Better Buildings Residential Network Peer Exchange Call Series:

Back to School: Building Science Training

September 27, 2018

Agenda and Ground Rules

- Agenda Review and Ground Rules
- Opening Poll
- Residential Network Overview and Upcoming Call Schedule
- Featured Speakers:
  - **Glenn Dickey**, Alleghany Science & Technology
  - **Asa Foss**, US Green Building Council
- Open Discussion
- Closing Poll and Announcements

Ground Rules:

1. **Sales of services and commercial messages are not appropriate** during Peer Exchange Calls.
2. Calls are a safe place for discussion; **please do not attribute information to individuals** on the call.

Better Buildings Residential Network

Join the Network

Member Benefits:

- Recognition in media and publications
- Speaking opportunities
- Updates on latest trends
- Voluntary member initiatives
- Solution Center guided tours

Commitment:

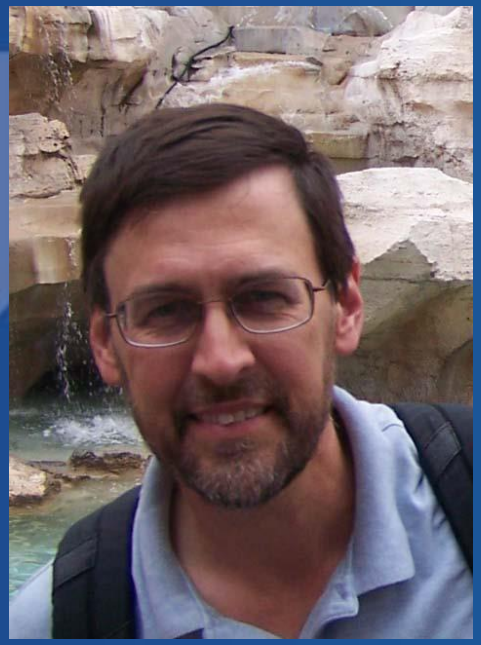
- Members only need to provide *one number*: their organization's number of residential energy upgrades per year

Upcoming calls:

- October 11th: Resiliency in the Face of Disaster: Energy Efficiency's Role
- October 25th: Horror Stories from the Field

Peer Exchange Call summaries are posted on the Better Buildings website a few weeks after the call

For more information or to join, for no cost, email bbresidentialnetwork@ee.doe.gov, or go to energy.gov/eere/bbrn & click Join



Glenn Dickey
Allegheny Science & Technology

U.S. DEPARTMENT OF ENERGY

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Building Science Basics

BBN Webinar

September 27, 2018

The Basics

- **Do No Harm**
- **Home Performance includes:**
  - Occupant Health and Safety
    - Indoor Air Quality
  - Building Durability
  - Energy Efficiency
- **When done correctly, doing one enhances the others**

House as a System

- **Changing one thing will effect other things in the house**
  - Air sealing the envelope could cause the water heater to back draft and could improve or cause indoor moisture issues
  - Insulating the attic floor could cause moisture problems in the attic including mold and rot
  - Closing bedroom doors can cause comfort and IAQ problems,

For example ...

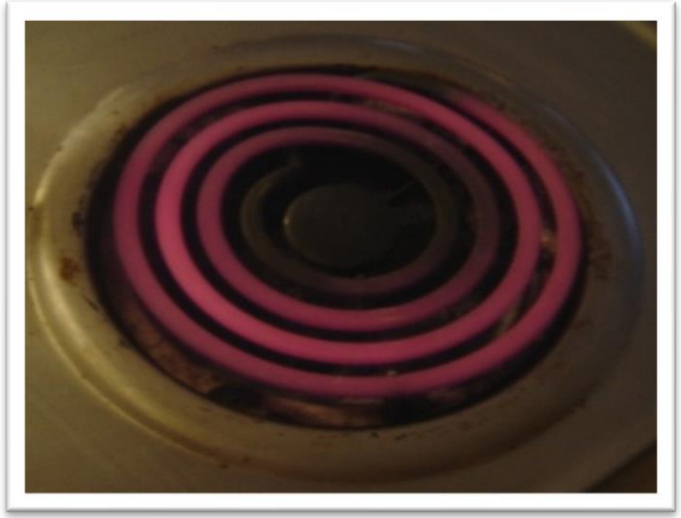
50 year old house, standing water on the crawlspace floor? Why is there no mold? What would happen if the floor and ducts were insulated and the ducts air sealed?

Comfort

- **A combination of several elements**
  - Ambient temperature
  - Surface temperatures enclosing the space
    - Mean radiant temperature
    - Windows vs walls
  - Relative humidity
    - Hot and dry is more comfortable than hot and humid
  - Air movement
    - Why we use fans
  - Activity
  - Clothing

Heat Transfer

- **Conduction**
  - Heat transfer through contact
- **Convection**
  - Heat transfer by fluid motion
- **Radiation**
  - Heat transfer without a medium
    - The sun radiates heat across empty space by means of radiation
    - Standing in front of a camp fire. Your front is warmed mostly by radiation while your back radiates heat to space.



Heat Transfer in the House

- **Conductive heat loss across surfaces**
  - The gypsum board that separates the house from the attic is heated (winter) by the warm air in the house
  - The heat is transferred across the gypsum board by conduction
- **Convective heat loss**
  - As warm air rises (winter) it will escape to the attic through gaps and holes in the attic floor
- **Radiation**
  - The roof is heated by the sun. The underside of the roof acts as a radiator and transfers heat to other materials in the attic
  - If there is no insulation in the attic the gypsum board ceiling would act as a radiator to the house

Convection inside

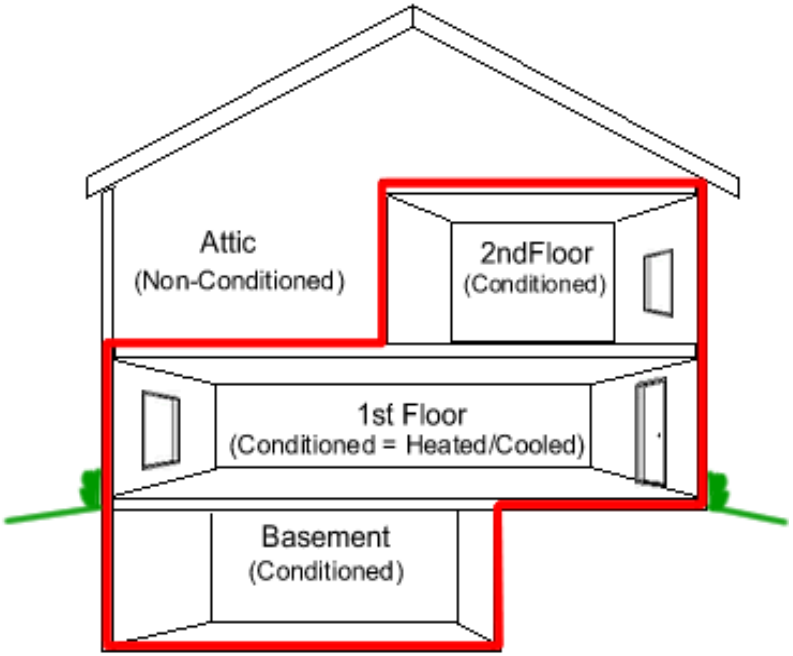
- Convection can also cause problems even when the conditioned air is not leaving the house
- The air tends to rise in the middle of the room and move to the exterior wall.
- The air cools as it passes the windows and feels like an outside draft at the window bottom
- In most houses the HVAC registers are put on outside walls to reduce this effect

Controlling Conductive Losses

- **Use insulation**
  - In general insulation works due to dead air spaces. The more dead air the more effective it is.
  - The insulation must be against the surface it is insulating
  - Must be dry
  - Should be enclosed to avoid air movement within the insulation
  - Can be compromised if compressed or “wind washed”

Thermal Boundary

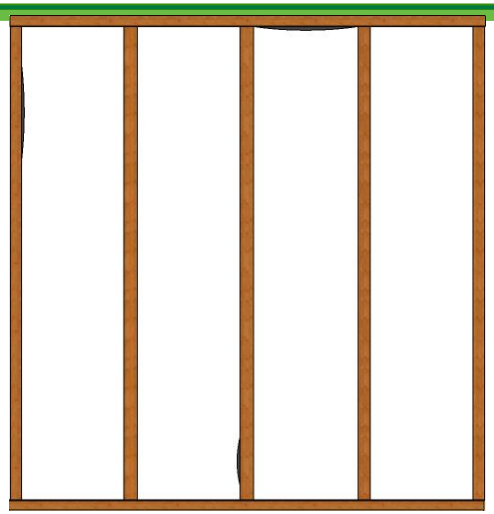
- It must be continuous and in contact with the insulated surface
- Should align with the air barrier
- The more complicated the house, the more difficult it is to define



