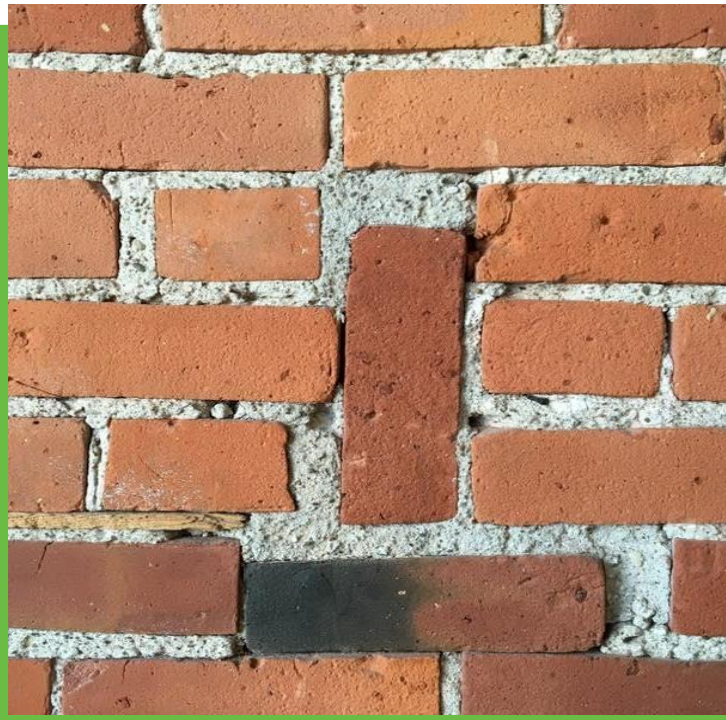
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

PARR

Energy Savings with Acceptable Indoor Air Quality Through Improved Air Flow in Residential Retrofit



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Project Summary

Timeline:

Start date: September 1, 2015

Planned end date: September 30, 2019

Key Milestones

1. Expert and Practitioner Meetings; 5/2016
2. Go/No-Go Budget Period 2; 8/2018
3. Recruitment ongoing; homes being monitored

Budget:

Total Project $ to Date:

- DOE: $478,032
- Cost Share: $170,033

Total Project $:

- DOE: $750,000
- Cost Share: $250,000

Key Partners:

GTI (prime)
University of Illinois at Urbana-Champaign (UIUC)
Midwest Energy Efficiency Alliance (MEEA)
National Center for Healthy Housing (NCHH)
Frontier Energy, Inc. (FEI)

Project Outcome:

Validate improved air sealing protocols to systematically manage airflows and indoor air quality (IAQ).

This will help meet BTO's MYPP goals of 40% EUI reduction in existing homes while optimizing home performance.

Core Team

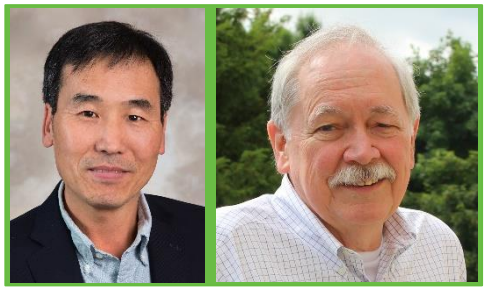
PARR

ILLINOIS APPLIED RESEARCH INSTITUTE
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

gti

Paul Francisco

Jason LaFleur



Yigang Sun Bill Rose

Larry Brand

Kara Jonas

FRONTIER energy

MEEA
Midwest Energy Efficiency Alliance

Challenge

Problem Definition: Concern about indoor air quality (IAQ) frequently limits energy efficiency upgrades. Airflows within the home are often considered independently.

This project aims to demonstrate that systematic management of airflows increases the ability to deliver energy savings without sacrificing IAQ. This contributes to BTO's MYPP by unlocking the energy savings potential of air sealing in existing homes.

Knowledge Gaps explored:

- How does an integrated approach to improving airflows in home performance retrofits affect IAQ?
- What is the impact of enhanced retrofit measures?
- How can contractors apply protocol to deliver maximum energy savings without negatively impacting IAQ?

