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BUILDING TECHNOLOGIES PROGRAM

Building America Expert Meeting: Combustion Safety

L. Brand
Partnership for Advanced Residential Retrofit

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Building America
U.S. Department of Energy

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Building America Expert Meeting: Combustion Safety

Prepared for:

The National Renewable Energy Laboratory

On behalf of the U.S. Department of Energy's Building America Program

Office of Energy Efficiency and Renewable Energy

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Unless otherwise indicated, all tables were created by PARR.

Definitions

ACH	Air changes per hour
ACH_{50}	Air changes per hour at 50 pascals
AFUE	Annual fuel utilization efficiency
AGA	American Gas Association
ANSI	American National Standards Institute
BA	Building America
BPI	Building Performance Institute
CO	Carbon monoxide
DOE	U. S. Department of Energy
FSEC	Florida Solar Energy Center
GTI	Gas Technology Institute
LBNL	Lawrence Berkeley National Laboratory
NFGC	National Fuel Gas Code
NREL	National Renewable Energy Laboratory
Pa	Pascal
PARR	Partnership for Advanced Residential Retrofit
RESNET	Residential Energy Services Network

Acknowledgments

PARR would like to thank all the attendees for their participation in the meeting, especially the panel members. PARR also thanks Jeff Tuttle and Alex Chavez from CPS Energy for hosting the meeting and for their hospitality and Kristy Usnick from the National Renewable Energy Laboratory for assistance with the webinar.

1 Meeting Overview

1.1 Title

This expert meeting was called The Best Approach to Combustion Safety in a Direct Vent World.

1.2 Who

The Partnership for Advanced Residential Retrofit (PARR) invited industry experts from Building America (BA) teams, manufacturers, HVAC installers, national laboratories, the U.S. Department of Energy (DOE), and PARR partners. Twenty-four experts participated in the meeting.

1.3 What

The objectives of this expert meeting were to identify gaps and barriers that need to be addressed by future research, and to develop data-driven technical recommendations for code updates so that a common approach for combustion safety can be adopted by all members of the building energy efficiency and code communities.

1.4 Where

This meeting was hosted by CPS Energy in San Antonio, Texas.

1.5 When

The meeting took place on Thursday June 28, 2012, from 9:00 a.m. to 3:00 p.m. Central Daylight Saving Time.

1.6 Why

The DOE BA program focuses on reducing energy consumption in the nation's housing stock through smart integration of energy efficient design and upgrades. The target is 30%–50% energy savings captured through the application of many measures, including reduction in air infiltration, equipment upgrades, smart controls, and thermal envelope improvements. Combustion safety testing is an important part of the test-in and test-out process in new construction and retrofit (upgrade) projects when direct vent appliances are not used and houses are being tightened to reduce energy losses through air infiltration. Where combustion safety testing identifies excessive spillage or continuous back-drafting, remedial measures are required.

Members of building science community hold many different opinions about the best overall remediation method (testing to verify performance or replacement of the appliance) and the proper test procedures to use to verify combustion safety for appliances equipped with draft hoods. Practitioners and codes differ in the recommendations for two variables: the level of home depressurization and the time required for cold vent establishment pressure.

In addition, statistics on incidents and data collected from the field have not supported stringent testing requirements.

The meeting's objectives were as follows:

- Evaluate the pros and cons of upgrading to direct vent appliances, especially when existing appliances and/or venting mechanisms do not meet current code or are near their end of life.

- Investigate current Building Performance Institute (BPI) and Residential Energy Services Network (RESNET) practices for combustion safety testing in the field.
- Review the International Code Council and National Fire Protection Association (NFPA)/American National Standards Institute (ANSI) code requirements.
- Evaluate data collected from the field in several programs.
- Discuss ongoing research on this topic.

This discussion identified gaps and barriers that need to be addressed by future research. In addition, the participants developed data-driven technical recommendations for code updates that will allow a common approach to be adopted by all members of the building energy efficiency and code communities.

The following research questions were addressed:

- What are the risks associated with continued use of appliances that are near their end of life or venting systems that do not meet the current mechanical codes?
- What data have been collected and what additional data need to be collected to support the analysis that will lead to the development of a common standard for combustion safety?
- How do field practices agree or disagree with the code coverage?
- What low- or no-cost options are currently available that satisfy the need for combustion safety in homes with low infiltration?

1.7 How

Expert meetings are designed to be an interactive experience, where all participants contribute in substantive ways. Representatives from PARR, other BA teams, the national laboratories, as well as other panel members, were chosen to discuss code coverage, field practices, previous research, and ongoing research. Table 1 lists the presenters, their affiliations, and their topics.

The appendix to this report contains the first page of each presenter's slides. Full presentations and the webinar recording are available from PARR and accompany this report on the NREL website at http://www1.eere.energy.gov/buildings/residential/ba_meetings.html.

Table 1. Presenters, Affiliations, and Job Titles

Presenter	Company	Title	Role
Larry Brand	Gas Technology Institute (GTI)	R&D Manager	R&D manager at GTI and a principal investigator for PARR. Brand developed and led the expert meeting.
Paul Cabot	American Gas Association (AGA)	Administrator, National Fuel Gas Code	Administrator for the National Fuel Gas Code at the AGA. He presented the National Fuel Gas code requirements for combustion safety.
Dan Cautley	Energy Center of Wisconsin	Senior Project Manager	Senior project manager at the Energy Center of Wisconsin in Madison. He presented a perspective on the issue from past research that included long-term monitoring of residential water heaters.
Jim Cummings	Florida Solar Energy Center (FSEC)	Program Director, Buildings Research	Program director for buildings research at FSEC and an ASHRAE Fellow. He presented a perspective on house airtightness, ventilation, and combustion safety.
Jim Fitzgerald	Minnesota Center for Energy and the Environment	Senior Building Analyst	Senior building analyst for the Minnesota Center for Energy and the Environment. He presented information on the background of BPI requirements from field research.
Paul Francisco	University of Illinois Sustainable Technology Center	Research Specialist	Research specialist at the University of Illinois. His research focuses on field evaluations of energy efficiency and indoor air quality. He presented the current ASHRAE 62.2 requirements and implications for combustion safety.
John Jones	BPI	National Technical Director	BPI's national technical director. He presented the BPI combustion safety testing guidelines and the reasons behind some of the recommendations.
Vi Rapp	Lawrence Berkeley National Laboratory (LBNL)	Postdoctoral Fellow	Postdoctoral fellow in the Environmental Energy Technology Division at LBNL. She presented LBNL's recent work for the California Energy Commission on venting and discussed an upcoming project.

Table 2 names participants who did not present at the meeting.

Table 2. In-Person Participants

Attendees	Organization
Ren Anderson	National Renewable Energy Laboratory (NREL)
Alex Chavez	CPS Energy San Antonio
Dane Christensen	NREL
Zach Merrin	University of Illinois Sustainable Technology Center
Nick Mittereder	IBACOS
Bill Rose	University of Illinois Sustainable Technology Center
Stacey Rothgeb	NREL
Jeff Tuttle	CPS Energy San Antonio
Craig Wray	LBNL

Table 3 lists the participants who joined the meeting by phone.