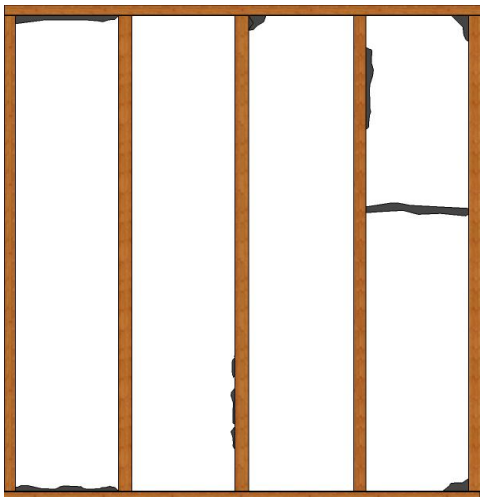
Insulation Derate

	Good	Fair	Poor
Measured Batt Thickness	Effective R-value (2.5 per inch)	Effective R-value (1.8 per inch)	Effective R-value (0.7 per inch)
0	0	0	0
1	3	2	1
2	5	4	1.5
3	8	5	2
4	10	7	3
5	13	9	3.5
6	15	11	4
7	18	13	5
8	20	14	5.5
9	23	16	6
10	25	18	7
11	28	20	8
12	30	22	8.5

Gaps and voids
Compression
Non-contact

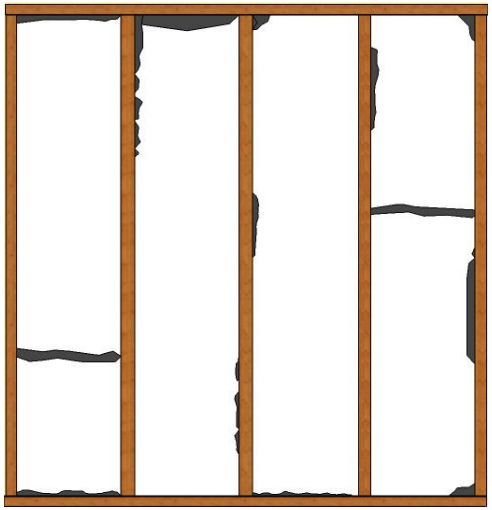


Good



Fair

2.5% gaps = 3/8 inch along edge



Poor

5% gaps = ¾ inch gap along length

Averaging R-values

95% of attic floor is covered with R-30 Insulation
5% of attic floor (attic access) has no insulation

(30*.95) + (1*.05) = 28.5 + .05 = 28.55 - WRONG

Column A	Column B	
Building Component 1 R-value	Building Component 1 Area	Building Component 1 UA
30	95	3
Building Component 2 R-value	Building Component 2 Area	Building Component 2 UA
1	5	5
Building Component 3 R-value	Building Component 3 Area	Building Component 3 UA
		0

Weighted Average R-value
12

Cavity U-Factor
0.082

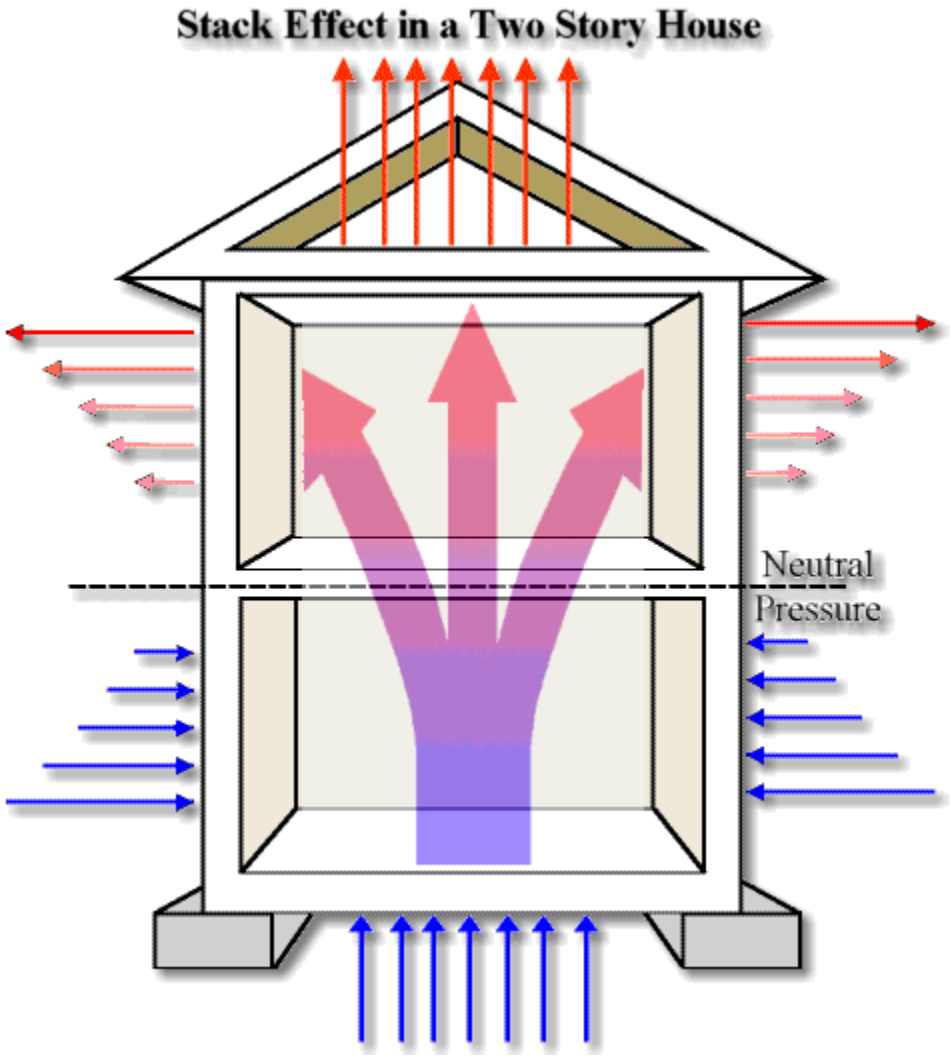
(95/30 + 5/1)/100
(3.17 + 5)/100
8.17/100 = 0.0817
12.2 = R-value

Radiant Barrier

- R-0
- Only applicable in very high cooling load areas and only when the hvac equipment is in the attic
- Must have a ¼ “ gap on either side

Pressure on the House

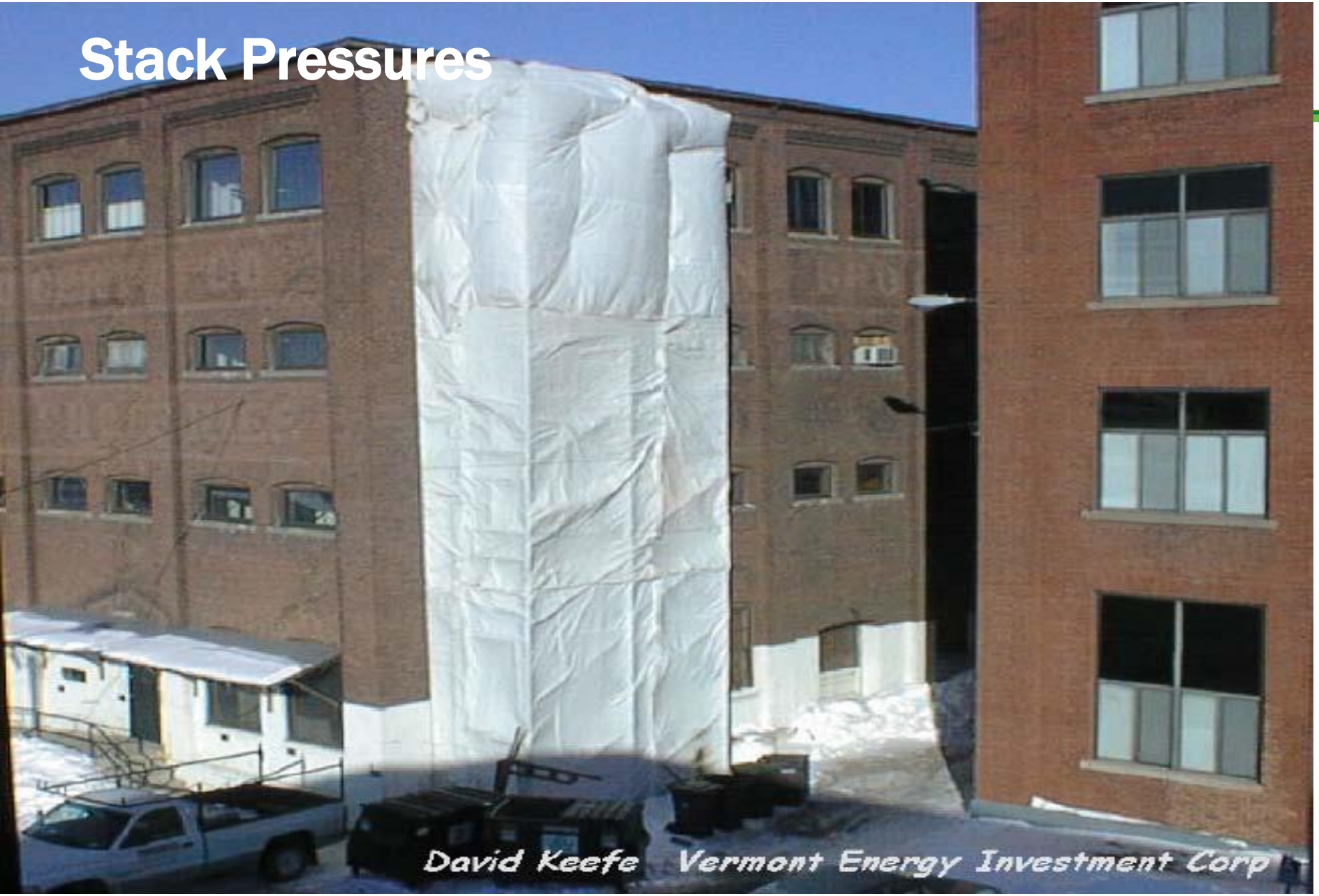
- **Stack effect**
  - Temperature
  - Building height
- **Wind**
  - Speed
  - Exposure
- **Mechanical**
  - Fans