Stakeholder Engagement

Stage: Mid-project; ongoing data collection

Partners, Subcontractors, and Collaborators:

- GTI is leading the project
- UIUC/ICRT is leading the scientific effort
- MEEA is coordinating with practitioner collaborators and organizing stakeholder workshops
- National Center for Healthy Housing provides a tie to the environmental health industry and will help with analysis
- Home performance contractors are conducting the field interventions.

Market Impact: We have worked closely with retrofit contractors piggybacking on utility incentives. Contractors have been trained on test methods and potential benefits. By working with them we are accelerating impact by demonstrating not just the theory, but the practicality of implementation.

Approach

Approach: We are evaluating how to address IAQ concerns while maximizing energy savings.

- case-control study of 40 homes
  - 20 control homes weatherized conventionally
  - 20 treatment homes with systematic airflow management
- IAQ monitoring pre/post retrofit
- Adopting whole-house approach that considers multiple air flow streams

Key Issues: Energy savings are often sacrificed due to concerns about IAQ. Some interventions may improve one metric while causing problems in another. Airflow management is also typically not viewed systematically, which can result in suboptimal energy and IAQ outcomes.

Distinctive Characteristics: This project involves field measurements of multiple contaminants in a case-control approach.

Approach: Site Recruitment

Participating homes must be:

- Single-family detached
- Unfinished basement
- Single forced-air heating system
- Non smokers
- Reasonable achievement of <6.5 ACH50
- Pre / Post within same space conditioning season

Control Home Features:

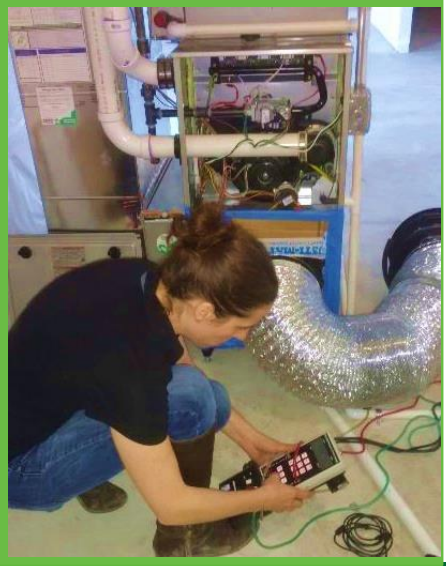
- Standard home performance measures in attic and rim joist
- Little / no duct sealing
- Exhaust-only ventilation

Treatment Home Features:

- Enhanced home performance measures in basement
  - Sealing slab/foundation wall
  - Sealing sump pumps
  - Improved targeting of air sealing
- Duct sealing
- Exhaust and/or supply ventilation

Approach: Airflows Assessed

- **Infiltration**
  - Heating/cooling losses; addressed by air sealing
- **Ventilation**
  - Provide controlled air exchange;
    desire to minimize energy use for ventilation make-up
- **Duct leakage**
  - Leakage to outside is an energy penalty
  - Unbalanced duct leakage causes pressure differentials
    - Impacts infiltration and can cause IAQ problems
- **Air handler flow**
  - Impacts comfort
  - Impacts humidity control in summer
  - Restricted ducts impact energy use