Table 3. Remote Participants

Attendees	Organization
Ron Caudle	Southern California Gas Company
Terry Clausing	Drysdale & Associates, Inc.
David Delaquila	Air Conditioning, Heating, and Refrigeration Institute
Ann-Marie Dougan	Vectren
Ronnie Frazier	Atmos Energy
Gary Heikkinen	Northwest Natural Gas
Pat Huelman	University of Minnesota
David Mallay	National Association of Home Builders Research Center
Andrea Papageorge	AGL Resources
Jim Ranfone	AGA
Brett Singer	LBNL
Jason Stanek	Omaha Municipal Utility District
Elizabeth Tate	American Public Gas Association
Kristy Usnick	NREL
Eric Wilson	NREL
Jon Winkler	NREL

Table 4 gives the meeting's agenda.

Table 4. Agenda

Time	Presenter	Topic
9:00	Larry Brand	Welcome, Introductions, Objectives
9:30	Paul Cabot	National Fuel Gas Code Coverage
10:00	Paul Francisco	ASHRAE 62.2 Ventilation Requirements
10:30	John Jones	BPI Combustion Safety Procedures
11:15	Larry Brand	Gaps and Barriers in the Codes; Opportunities to Harmonize
11:45	Jim Fitzgerald	Field Research and BPI Guidelines
12:15	Lunch	
1:00	Jim Cummings	House Airtightness and Combustion Safety
1:30	Dan Cautley	Long-Term Monitoring of Residential Water Heaters
2:00	Vi Rapp	LBNL Research; California Energy Commission Project on Combustion Safety
2:30	Larry Brand	Gaps and Barriers in the Research
3:00	Close	

2 Meeting Recap

2.1 Welcome

Larry Brand welcomed the panel and participants and introduced the topic of the expert meeting. He indicated that the webinar was presented by the PARR team on behalf of DOE's BA program. He mentioned that the speakers would focus on combustion safety from several perspectives and then work to identify gaps and barriers in the research. He also suggested that the team should identify opportunities to harmonize the codes where they differ.

Brand introduced each speaker in turn. Questions and responses are included in the key points for each presentation, which follow.

2.2 Presentation 1—National Fuel Gas Code Coverage

Paul Cabot presented a perspective on the topic from the gas industry and the National Fuel Gas Code (NFGC).

2.2.1 Presentation Title

Fuel Gas Appliances Combustion Air and Inspection, National Fuel Gas Code ANSI Z223.1 and NFPA 54

2.2.2 Key Points

The NFGC has been an ANSI standard since 1974. It establishes combustion air requirements for natural gas appliances across most of the United States. All listed appliances refer to the NFGC, which has dual listing as ANSI Z223.1 and NFPA 54. The same combustion air requirements are in all the model fuel codes (the two just mentioned and the Uniform Plumbing Code).

There are two basic methods for determining combustion air for appliances: the standard method and the alternate method. The standard (required volume) method is based on an infiltration level of 0.5 ACH in the house. The alternate method (known as the air infiltration rate method) is used where the known infiltration rate is less than 0.4 ACH. Another method is prescribed for air taken from the outdoors. Engineered and mechanical methods are also permitted. The code contains many restrictions and requirements relating to appliance installation.

Venting tables are given for Category I appliances so the proper vent performance is achieved. Manufacturers' installation instructions are to be consulted for non-draft type appliances. A recommended procedure is provided for the safety inspection for furnaces and boilers in Annex G. This procedure includes checking the draft after 5 min of operation with doors, windows, and fireplace dampers closed.

Key takeaways from this presentation follow:

- The NFGC is the recognized ANSI code and its combustion air and venting requirements are the basis for codes adopted by most U.S. jurisdictions for installation and operation of gas appliances.
- Combustion air guidelines were revised in 2001 to account for lower infiltration rates in newer homes. It might be appropriate to revisit these assumptions as houses are built tighter (gap).
- Annex G in the code (safety inspection) applies only to furnaces and boilers and it should be expanded to include water heaters (gap).

- The draft spillage test in Annex G is conducted for each appliance. The test is first conducted with each appliance operating separately and is then repeated with all appliances operating in the same location. The written procedure is somewhat vague (gap).
- NFGC and ASHRAE 62.2 should reference each other with regard to combustion air requirements and vent safety testing (gap).

2.3 Presentation 2—ASHRAE 62.2 Ventilation Requirements

Paul Francisco presented the current ASHRAE 62.2 residential ventilation requirements and implications for combustion safety.

2.3.1 Presentation Title

ASHRAE 62.2—Ventilation and Combustion Safety

2.3.2 Key Points

ASHRAE Standard 62.2 (an ANSI standard) addresses the need for ventilation to achieve acceptable indoor air quality in increasingly tight houses in the United States. Key objectives are to ensure that occupants express no dissatisfaction with respect to odor and irritation and, at the same time, to maintain an indoor environment in which contaminants are below levels that create a health risk. A calculation method is used to determine how much mechanical ventilation is required. Ventilation can be provided by several methods including exhaust-only, supply-only, or balanced (energy recovery ventilators or other means). Typically, smaller (ventilation) fans do not produce significant levels of depressurization that can cause combustion safety issues, but poorly sealed HVAC ducts, kitchen fans, dryers, and fireplaces can be major contributors.

Key takeaways from this presentation follow:

- Appliances should first be installed to code to minimize depressurization-induced back-drafting.
- Typically, appliances can handle 5 Pa of depressurization, but this number needs to be verified (gap).
- The largest contributors to depressurization are leaky HVAC ductwork and the larger exhaust systems—such as kitchen fans, dryers, and fireplaces.
- There are several approved methods to comply with ASHRAE 62.2. E—xhaust-only ventilation is not required.
- Field data on exhaust fan flow rates and house depressurization level are needed to verify assumptions (gap).
- A risk assessment tool to determine if exhaust-only ventilation is inappropriate for a particular house is needed to avoid creating an issue with atmospheric appliances or fireplaces (gap).
- Organizations with combustion safety testing protocols and other combustion air code language should reconcile their different approaches to meet the needs of all stakeholders. Of particular importance is a common approach to addressing the full range of factors that can influence proper venting, given the variety of conditions found in older homes (gap).

2.4 Presentation 3—Building Performance Institute Combustion Safety Procedures

John Jones gave a presentation on BPI's combustion safety test procedures.

2.4.1 Presentation Title

BPI Combustion Safety Testing Requirements, Raising the Bar in Home Performance Contracting, Combustion Safety in a Direct Vent World

2.4.2 Key Points

About two-thirds of owner-occupied homes in the United States are at least 25 years old and were built before modern mechanical and energy codes were put into place. These homes have likely had numerous modifications, and some equipment could have been installed incorrectly or might have deteriorated from age or improper use. Testing these systems is necessary to ensure that improvements can be done safely and that the building is safe after the work is complete.