Stack Effect

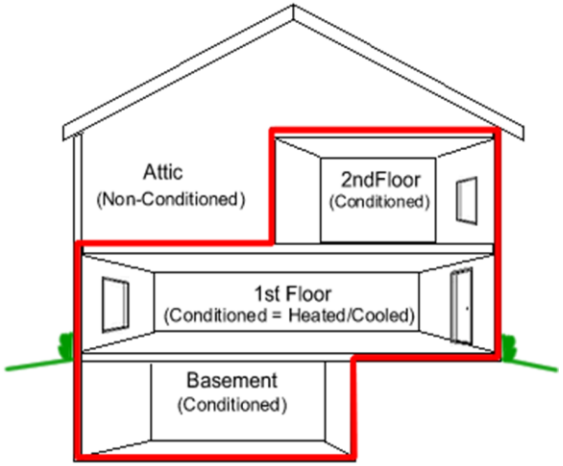
- Warm air rises and increases pressures wrt outside at the top of the house – warm air escapes
- This causes a vacuum at the bottom of the house, which causes higher negative pressures wrt outside at the bottom – cold air enters
- Somewhere in between the pressure wrt outside is zero – the zero pressure plane
- Infiltration/exfiltration requires a pressure difference and a hole. If there is no pressure difference, it doesn't matter how big the hole is.
- Typically spend little time looking for air leaks in the middle of the house because the stack induced pressures there are lower and typically more difficult to fix

Stack Pressures



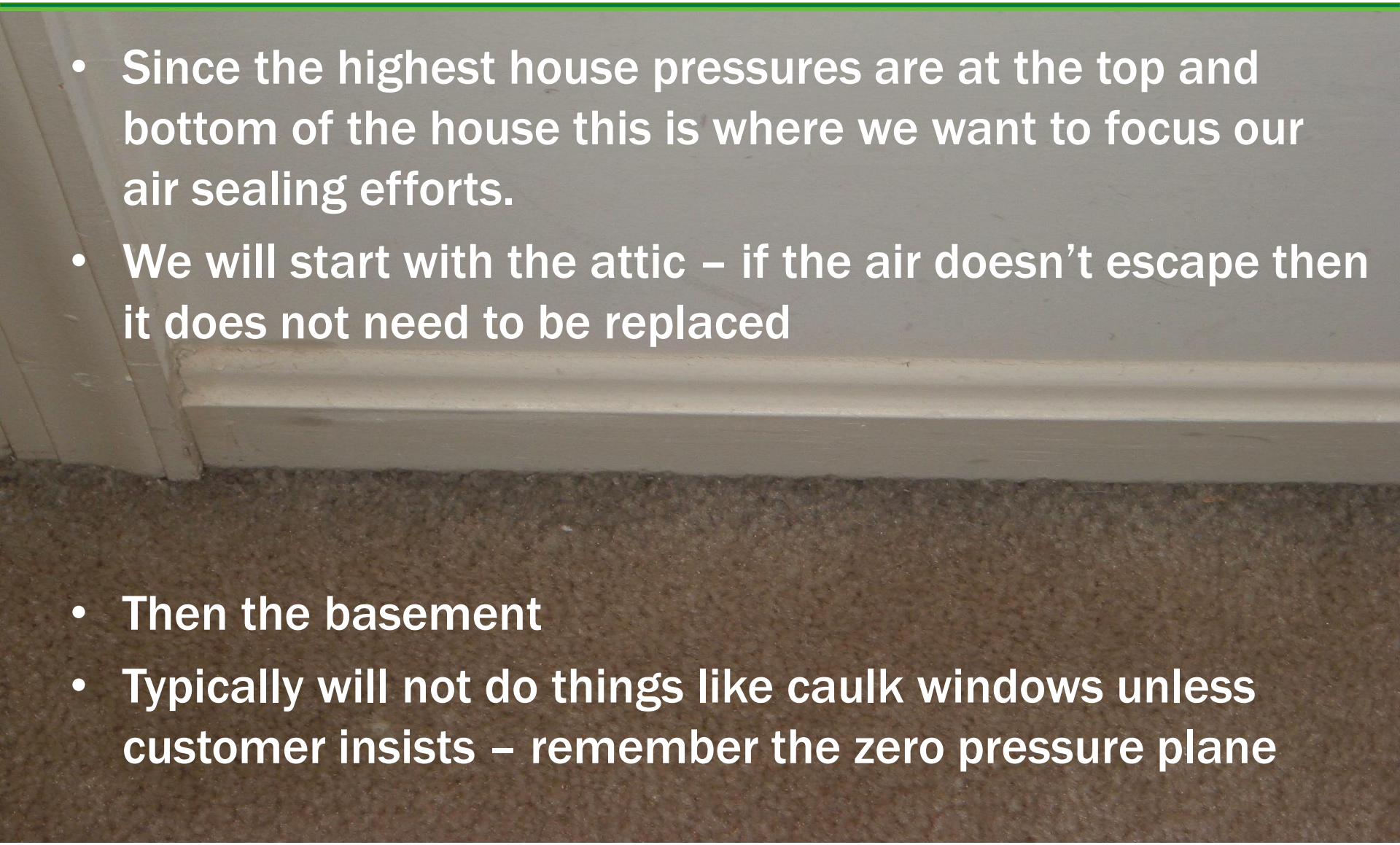
Pressure Boundary/Air Barrier

- Controlling infiltration and exfilitration
- The surface where we want to stop air movement into and out of the house
- Should align with the thermal boundary
- Most houses have many places where they do not align



Misaligned Thermal and Air Barrier

Air Sealing



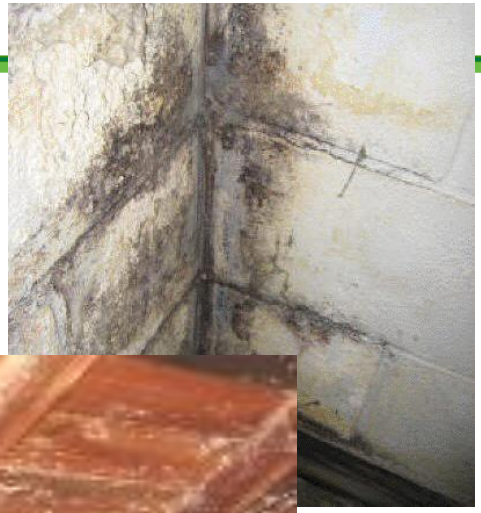
- Since the highest house pressures are at the top and bottom of the house this is where we want to focus our air sealing efforts.
- We will start with the attic – if the air doesn't escape then it does not need to be replaced
- Then the basement
- Typically will not do things like caulk windows unless customer insists – remember the zero pressure plane

Blower Door

- Device used to estimate the leakiness of a building
- It can be very effective at finding air leaks in the envelope
- Pressure diagnostics can help define the existing air barrier

Moisture

- **Moisture**
  - Types
    - Bulk water
    - Vapor
  - Sources
    - Rain / ground water
      - Roof leaks
      - Foundation leaks
      - Poor diversion from the foundation
    - Human activities
      - Breathing & Sweating
      - Laundry & Cooking
      - Hobbies



More Moisture

- **Transport**
  - Bulk
  - Capillary Action
  - Diffusion
  - Airborne
- **Solutions**
  - Avoidance
    - Fix things that are leaking
  - Diversion
    - Make sure water does not pool around the foundation or under the house
    - Provide breaks between building materials that will wick moisture
  - Air movement control
    - More soon
  - Last choice is active dehumidification

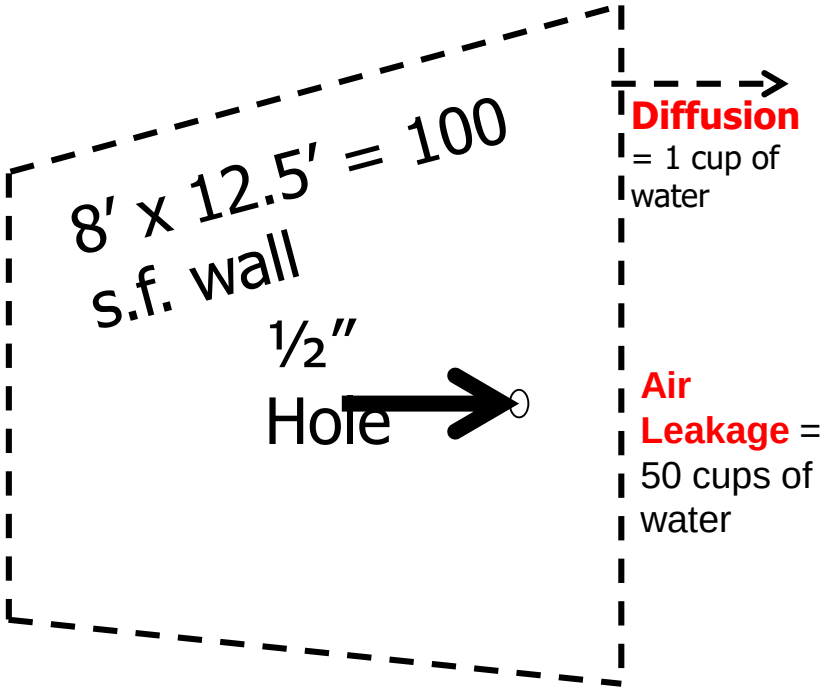
Humidity

- The higher the temperature the more moisture the air can hold
- As temperature goes up relative humidity goes down