Approach: Test Procedures

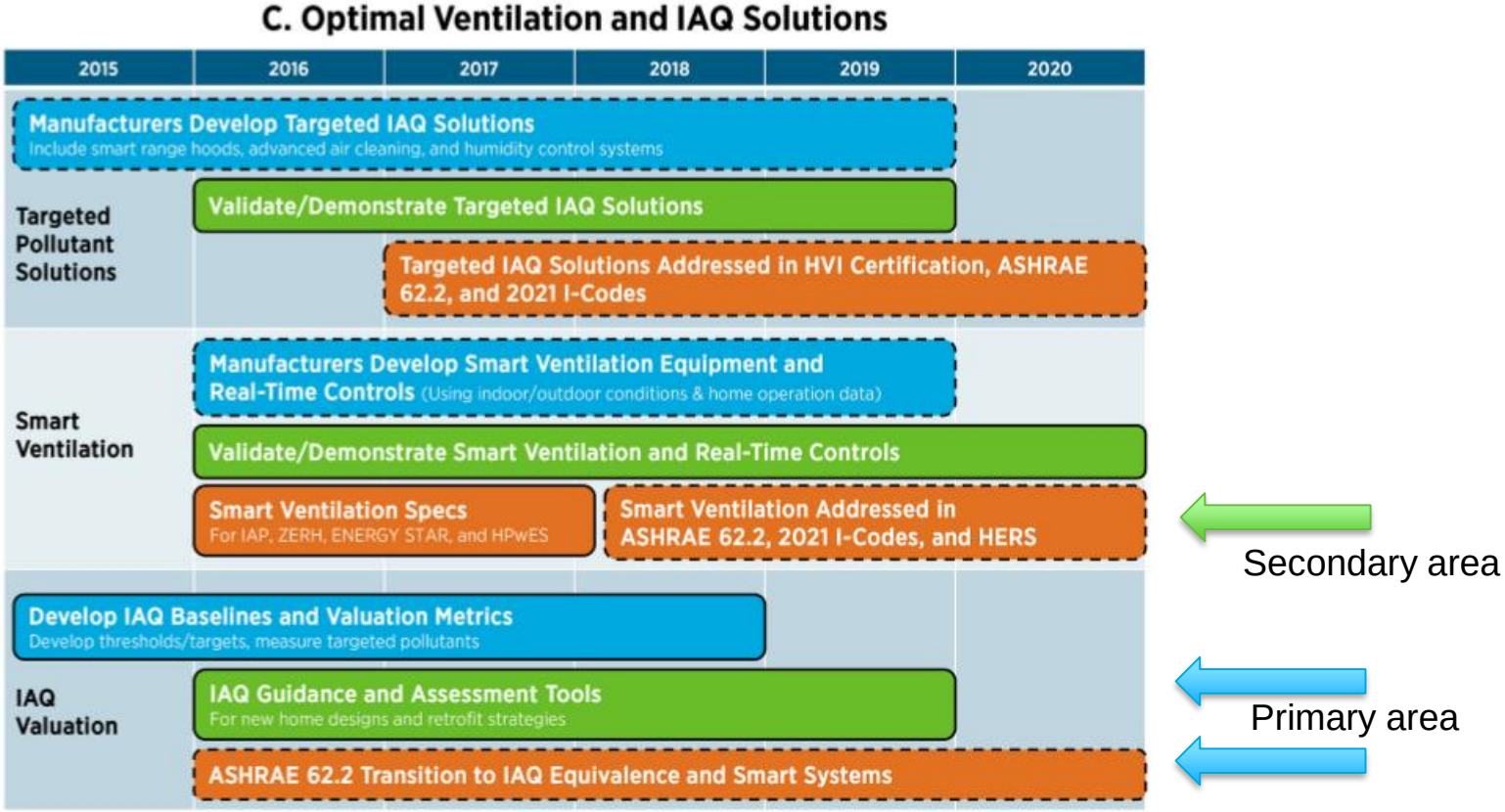
- **Baseline:** 3 weeks pre-retrofit;
  Follow-up: 3 weeks post-retrofit

- **Indoor Air:**
  - Formaldehyde (continuous indoor generation)
  - Radon (soil/exterior generation)
  - CO2 (human generation)
  - Humidity (human and outdoor generation)
  - Particles when possible (periodic indoor and outdoor generation)

- **Energy:**
  - Heating/cooling
  - Ventilation

Impact

Building America Roadmap: Primary area influencing retrofit IAQ guidance. Sensor data collected may also be useful for smart ventilation research.



Results will be presented to stakeholders at industry conferences. Actionable guidance will be provided that can inform energy efficiency program measures and training.