BPI conducts preliminary and post-retrofit combustion safety inspections whenever there is a change to the building envelope or heating system as a part of the work scope. Carbon monoxide (CO) testing of undiluted flue gases is performed for every appliance (including direct vent appliances). Draft and spillage are evaluated for atmospherically vented appliances with the house set up for worst-case depressurization. Technicians are given a recommended test guide to that includes information on setting up worst-case depressurization, measuring spillage from the draft hood, and measuring CO action levels.

Key takeaways from this presentation follow:

- None of the BPI standards supersede codes or manufacturers' installation instructions.
- If BPI standards are too stringent, there is a mechanism to change them. Pre-and post-testing of all appliances, however, must be completed.
- The NFGC tests for spillage after 5 min of operation and the BPI test is conducted after 1 min of operation. The NFGC and BPI tests are based on different data sets and there is an opportunity to harmonize (gap).
- The CO limit for appliances is based on a Colorado study, not the ANSI appliance certification testing. There might be an opportunity to harmonize, but more testing is required (gap).
- BPI recommends more testing in the field on actual installations in actual homes. Manufacturers should be a part of the field testing to set performance limits for certification (gap).

2.5 Presentation 4—Field Research and Building Performance Institute Guidelines

Jim Fitzgerald gave a presentation on the basis for some of the BPI combustion safety guidelines and other research from the field.

2.5.1 Presentation Title

Testing Protocols & Results: Airport Sound Program Experience and BPI/RESNET Development

2.5.2 Key Points

Air tightening of existing homes can affect combustion appliance safety. A Minnesota airport sound reduction study in 3,000 houses reduced infiltration, on average, from 7.8 ACH_{50} to 5.4 ACH_{50}, creating unsafe conditions in many homes. Combustion safety tests were added to the retrofit protocol to ensure that safety issues were addressed. CO and worst-case spillage tests were included.

Many CO problems are related to poor maintenance and tuning, not design. Vents need to be checked against the NFGC sizing guidelines as a part of the safety test. Many vents have been poorly installed. Following the NFGC yields systems that are very likely to vent properly. Maintenance and tuning at a cost of $100 to $300 per appliance is less expensive than replacement and can reduce CO levels significantly.

More than 5 Pa of depressurization reverses most vent systems. That is equivalent to a dryer operating in a closed house tested at 450 cubic feet per minute at 50 Pascals of depressurization. Water heaters spill more in warmer weather than colder weather because of the physics of buoyancy; a warmer climate solution is to install water heaters in a garage or mechanical closet, but that is not a reasonable solution for cold climates.

Unbalanced central returns in the HVAC system can be a significant cause of depressurization.

Key takeaways from this presentation follow:

- The NFGC venting tables are not used properly in the field (a venting portable computer application would be useful). The industry needs a better way to check the existing vent for compliance (gap).
- The NFGC should furnish depressurization guidance followed by a pass/fail spill test (gap). In the airport study, even if the vents were sized properly, 82% of atmospheric vents failed the spillage test at 5 Pa of depressurization – indicating an extreme condition.
- More field data are needed to determine the effect of ambient temperature on depressurization, whether to use 5 min or 1 min for the spillage test, appropriate door position, and the impact of kitchen ventilation (gap).
- The only way to ensure absolute safety is to require direct vent natural gas appliances and seal systems from the house.
- The risk associated with failing the combustion safety test needs to be better characterized (gap). The risks associated with tightening houses could outweigh the benefits.

2.6 Presentation 5—House Airtightness and Combustion Safety

Jim Cummings presented his work on house airtightness and combustion safety with a focus on house ventilation.

2.6.1 Presentation Title

Combustion Safety Concerns and Energy Savings in Very Airtight Residences

2.6.2 Key Points

For very tight homes, further tightening will save very little energy (payback can exceed 50 years), but tightening envelopes can create substantial problems in terms of combustion safety and the risk of very poor indoor air quality if mechanical ventilation systems fail. Sealed combustion systems largely address atmospheric appliance issues where –5 Pa of depressurization creates back-drafting at the vent hood. Mechanical ventilation systems can fail in many ways: motors can burn out, belts can break, filters might not be maintained, and occupants could turn off the system. Very poor indoor air quality can result. The economics of decreasing infiltration rates are poor when energy recovery ventilators are required - going from an ACH_{50} of 5 to 1 saves $65/year in energy costs in Florida (net of energy recovery ventilator fan power), but the energy recovery ventilator costs $135/year of life (assuming $100 per year for maintenance). This results in a negative savings. Even without the annual maintenance cost, payback is 50 years. The proposal is to limit house leakage levels to a minimum of 5 ACH_{50} for climate zones 1–3, 4 ACH_{50} for climate zones 4–5, and 3 ACH_{50} for climate zones 6–7.

Key takeaways from this presentation follow:

- Tightening homes to extreme levels saves very little energy (payback can exceed 50 years), but can create substantial problems in terms of combustion safety and risk of very poor indoor air quality if mechanical ventilation systems fail. Even in cold climates (e.g., Chicago), the payback period is very long and the risks are very real.
- The proposal is to limit house leakage levels to approximately 5 ACH_{50} for climate zones 1–3, 4 ACH_{50} for climate zones 4–5, and 3 ACH_{50} for climate zones 6–7.
- The actual annual energy savings associated with tightening homes below these limits must be determined by field data collection and analysis along with measuring key components of indoor air quality (gap).

2.7 Presentation 6—Long-Term Monitoring of Residential Water Heaters

Dan Cautley presented the results of research done on field monitoring of residential water heaters.

2.7.1 Presentation Title

Combustion Safety: Some Context *and* Water Heater Monitoring Results

2.7.2 Key Points

Of the 250,000 accidental deaths in the United States each year, about 183 are attributable to CO deaths from consumer products of all types. The estimated deaths from hazards including secondhand smoke and radon far exceed those from CO poisoning. Cold vent establishment pressure is the maximum depressurization at which proper venting is established when the vent starts from a cold condition. That pressure can vary significantly according to the study cited.

Vent sizing might be more important than typically assumed. In a study, vents sized at 88% of the NFGC requirement on average for furnaces and 96% on average for water heaters pass the spillage test, but systems designed at 65% and 79%, respectively, fail the test.

There is poor correlation of worst-case testing with performance monitored over time. Spillage of up to 2 min is very common while the vent is priming and it is usually harmless.

In a DOE and Wisconsin Department of Administration-sponsored project, 10 natural draft water heaters were monitored along with 11 replacements. Brief vent spillage on startup was very common, but positive vent pressure in the off cycle was uncommon. In one home there were several flow reversals related to a short chimney and moderate outdoor temperature. No significant CO production was recorded.

