Recognition: None

Lessons Learned:

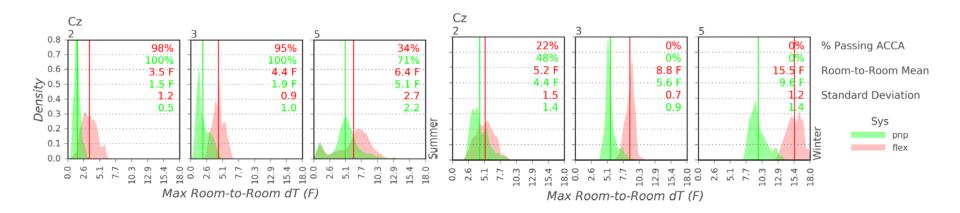
- All homes could use 3.0" flexible ductwork.
- 2.5" smooth ductwork provides sufficient airflow for a 2200 sq. ft. home in climate zones 2-5.
- Smaller homes (<1200 sq. ft.) or very low load homes built (i.e. Passive House) can use 2.0" smooth ductwork.
- A simplified design method is possible with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





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





Lessons Learned:

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

Duct System	Hours	Labor Cost @ \$33.35 hr.	Material Cost	SKU'S	Length of duct	Cost of ductwork system
Traditional	18 (including 6 hr bulkhead)	589	487	6	35' trunk + 50' flex	\$ 1,076
2.5" PVC	10 (including 6 hr bulkhead)	330	686	6	210'	\$ 1,017
2" PVC	6	195	440	6	250'	\$ 635

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



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





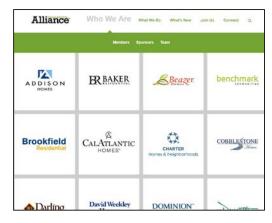
Project Integration and Collaboration

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
- http://www.housinginnovationalliance.com/

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								
Aug. 1, 2015 – FY 2016 (past) THRU 9/30/16		FY 2 (curr			.018 ined)			
DOE	Cost-share	DOE	DOE Cost-share DOE		Cost-share			
\$529,866.77	\$220,845.00	\$600,085.00	\$220,845.00	None	None			



Project Plan and Schedule

Project Schedule												
oject Start: August 1, 2015 Completed Work												
Project End: January 31, 2017		Active Task (in progress work)										
		Mile	stone	e/Deli	verab	le (O	rigina	lly Pla	anneo	d)		
	Milestone/Deliverable (Actual)											
	FY2015			FY2016			FY2017					
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work						•				·		•
Q4 Milestone: Conduct Lab Tests												1
Q5 Milestone: Complete Cost Analysis				ay							L y	2
Q5 Milestone: Performance Simulation Analysis				delay								
Q4 Milestone: Propose Design Methodology to				start							Milectone delave	due to NCTE
Standards Groups				t st							<u> </u>	
Q3 Milestone: Secure Manufacturer Interest				Project								gnp
Q5 Milestone: Secure Builder Interest				Pro							_ 2	
Q6 Milestone: Final Report												1