Progress

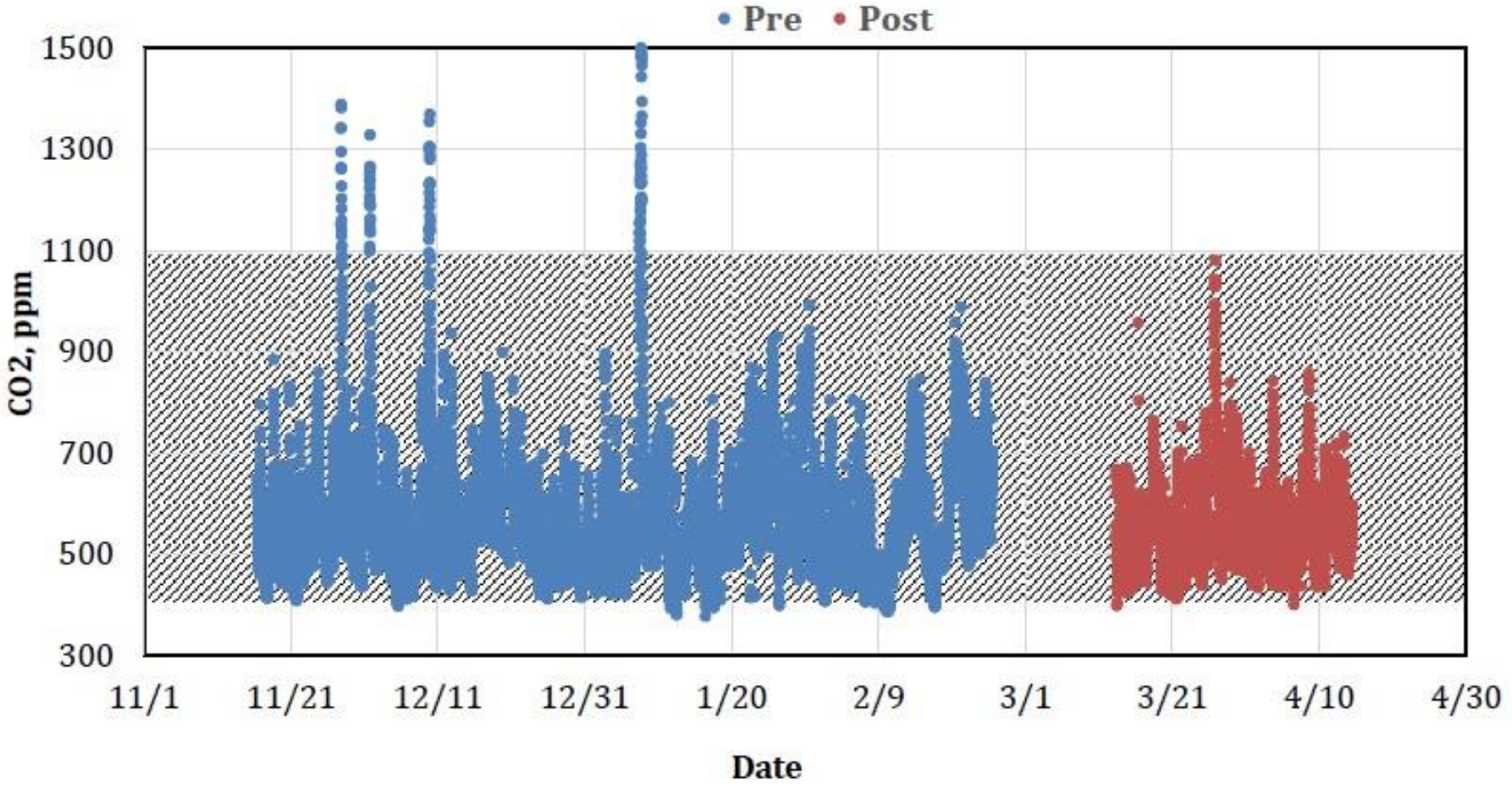
Stage: Mid-project; ongoing data collection

Accomplishments:

- Expert Meeting - helped refine the project design
- Contractor Meetings - identified challenges and solutions to project implementation; training on supply-side ventilation installation
- Site recruitment and field testing now underway
  - 23 Homes enrolled; 19 instrumented
  - Homeowner reports delivered
- Preliminary Data Trends focus on homes that have all the data, pre and post.