Key takeaways from this presentation follow:

- Existing pass/fail testing is very simplistic, and might not accurately predict performance under typical operating conditions. The industry needs long-term monitoring of appliances under normal operation to determine the frequency of spillage, not just the 1- to 5-min test period (gap).
- The draft hood is the typical spillage site in atmospheric appliances. Using direct vent/power vent appliances is one path to eliminating most spillage problems.
- CO alarms should be required to address periodic events not found in the testing, and events associated with sources other than vented appliances.
- More information on human CO exposure and health effects related to spillage needs to be gathered (gap).
- More modeling is needed to determine the sensitivity of depressurization and spillage to environmental factors and events in the home (gap).

2.8 Presentation 7—Review and Assessment of Combustion Safety Diagnostics

Vi Rapp presented the results of a recent California Energy Commission project on combustion safety and plans for upcoming research.

2.8.1 Presentation Title

Review and Assessment of Combustion Safety Diagnostics and Related Literature

2.8.2 Key Points

The hazards associated with combustion spillage are acute exposure causing death or hospitalization from CO poisoning, acute subcritical health effects, chronic health effects, and moisture-related damage including mold. Deaths from furnace and water heater CO poisonings are about 32 per year (2005–2007 U.S. average from the Consumer Product Safety Commission), fewer than the 37 annual deaths from lightning (2002–2011 average from National Oceanographic and Atmospheric Administration). It is not known, however, how often back-drafting produces subcritical hazards.

Many appliances fail stress testing by back-drafting based on three studies analyzed, but field monitoring data do not confirm the result. The correlation between stress testing and performance in the field is not known.

Many gaps in understanding remain: there is no clear indication of the risks of spillage, acceptable spillage durations are inconsistent, key physical parameters leading to back-drafting are not identified, and the literature does not address the concept that back-drafting and spillage are statistical phenomena. A tool that takes these factors into account and yields a risk assessment is needed.

Venting can be affected by weather, the design/condition of the vent system, and depressurization.

A draft LBNL report entitled *Assessment of Literature Related to Combustion Appliance Venting Systems* is out for review.

Key takeaways from this presentation follow:

- Appliance stress testing and field performance data are inconsistent. The first produces many failures and the second results in few incidents.
- Field research is needed to determine how often back-drafting produces subcritical hazards (gap).
- Improving test methods could reduce risk if the correct variables are addressed.
- A Contam model that adds environmental factors associated with vent performance might be a good tool for modeling the phenomenon. LBNL is investigating this possibility.
- Test results are needed to determine what remediation can be done in the field to produce an acceptable risk (gap).

3 Summary

Larry Brand thanked all the panel members and participants on the phone for their valuable contributions. Gaps and barriers identified and key research questions to be addressed are included in the key takeaway section for each presenter. Although not all research questions were addressed, the following expert advice can be drawn from this meeting:

- **What are the risks associated with continued use of appliances that are near end of life or venting systems that do not meet the current mechanical codes?**
  Data from Cautley indicate that vent systems that are 30% below code requirements will cause back-drafting failures, and data from Fitzgerald show that $100 to $300 in tune-up costs can reduce high CO levels in an atmospheric furnace to near zero. Clearly cleaning, tuning, and correcting vent deficiencies should be done before replacement is considered. If house depressurization is more than 5 Pa and only a water heater is present, replacement by a powered vent or direct vent appliance should be considered. Higher depressurization limits are permitted for an atmospheric furnace/boiler or common vented water heater and furnace/boiler.

- **What data have been collected and what additional data need to be collected to support the analysis that will lead to the development of a common standard for combustion safety?**
  Data from Cautley, Fitzgerald, Rapp, and others are provided in the slides, showing that there is poor correlation between stress tests and field failures. More long-term field data in warm and cold climates with a variety of common and single-appliance vent scenarios should be collected. An important first step is to identify and correct improper vent sizing and installation so only the house depressurization conditions are being studied.

- **How do field practices agree or disagree with the code coverage?**
  BPI/RESNET inspection practices differ from the NFGC in several important aspects: CO action limits, the test time for back-drafting after startup, combustion air zone definitions, and worst-case scenarios. Harmonization of the BPI procedures and the code would reduce confusion in the field. Also, data from Cautley, Fitzgerald, Rapp, and others are provided in the slides, showing that there is poor correlation between stress tests and field failures. This indicates a need to correlate field failures and inspection practices.

What low-cost or no cost options are currently available that satisfy the need for combustion safety in homes with low infiltration?

- The vent should be inspected and modified so that it meets the sizing and installation requirements in the NFGC.

- The combustion air provisions in the NFGC should be followed. Adding openings or removing doors, for example can improve combustion air supply.

- Appliances should be cleaned and tuned to ensure that they are operating safely.

- Power vented water heaters are available in the market to replace atmospheric gas water heaters.

- ASHRAE 62.2 ventilation requirements can be met with systems other than exhaust-only systems.

Direct vent gas-fired equipment is available for replacement where a higher price point is supported. As an example, significantly improving the efficiency level of the equipment as an energy saving measure would justify a higher cost.

4 Meeting Outcomes and Next Steps

The feedback from meeting participants was very positive. The results of this meeting will be shared at an upcoming BA technical meeting, as appropriate, as well as with gas utilities in an upcoming conference.

This expert meeting featured excellent interactions among the in-person attendees, and PARR recommends that future expert meetings should be conducted in person to foster idea exchange and collaboration between technical experts in the subject area.

Research topics identified during the expert meeting and under consideration for 2013 and beyond include the following:

- Identifying differences between BPI/RESNET inspection practices and the NFGC and determining opportunities for harmonization
- Recommending harmonization of ASHRAE 62.2 and the NFGC language to avoid confusion in the engineering community and in the field about applying both codes
- Collecting long-term performance data in the field to identify the correlation between stress tests and field performance, depressurization and back-drafting events, back-drafting/spillage and weather, and indoor contaminants and back-drafting
- Conducting a risk assessment to identify the health risks associated with back-drafting/spillage events as they occur in the field.
- Conducting a failure modes and effects analysis for exhaust recovery/energy recovery ventilators to determine the likely failures and their impact on indoor air quality in low-infiltration homes
- Developing a contamination model to simulate back-drafting events and their effect on indoor air quality.

5 Bibliography

ASHRAE (2010). *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings.* ANSI/ASHRAE Standard 62.2-2010. Atlanta, GA: ASHRAE. Accessed November 27, 2012: http://www.ashrae.org/standards-research--technology/standards--guidelines (available for purchase).