- Temperature down – relative humidity up
- Control relative humidity to control IAQ
- As house is tightened the relative humidity will go up during winter
  - During summer – HVAC dependent

Moisture movement

- During the course of a year, 1 cup of water will diffuse through a 100 square foot sheet of drywall that does not have a vapor barrier
- During the course of a year, 50 cups of water can travel through a ½ inch diameter hole
- How does air sealing affect moisture movement?



Stopping Airborne Moisture

- **Diffusion**
  - Typically addressed with membranes
    - Plastic sheathing – must be properly placed or will make matters worse
    - Impregnated paper – kraft paper faced insulation
    - Paints/Sealants
  - Non-permeable wall paper and the like can cause significant problems
- **Air leakage**
  - Air seal at the pressure boundary to stop the moist air from moving into cold spaces
    - Attics and wall cavities
  - Typically addressed with foam sealants, caulk and sheet insulation, for large pathways

Crawlspaces

- **Control moisture in crawlspace**
  - Proper slope away from the foundation
  - Moisture barrier on crawlspace floor
  - Seal foundation vents (typically a good idea)
- **Wet crawlspaces and foundation vents**
  - Winter the vents are closed
  - Summer the vents are open
    - Low crawlspace temperatures (60-65 degrees)
    - High relative humidity
    - High outside temperatures
    - Moderate to high outside relative humidity
      - What happens when the outside air migrates into the crawlspace?

Ducts

- **Deliver heated or cooled air to the living portion of the house**
- **Duct leakage affects house pressures which can lead to:**
  - Comfort problems
  - IAQ problems
  - House durability issues
  - Higher energy use

Leaky Ducts

- **Leaks to outside**
  - Supply leaks suck – depressurize the house
  - Return leaks blow – pressurize the house
  - Sealing supply side leaks in the attic or crawlspace will improve the draft performance of an atmospherically drafted furnace
  - Sealing return side leaks could make it worse
- **Leaks to inside**
  - Supply leaks blow
  - Return leaks suck
  - Sealing return leaks in the furnace room will help the furnace draft
  - Sealing supply leaks may lead to a backdrafting system
- **When pressures change where does the air go and/or where does it come from?**

Leaky Ducts and IAQ

- **If duct leaks depressurize the house, where does the make up air come from?**
  - Garage
  - Crawlspace
  - Attic
  - ???
- **If duct leaks pressurize the house, where does the air go?**
  - Same places
- **What does that air carry with it?**
  - Moisture
  - Radon
  - Pesticides
  - Fertilizers
  - Carbon Monoxide
  - ???
- **If it is moisture where does it condense?**

Duct Issues

Breaks

Blockage

Using building cavities

Flex Ducts

Closing Doors

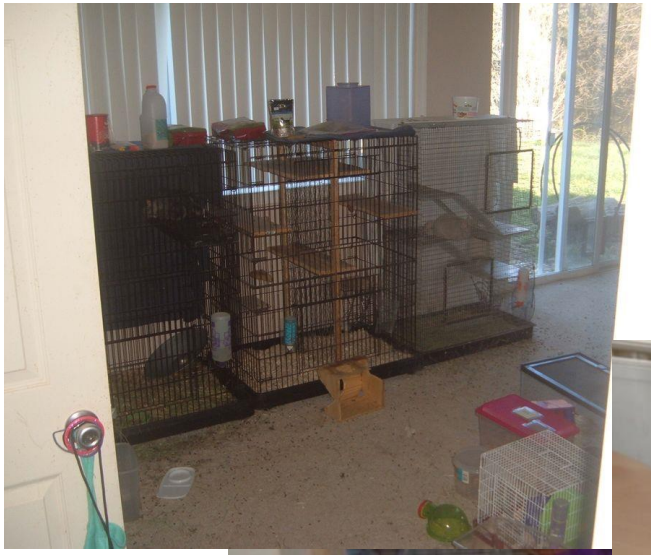
- **Most houses built since 1970 have central returns registers in an open portion of the house – hall, family room, etc**
- **Supply registers are in each room**
- **When room doors are closed pressures change**
  - The rooms become pressurized – oftentimes leads to stuffy feeling
  - The central part of the house becomes depressurized – increases outside drafts
- **Solutions include**
  - Bypass pathways through the wall, door or ceiling

Mechanical Ventilation

- **Need to bring in fresh air**
  - Houses do not breathe, people do
  - Best to control than to count on the weather
- **Exhaust fans will depressurize the house**
  - Potential for backdrafting combustion appliance
  - Where is the air coming from
  - Pollutants/moisture
- **Supply fans will pressurize the house**
  - Where is air coming from (can be filtered),
  - Where is the air going
  - Moisture
- **Balanced will provide both and have less pressure affects – but source and destination still a concern**
- **HVAC fans and duct location will effect house pressures and air movement**

IAQ

IAQ



What's wrong here?

What were they thinking?

Three Key Take-Aways

- Home performance includes the addressing of occupant health and safety, building durability and energy efficiency.
- It is vital to view the house as a system – and understand how pieces can and will interact before making changes.
- Beyond this presentation, see John Krigger's book, Residential Energy for a more thorough overview of basic building science principles.

Asa Foss
US Green Building Council

U.S. DEPARTMENT OF ENERGY

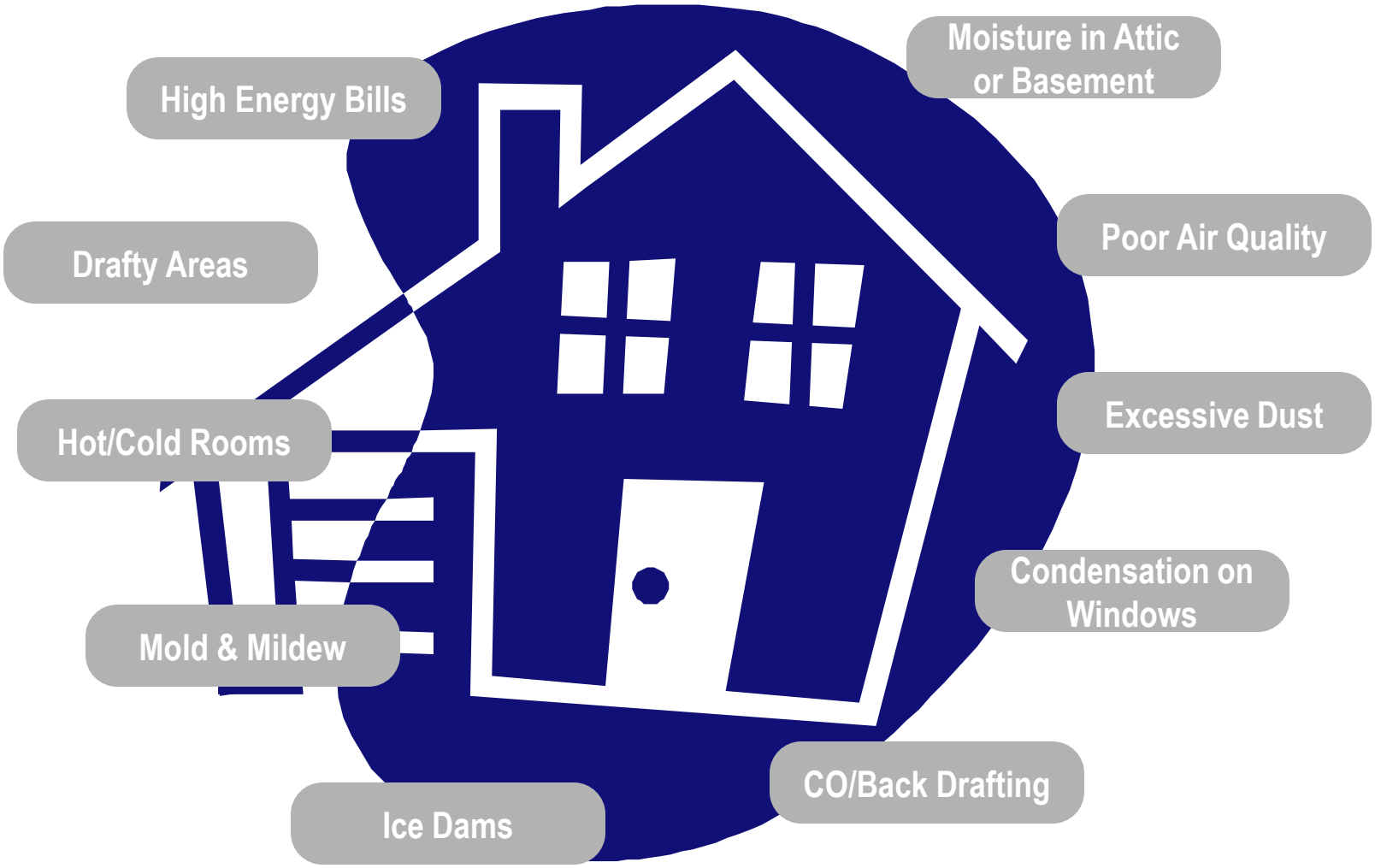
Topics of Discussion

- Why are home energy assessments important?
- What is a home energy assessment?
- Common recommendations
- How to find professionals