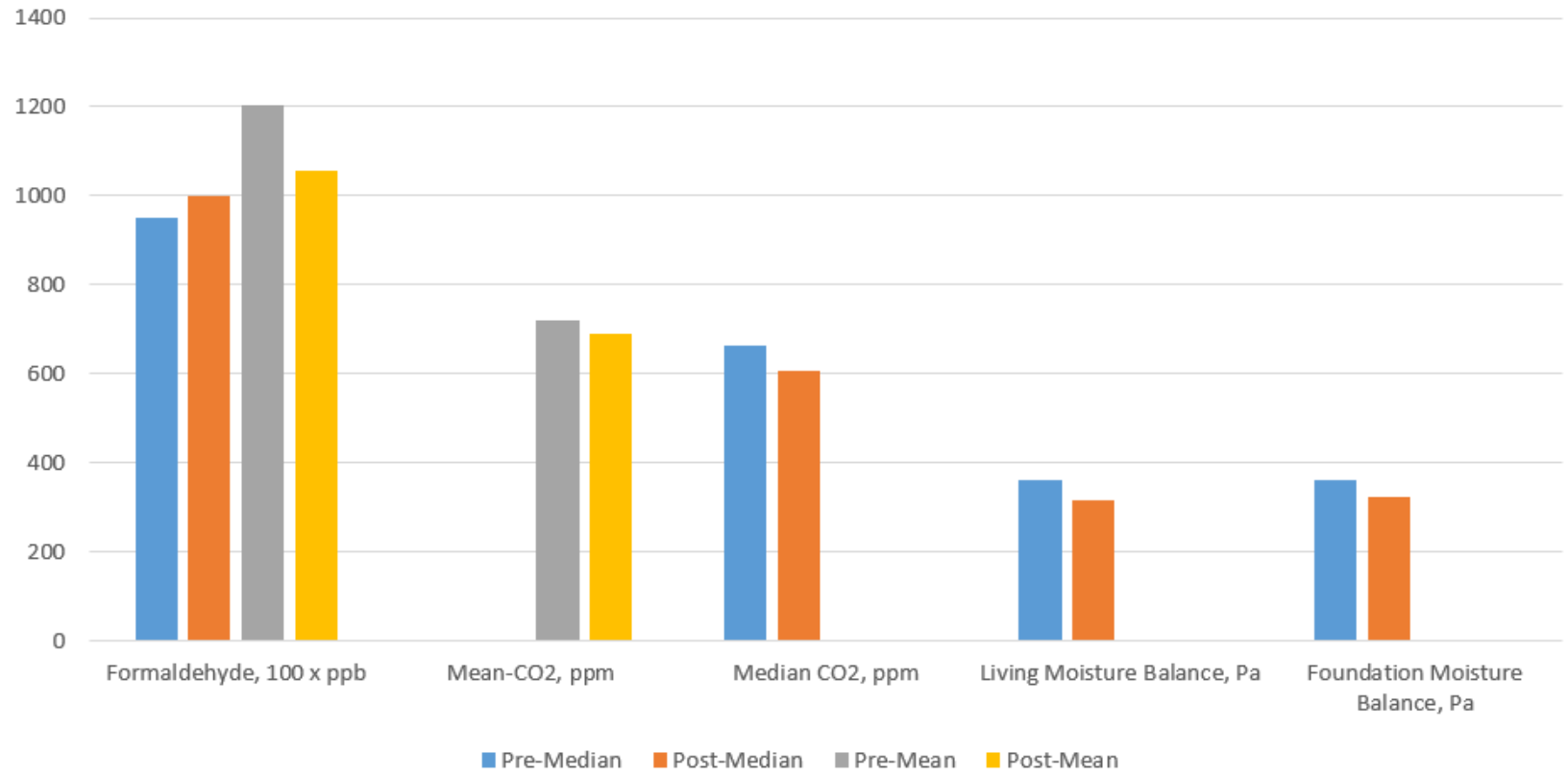
Progress - Sample Findings

CO_2 levels before and after retrofit in a control home.