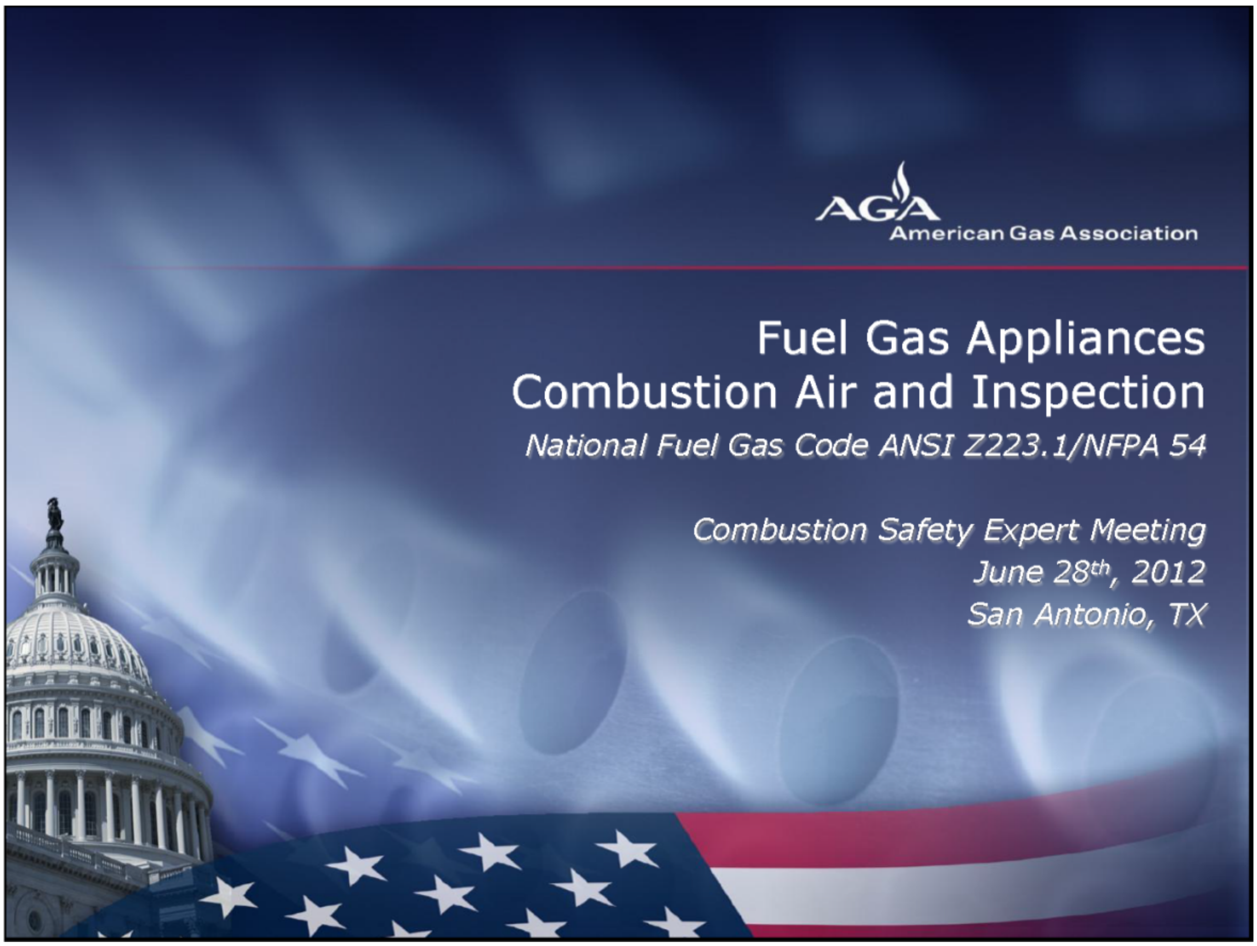
International Code Council (2012). *National Fuel Gas Code.* ANSI Z223.1/NFPA 54. Accessed November 27, 2012: http://www.nfpa.org/catalog/product.asp?PID=5412&order_src=C900&gclid=CNqvgrC577MCFegWMgodxwIAaA (available for purchase).

Appendix A: Meeting Slides

This appendix shows the first page of each presenter's slides. The full presentations are available from PARR and accompany this report on the NREL website: http://www1.eere.energy.gov/buildings/residential/ba_meetings.html#expert.

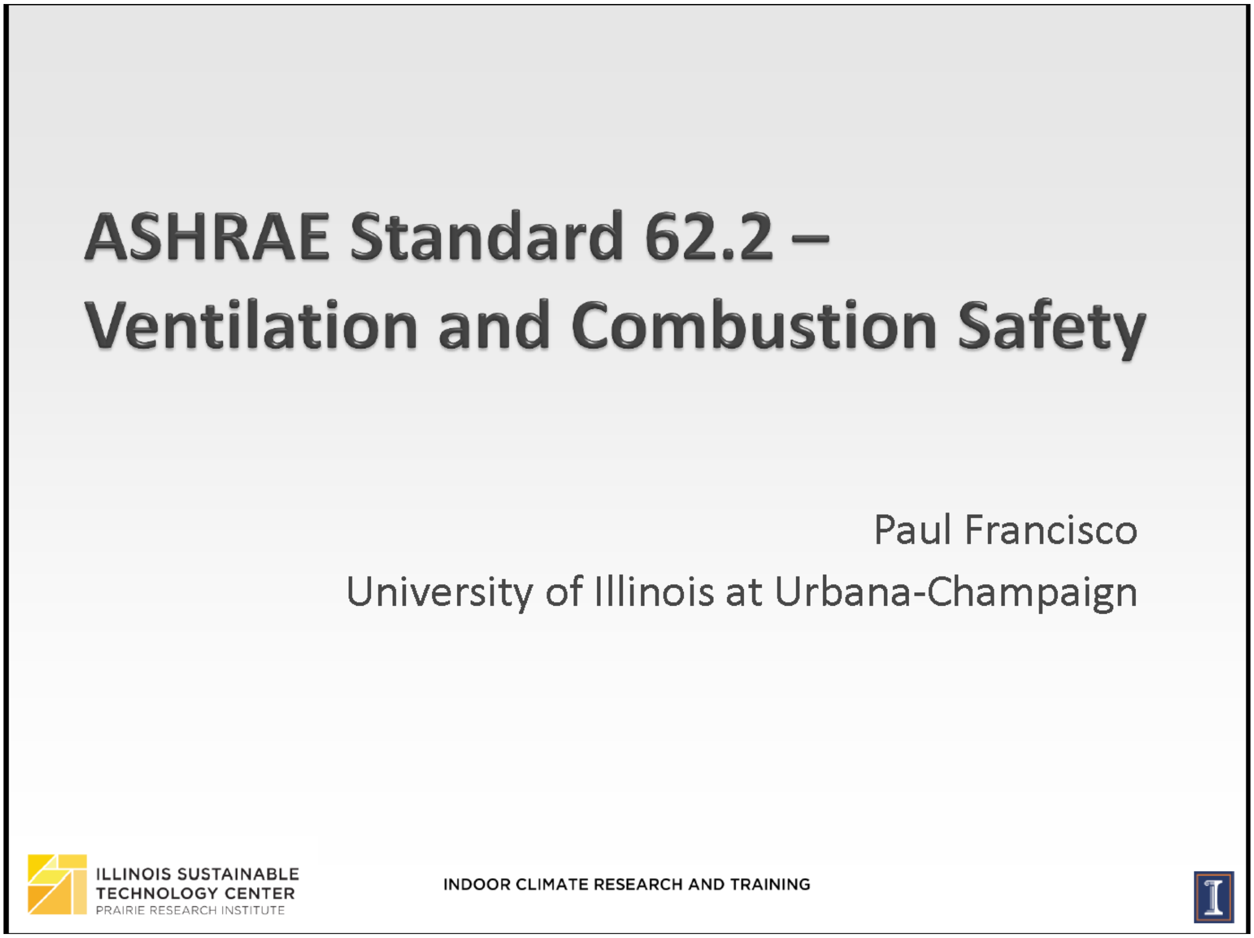
Presentation 1—National Fuel Gas Code Coverage

Paul Cabot presented a perspective on the topic from the gas industry and the National Fuel Gas Code.