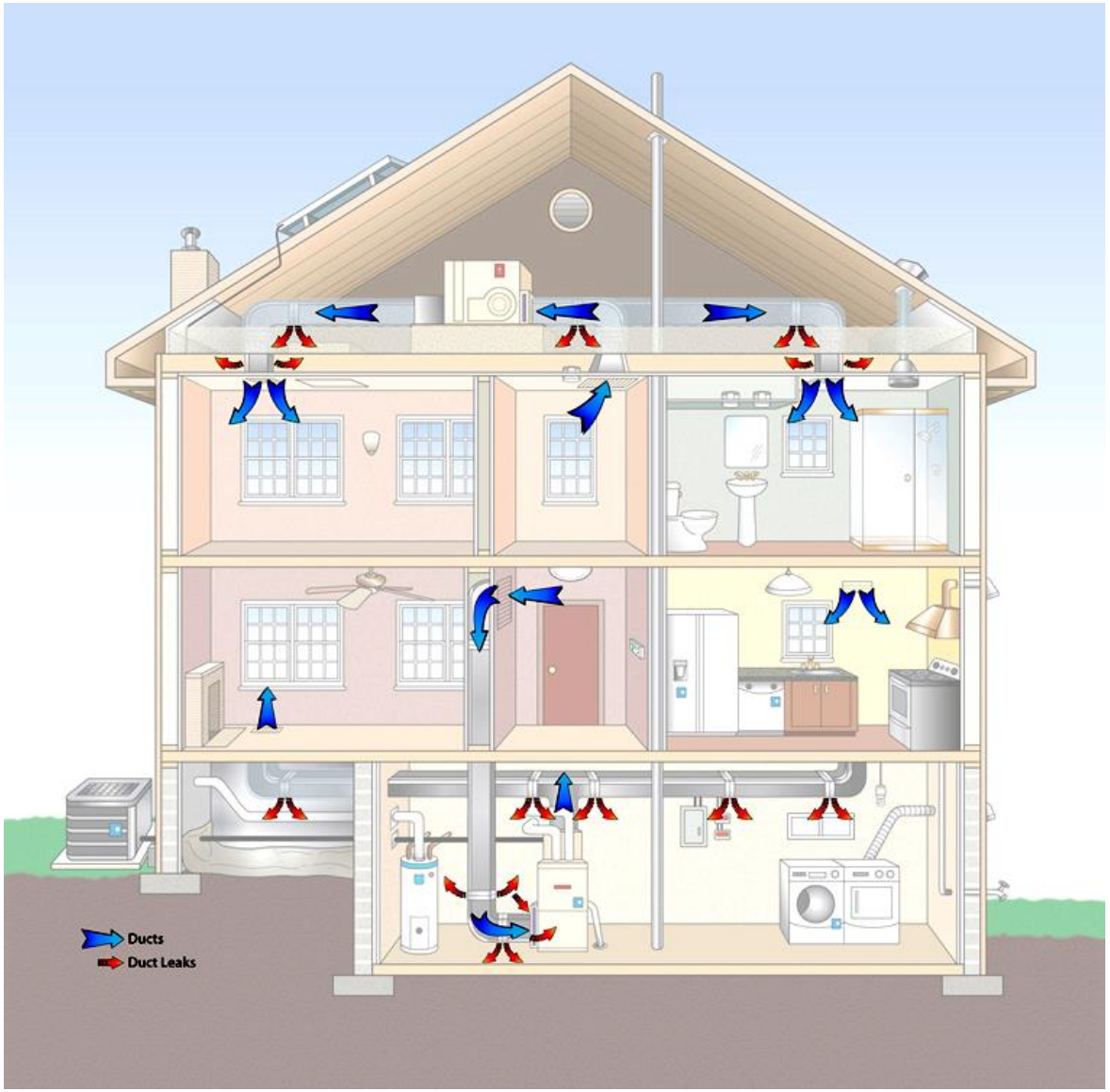
A Whole-House approach to comfort, safety, and energy-efficiency

- Your home is a complicated system of interacting parts and forces.
- The best way to improve your home is to look at the entire system and diagnose the real issues.
- Guessing, or looking at only one piece of the puzzle, can produce undesirable and potentially dangerous effects.