Progress – Preliminary Data Trends

Indoor Air Quality (IAQ) across homes to date (n=15)



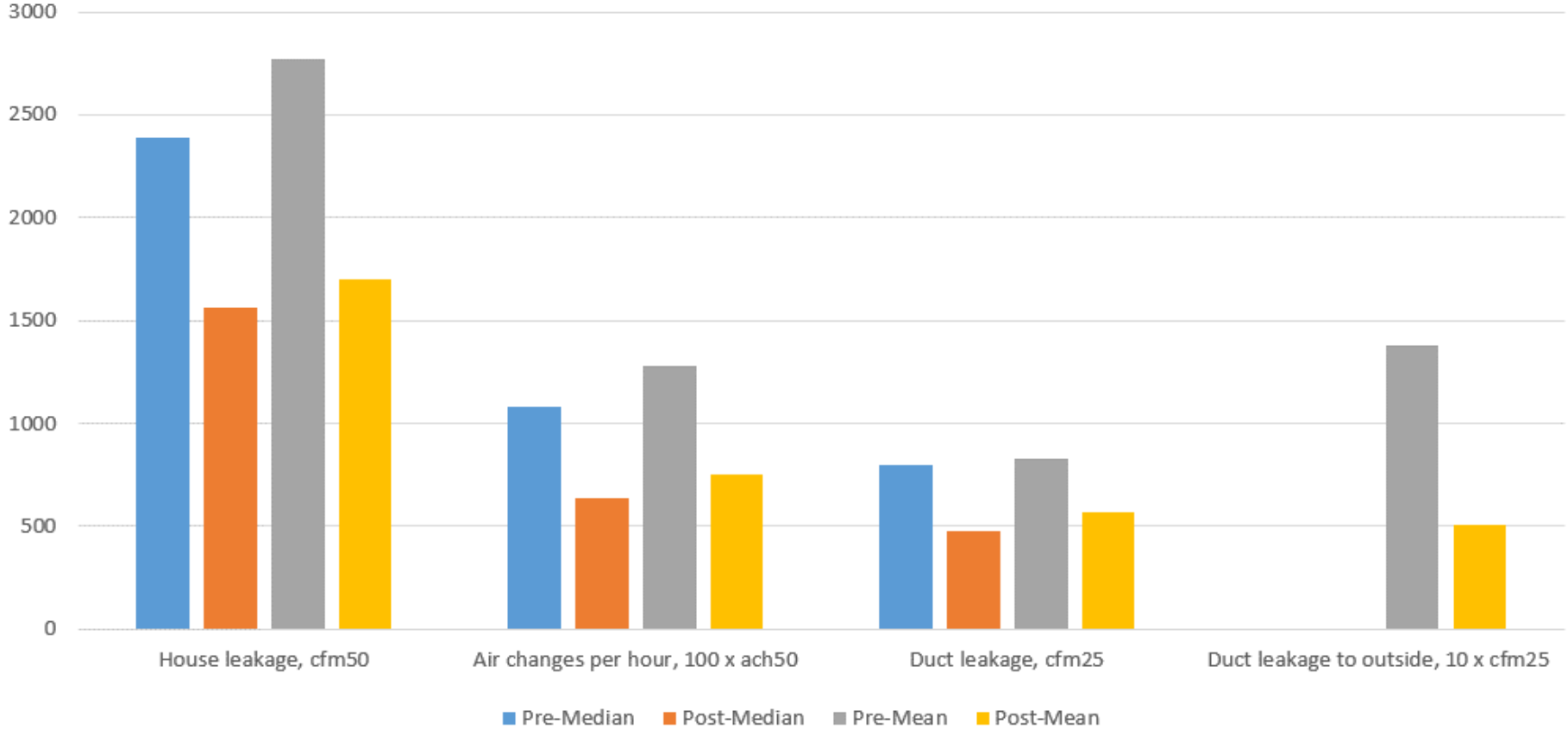
Note: Scale for formaldehyde is multiplied by 100 to fit all data on one graph.

Formaldehyde is generally similar (and low); CO_2 slightly decreasing.

Homes are not getting wetter in either main level or basement/crawl levels.

Progress – Preliminary Data Trends

Air Flow Results across homes to date (n=15)



Note: Scale for ACH50 is multiplied by 100 to fit all data on one graph.