Presentation 2—ASHRAE 62.2 Ventilation Requirements

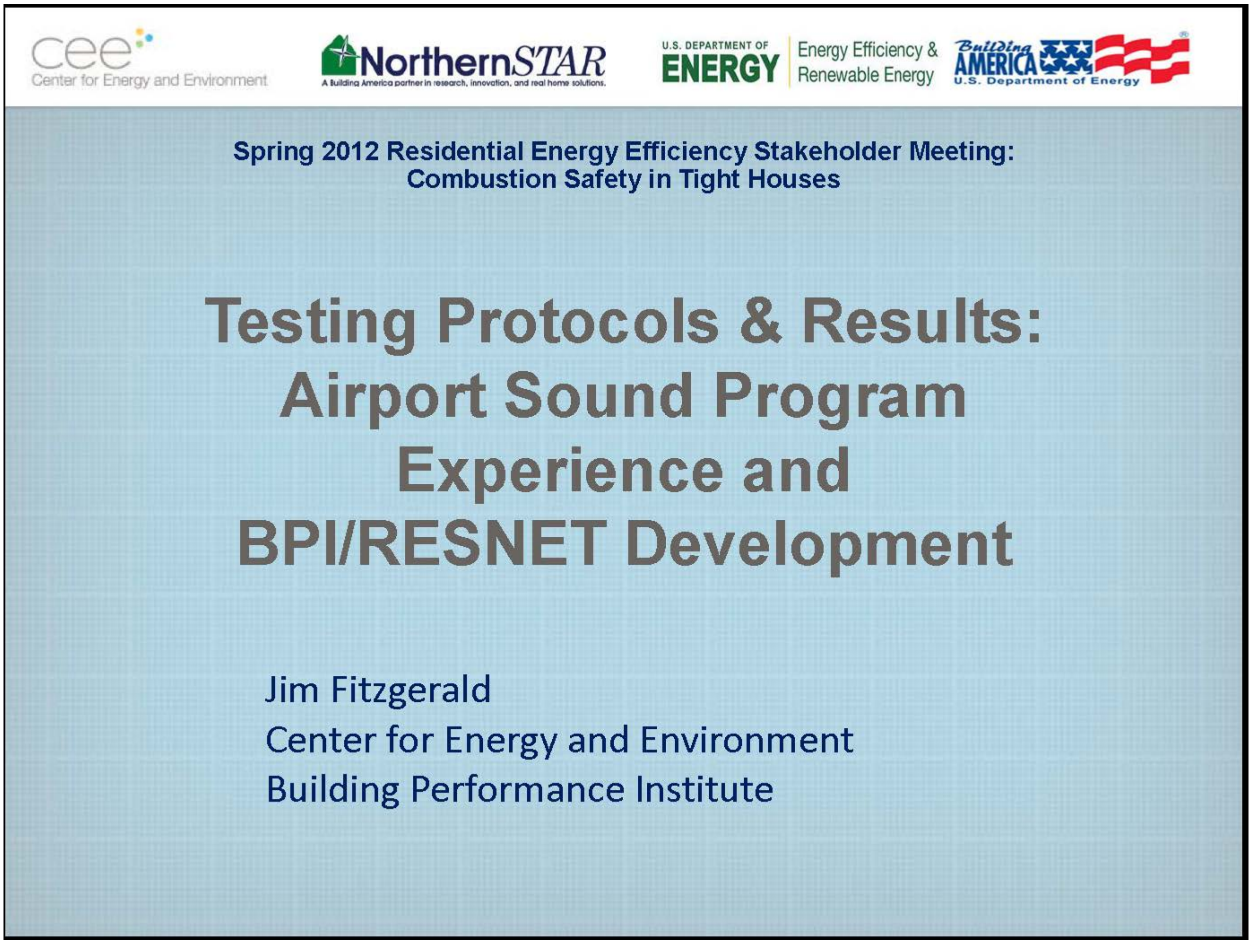
Paul Francisco presented the current ASHRAE 62.2 residential ventilation requirements and implications for combustion safety.



Presentation 3—Building Performance Institute Combustion Safety Procedures
John Jones gave a presentation on BPI's combustion safety test procedures.

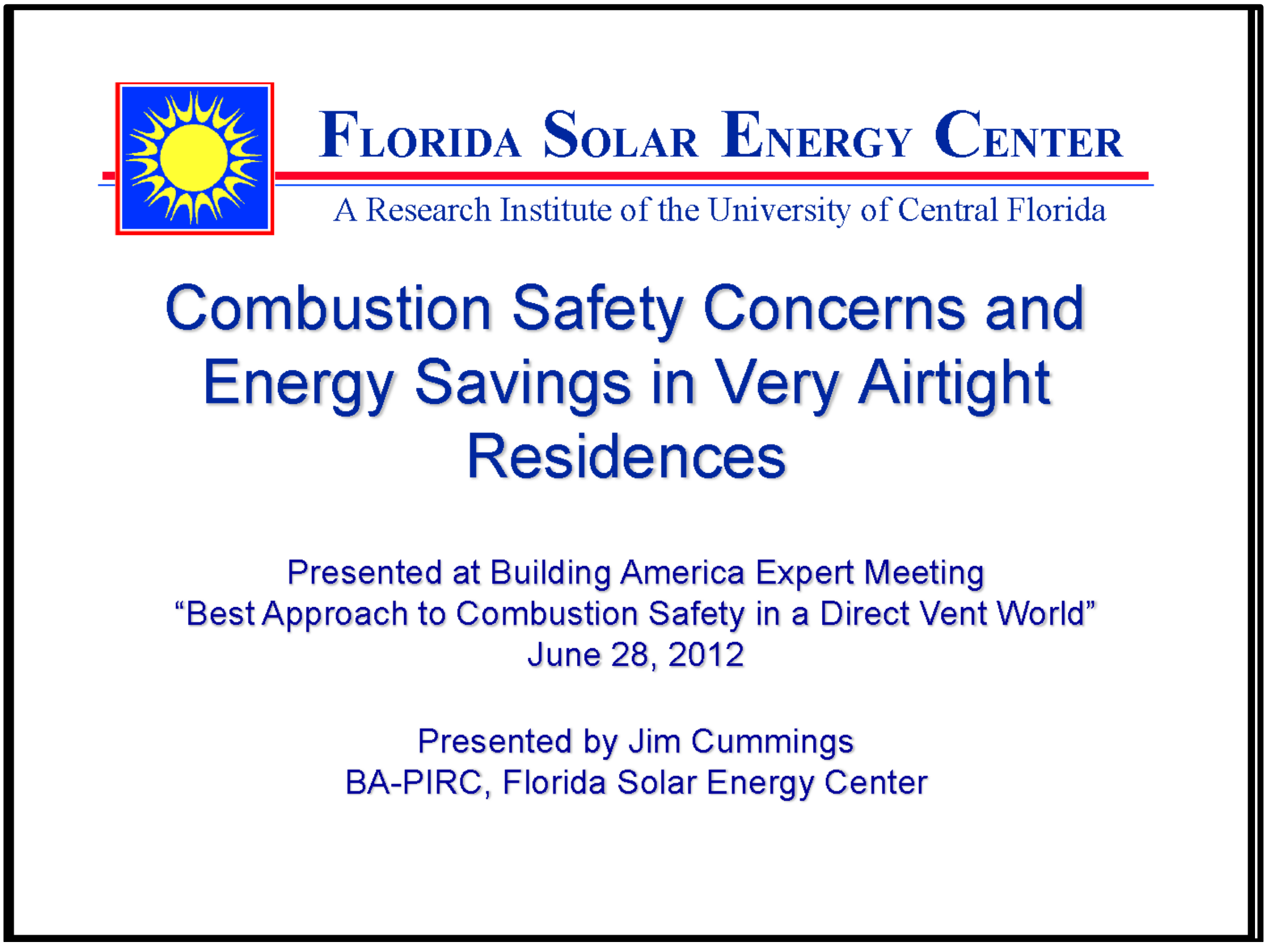
Presentation 4—Field Research and Building Performance Institute Guidelines