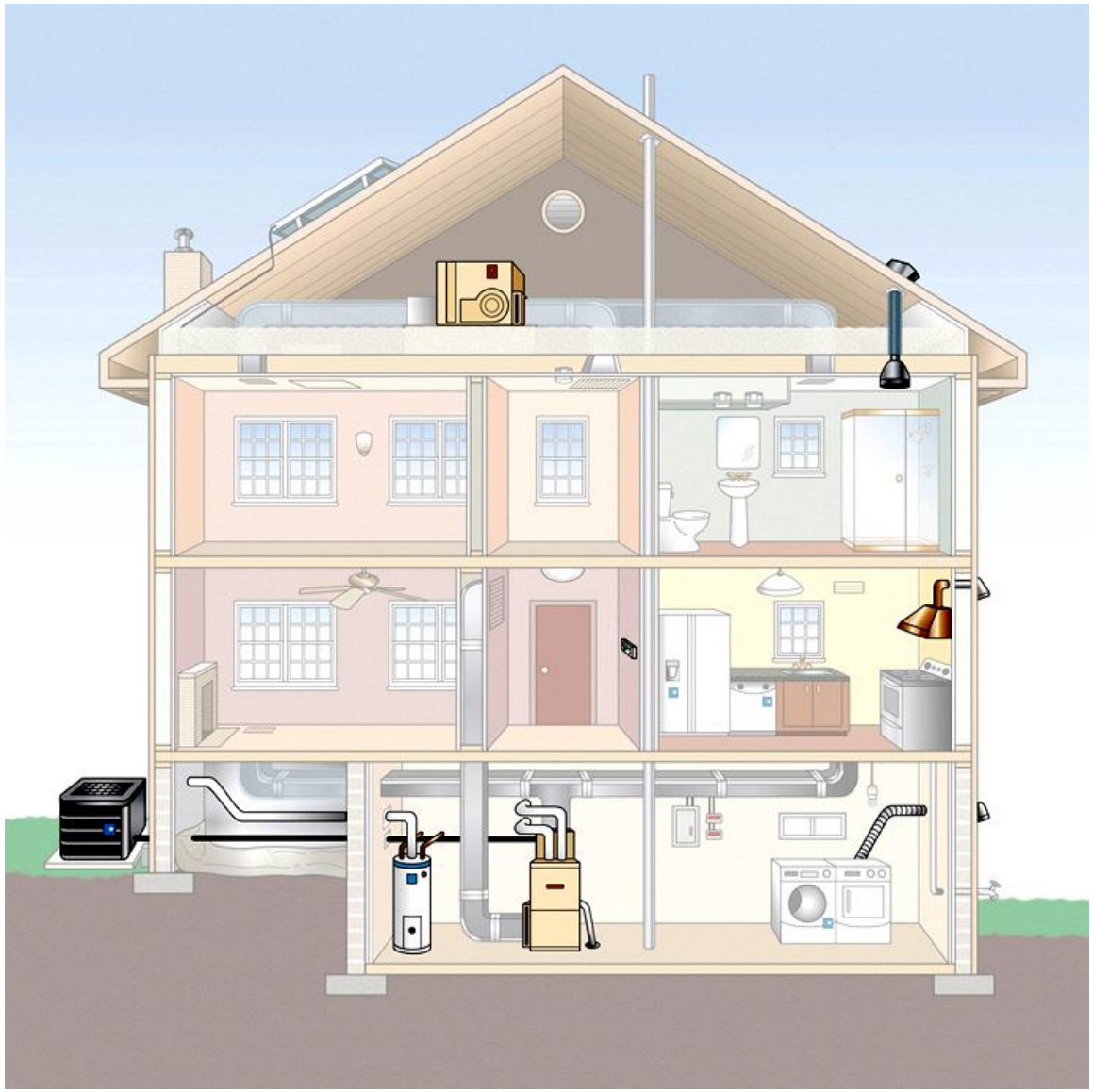
Frequent Home Performance Symptoms



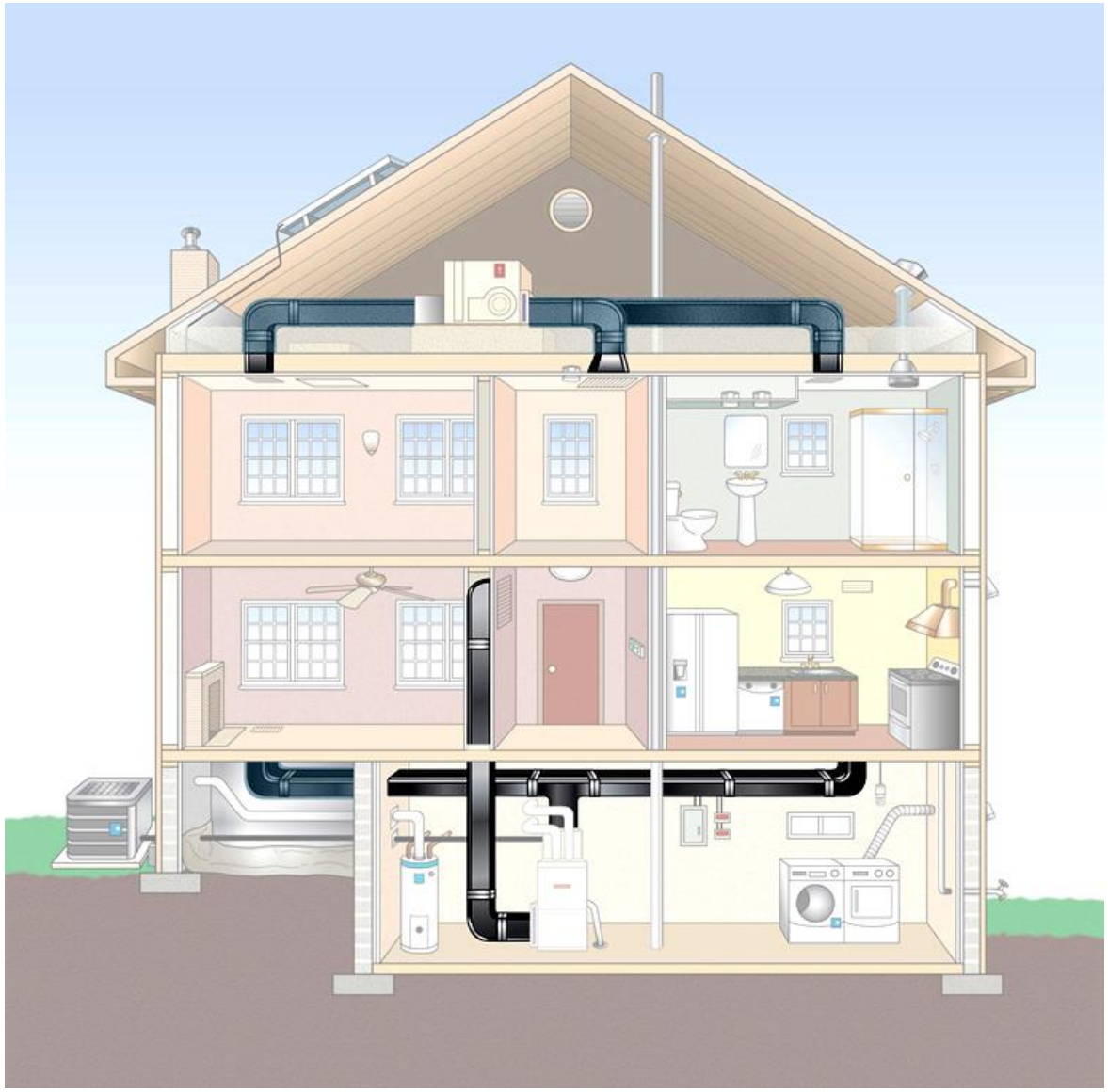
Home Performance Treats the House As a System