Infiltration reduced by about 1/3, with whole-home approach, not just ceiling plane air sealing.

Means used for DLtO as due to primarily basement duct locations

Remaining Project Work

Preliminary Analysis Summary

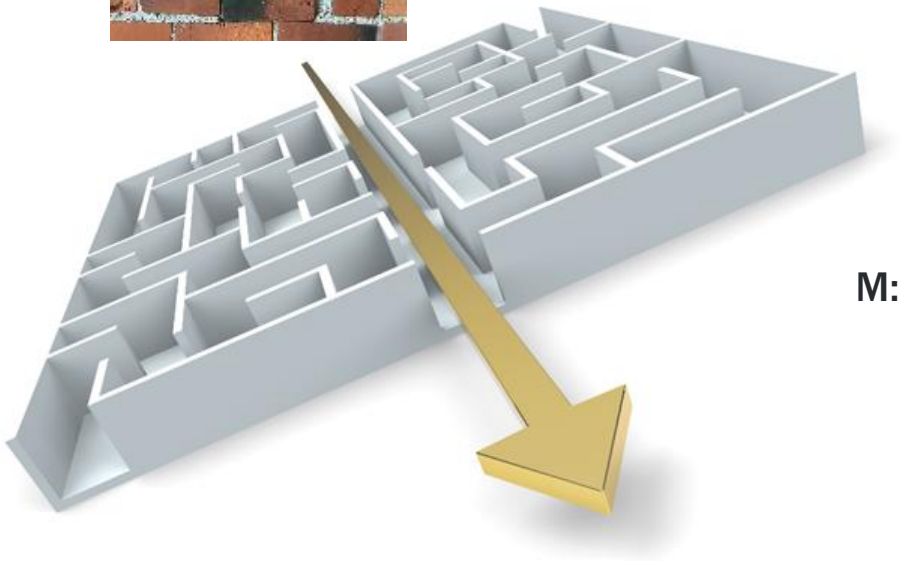
- **Reduced infiltration** is resulting in **dryer homes** with **less CO_2**
- Systematic airflow management techniques (aka whole-house approach) with ventilation installed is **not** adversely affecting IAQ.
- Implementers should be comfortable proceeding with whole-house strategies.

Adaptations of work plan:

Initial findings demonstrated the complexity of finding adequate sites to meet the test plan. Incentives have been adjusted multiple times for contractors due to their increased work scope.

Next Steps and Future Plans:

- Complete testing on 40 homes, including 20 treatment and 20 control homes.
- Full analysis of IAQ and energy impacts across treatment and control forthcoming.
- Disseminate at stakeholder conferences, webinars, and modify training and energy efficiency program policies.



Thank You!

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Project Budget

Project Budget: $1,000,000; DOE: $750,000; Cost Share: $250,000
Variances: N/A
Cost to Date: $648,065; DOE: $478,032; Cost Share: $170,033
Additional Funding: N/A

Budget History					
September 1, 2015 – FY 2018 (past)		FY 2019 (current)		FY 2020 – 9/30/2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$449,351	$161,135	$28,681	$8,898	$271,968	$79,967

Project Plan and Schedule

- The project experienced an initial 6 month delay closing the Field Test plan
- Following 9 months unsuccessful site recruiting, the Field Test plan was revised in August 2017 to increase pool of eligible study candidates
- Following Test Plan changes, 23/40 homes were recruited through March 2019
- Recruiting remains challenging, and No-Cost Time Extension to September 2019 has been proposed to reach original goal of 40 homes

Project Schedule

Project Start: September 1, 2015	Completed Work
Projected End: September 30, 2020	Active Task (in progress work)
	Milestone/Deliverable (Originally Planned) use for missed milestones
	Milestone/Deliverable (Actual) use when met on time

	FY2016				FY2017				FY2018				FY2019				FY2020			
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)	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																				
Expert Meeting																				
Air Control and IAQ Best Practices Task																				
Field Test Plan																				
Field Test Preparation and Baseline Task																				
Current/Future Work																				
Air Control and IAQ Field Test Task																				
Data Analysis																				
Technology Transfer Workshop																				
Final Report																				