Jim Fitzgerald gave a presentation on the basis for some of the BPI combustion safety guidelines and other research from the field.



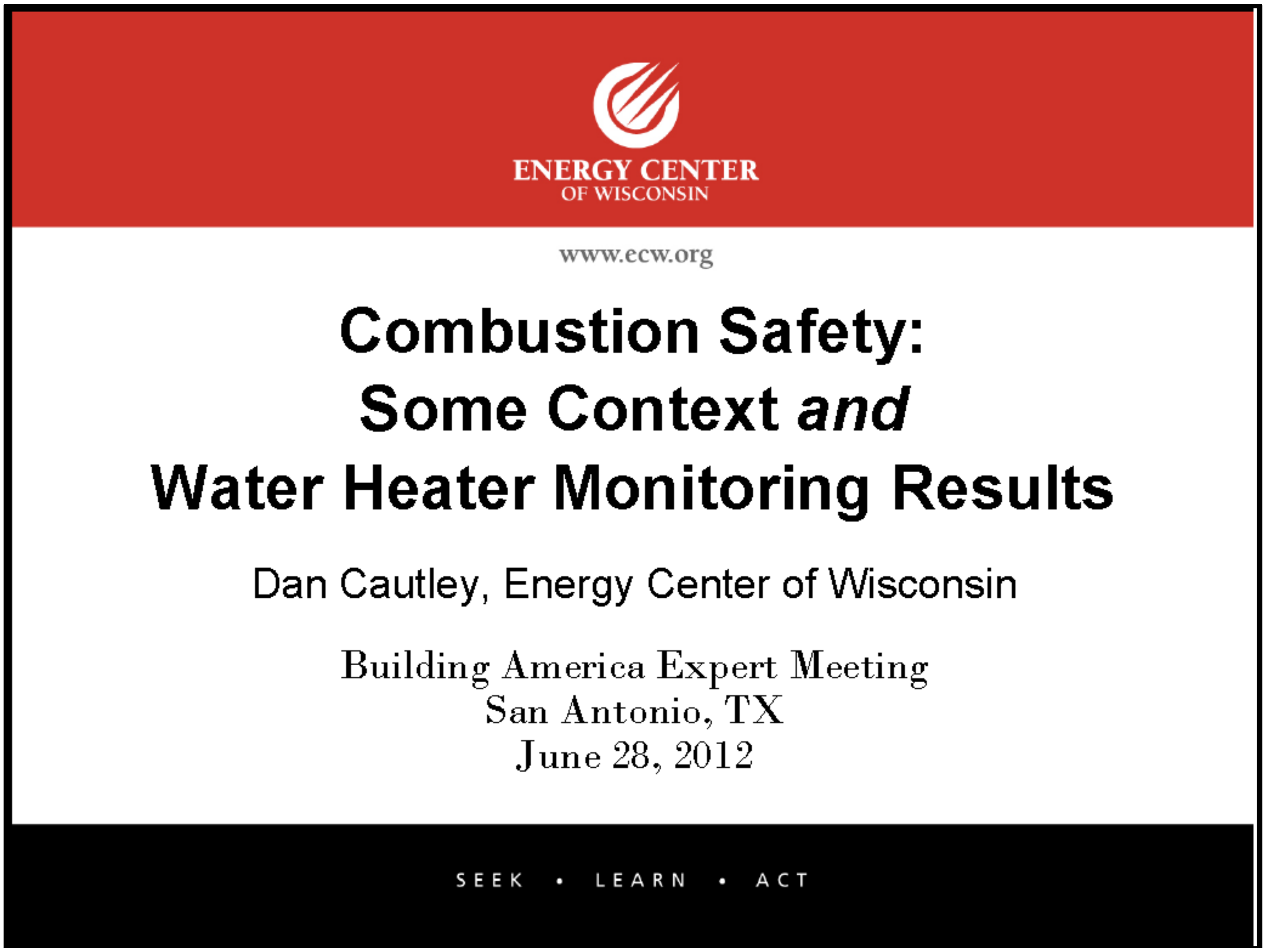
Presentation 5—House Airtightness and Combustion Safety

Jim Cummings presented his work on house airtightness and combustion safety with a focus on house ventilation.