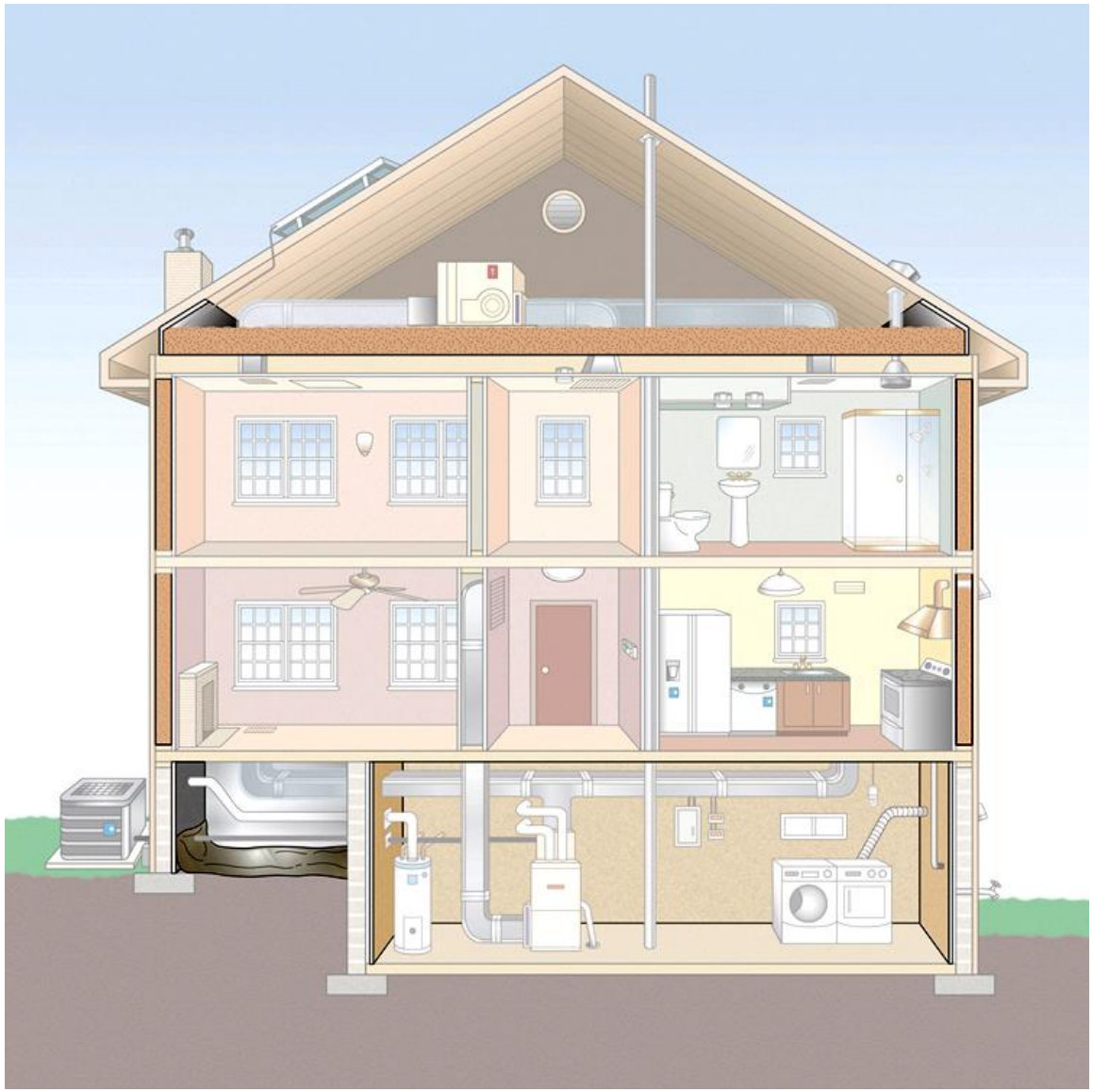
HVAC AND VENTILATION



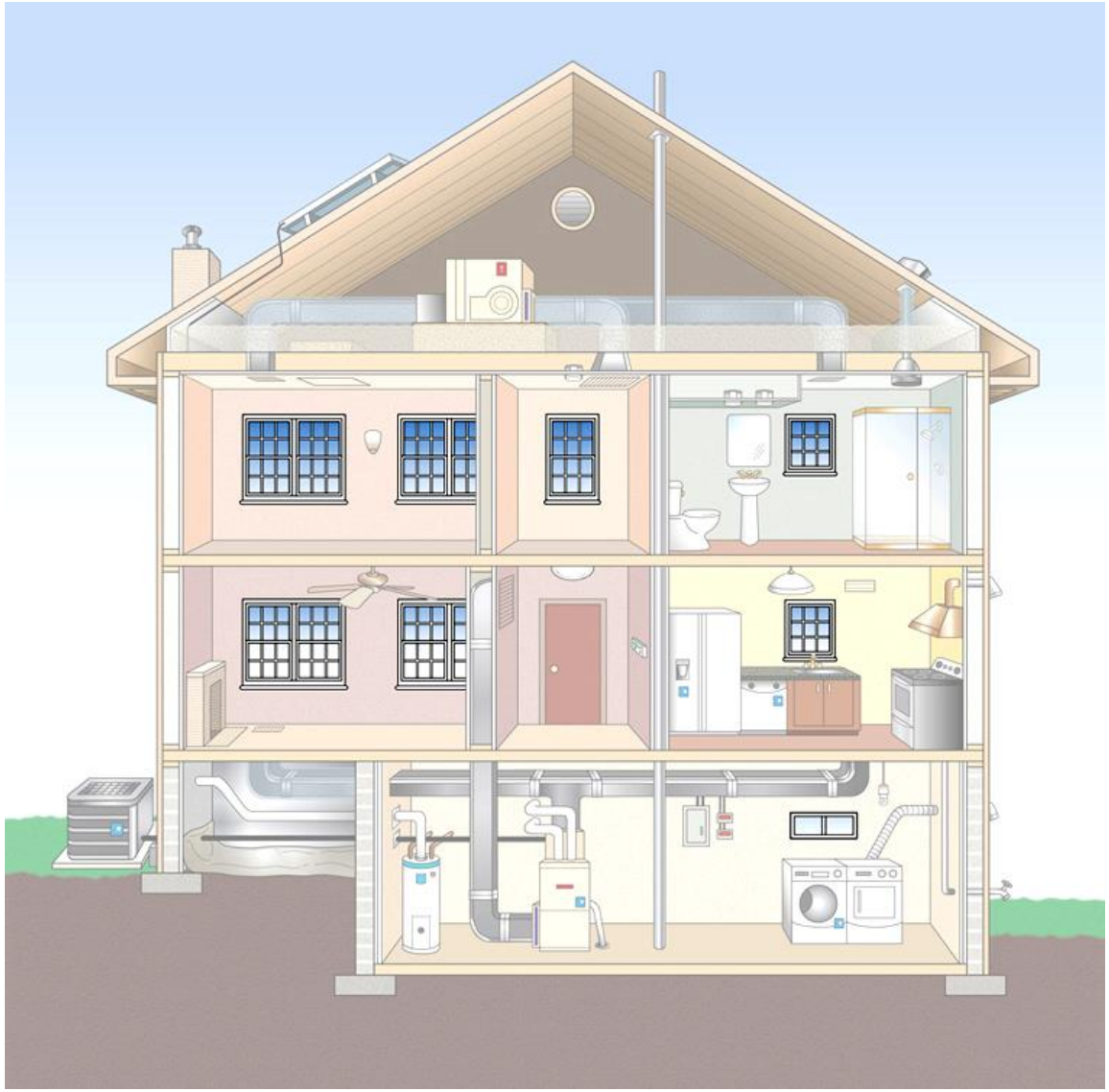
DUCTS



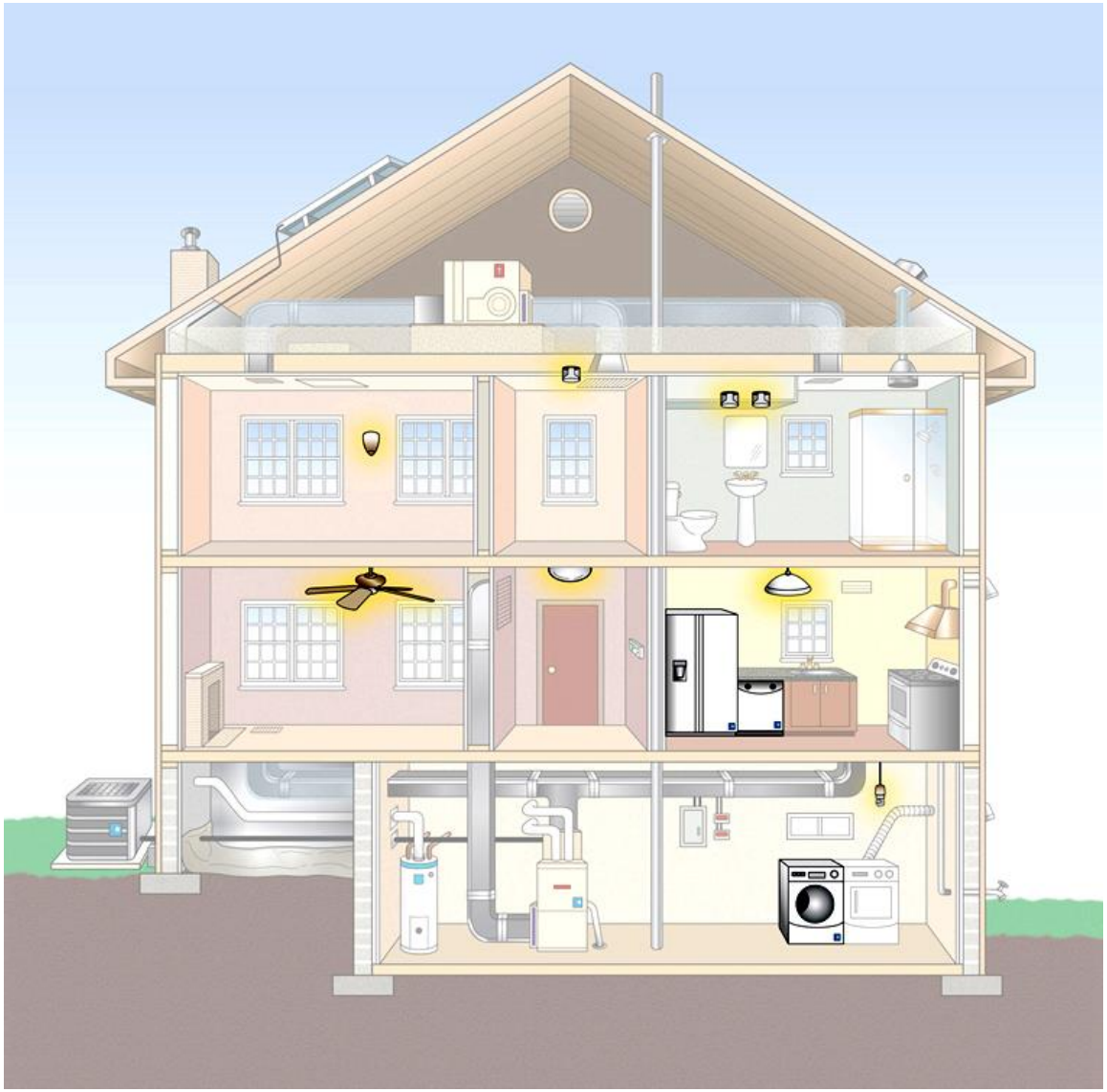
INSULATION



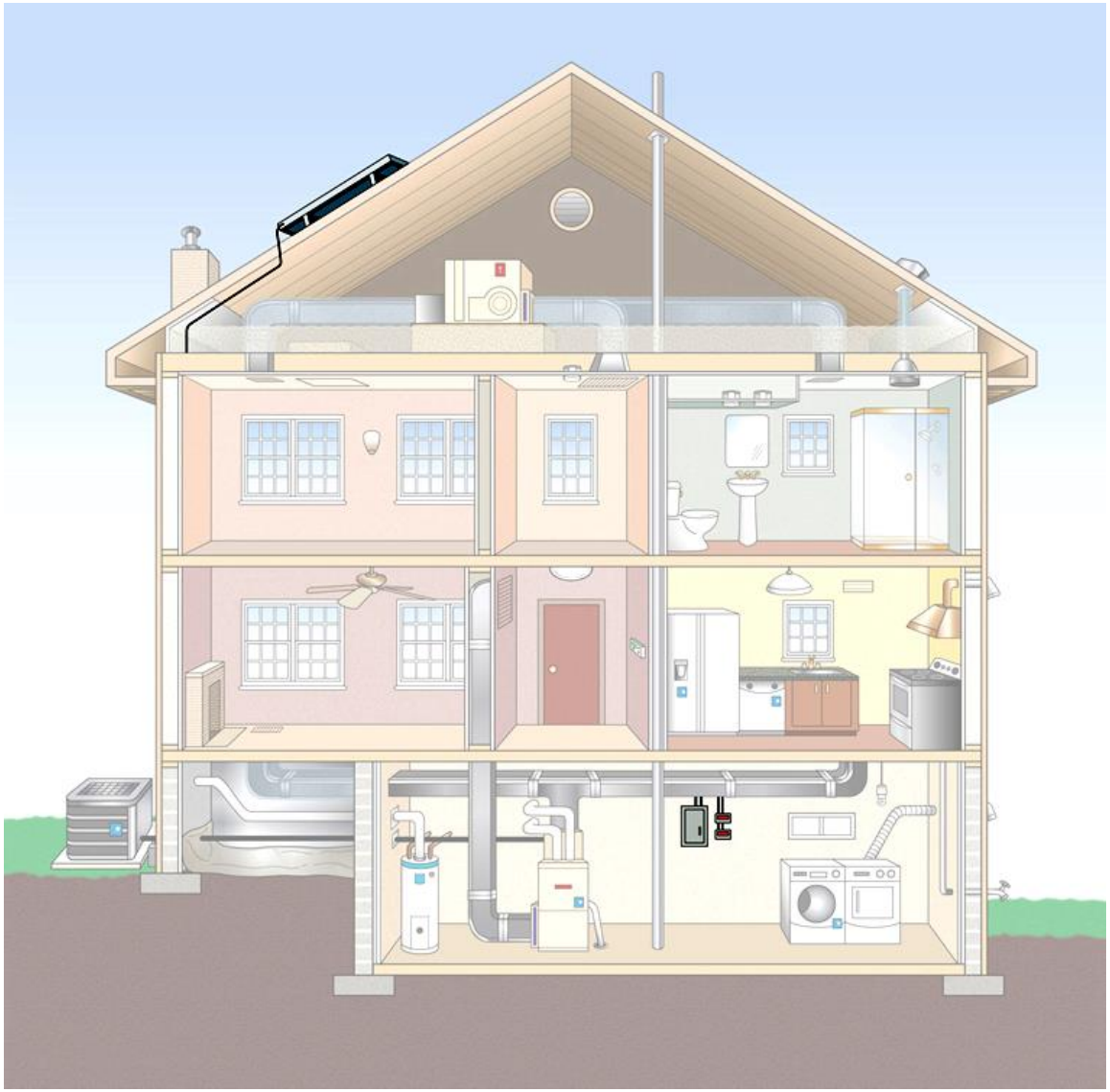
WINDOWS



LIGHTS AND APPLIANCES



SOLAR ENERGY



Example: Your house is cold and drafty and you have high energy bills

- Common Approach
- Add insulation in the attic
- [or replace furnace]