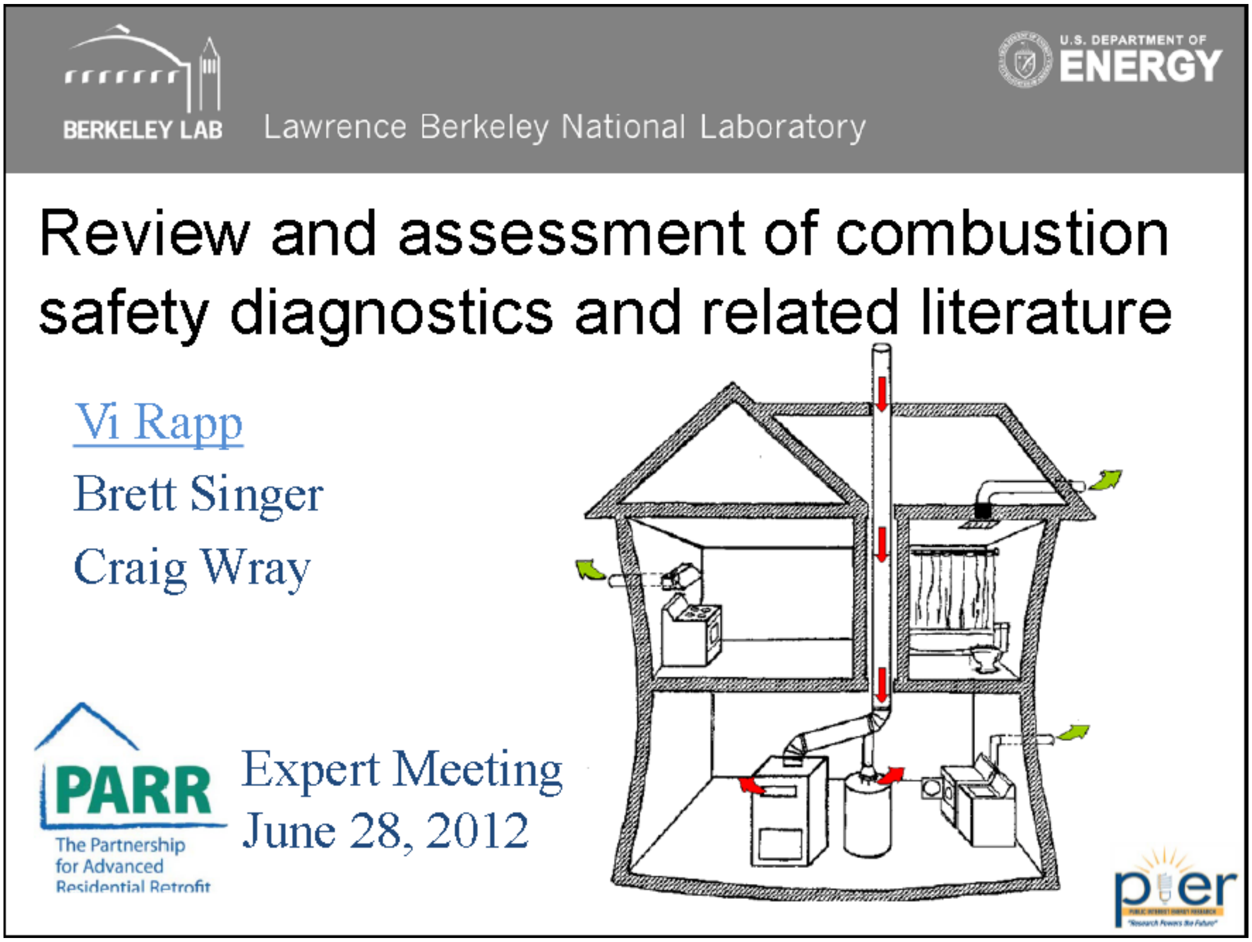


Presentation 6—Long-Term Monitoring of Residential Water Heaters

Dan Cautley presented the results of research done on field monitoring of residential water heaters.



Presentation 7—Review and Assessment of Combustion Safety Diagnostics
Vi Rapp presented the results of a recent California Energy Commission project on combustion safety and plans for upcoming research.



Appendix B: Meeting Flyer

Expert Meeting

U.S. Department of Energy, Energy Efficiency and Renewables, Building America Program

Partnership for Advanced Residential Retrofit (PARR)

PARR
The Partnership for Advanced Residential Retrofit

Topic: "Best Approach to Combustion Safety in a Direct Vent World"

When: Thursday June 28, 2012; 9 a.m. to 3 p.m. Central, (post-ASHRAE)

Where: CPS Energy Oak Room #1, 145 Navarro Street, San Antonio Texas

Dial-in Number: 877-917-2509 Passcode: 8739836

WebMeeting: https://www.mymeetings.com/nc/join.php?i=PW6551078&p=8739836&t=c

Description: : The Department of Energy Building America program focuses on reducing energy consumption in the nation's housing stock through smart integration of energy efficient design and upgrades. The target is a 50% energy savings captured through application of many measures including reduction in air infiltration, equipment upgrades, and thermal envelope improvements. Combustion safety testing is an important part of the test-in and test-out process in new construction and retrofit (upgrade) projects when direct vent appliances are not used and houses are being tightened to reduce energy losses through air infiltration. Where combustion safety testing identifies excessive spillage or continuous back-drafting, remedial measures are required.

The building science community holds many different opinions regarding the best overall value proposition (testing vs. replacement) and the proper test procedures to use to verify combustion safety for draft-hood equipped appliances. Practitioners and codes differ in the recommendations for two variables: level of home depressurization, and time required for cold vent establishment pressure. In addition, statistics on incidents and data collected from the field have not supported stringent testing requirements.

The Gas Technology Institute, through the Partnership for Advanced Residential Retrofit, will hold an expert meeting on combustion safety to:

- Evaluate the pros and cons of upgrading to direct vent appliances, especially when existing appliances and/or venting do not meet current code or are near end of life,
- Investigate current BPI and RESNET practices for combustion safety testing in the field,
- Review the ICC and NFPA/ANSI code requirements,
- Evaluate data collected from the field in several programs, and
- Discuss ongoing research on this topic.

This discussion will result in the identification of gaps and barriers that need to be addressed by future research and data-driven technical recommendations for code updates so that a common approach can be adopted by all members of the building energy efficiency and code communities.

Research Questions:

1) What are the risks associated with continued use of appliances that are near end of life or venting systems that do not meet the current mechanical codes?
2) What data has been collected and what additional data needs to be collected to support the analysis that will lead to the development of a common standard for combustion safety?
3) How do field practices agree or disagree with the code coverage?
4) What low-cost or no cost options are currently available that satisfy the need for combustion safety in homes with low infiltration?

This expert meeting will be structured to review the material presented and encourage discussion among the panel members and participants. Possible discussion topics include: gaps and barriers to a single solution, areas of agreement and disagreement, low-cost or no-cost solutions, and a path forward.

A strategy guideline will be developed based on this input to identify best practices and the PARR team will work with other researchers to address the gaps and barriers outlined in the expert meeting.

Panel Members (tentative):

Larry Brand, Gas Technology Institute – Moderator

Dave Bohac/Jim Fitzgerald, Minnesota Center for Energy and the Environment – Field Research and BPI Guidelines

Paul Cabot, American Gas Association – National Fuel Gas Code Combustion Air Safety Requirements

Dan Cautley, Energy Center of Wisconsin – Long-term Monitoring of Residential Water Heaters for Performance and Spillage

Jim Cummings, FSEC – House Airtightness and Combustion Safety

Paul Francisco, University of Illinois – ASHRAE 62.2 Ventilation Requirements

John Jones, Building Performance Institute – BPI combustion safety testing

Vi Rapp/Craig Wray, LBNL – DOE Project on Range Hoods and California Energy Commission Project on Combustion Safety

Participants: Researchers, trainers, manufacturers, HVAC installers, national laboratories, Building America teams, DOE, PARR partners. Attendance is limited to 30 people.

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