- Resulting Problems
- Air leaks still rob most of the heated air
- Attic condensation can lead to mold and rot
- Leaky ducts waste energy and money
- Heating/cooling systems aren't working properly

Solution: A whole-house approach

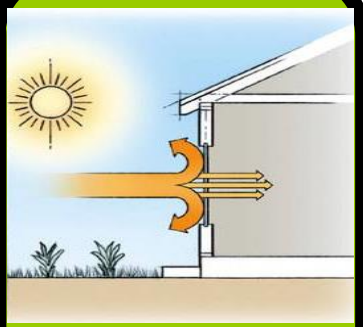
- Better Approach
- Seal air leaks
- Add insulation where needed
- Seal, insulate, and balance ducts
- Tune HVAC equipment
- Verify combustion safety

- Benefits
- Greater comfort with reduced drafts
- Healthier and more durable home
- Cleaner environment
- Lower energy bills

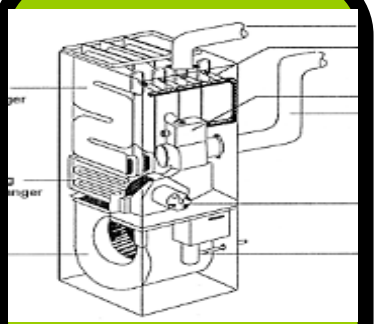
Controlling Air, Thermal and Moisture Flow – Will fix a Sick House and Deliver Long Lasting Savings!

Air Sealing

Tight Ducts

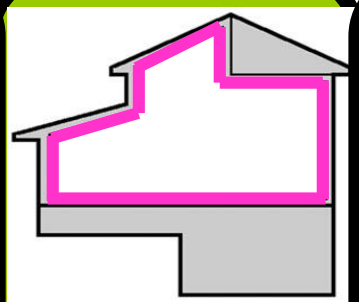


Advanced Windows



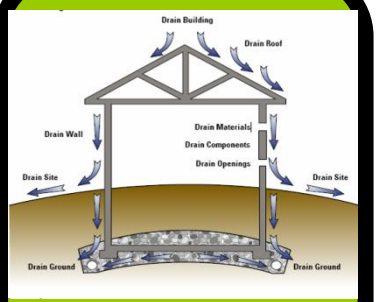
Efficient Equipment

Insulation Installation



Complete Air Barrier

Right Sizing



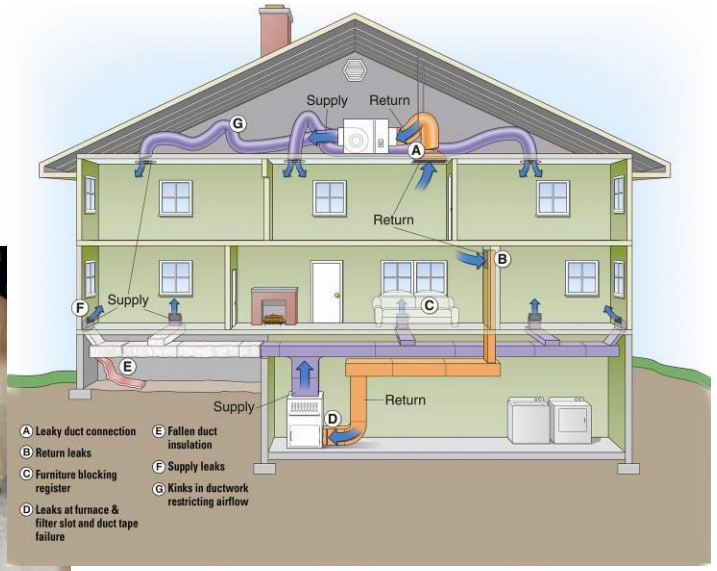
Bulk Moisture

Steps of a typical energy audit

1. Homeowner interview
2. Exterior walk around
3. Interior walk through
    a. Insulation inspection
4. Combustion safety test
5. Blower door test
6. Report to homeowner

Diagnostics: House Leakage Test

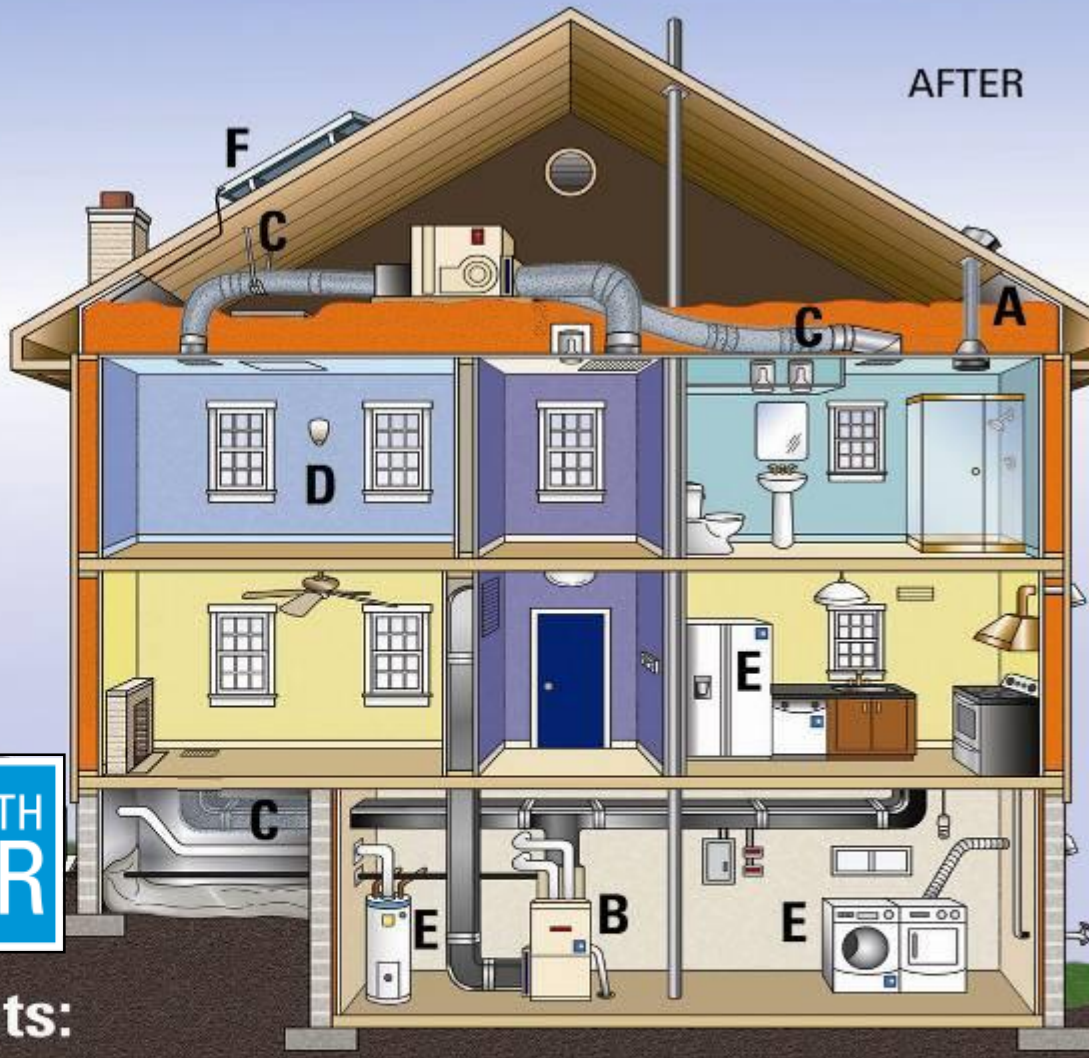
Diagnostics: Duct Leakage and Air Flow Tests



Diagnostics: Combustion Safety Testing

BEFORE

AFTER



HOME PERFORMANCE WITH ENERGY STAR

Typical Home Improvements:

- A Sealing Air Leaks and Adding Insulation
- B Improving Heating and Cooling Systems
- C Sealing Ductwork
- D Replacing Windows
- E Upgrading Lighting, Appliances, and Water Heating Equipment
- F Installing Renewable Energy Systems

Common Improvements: Air Sealing

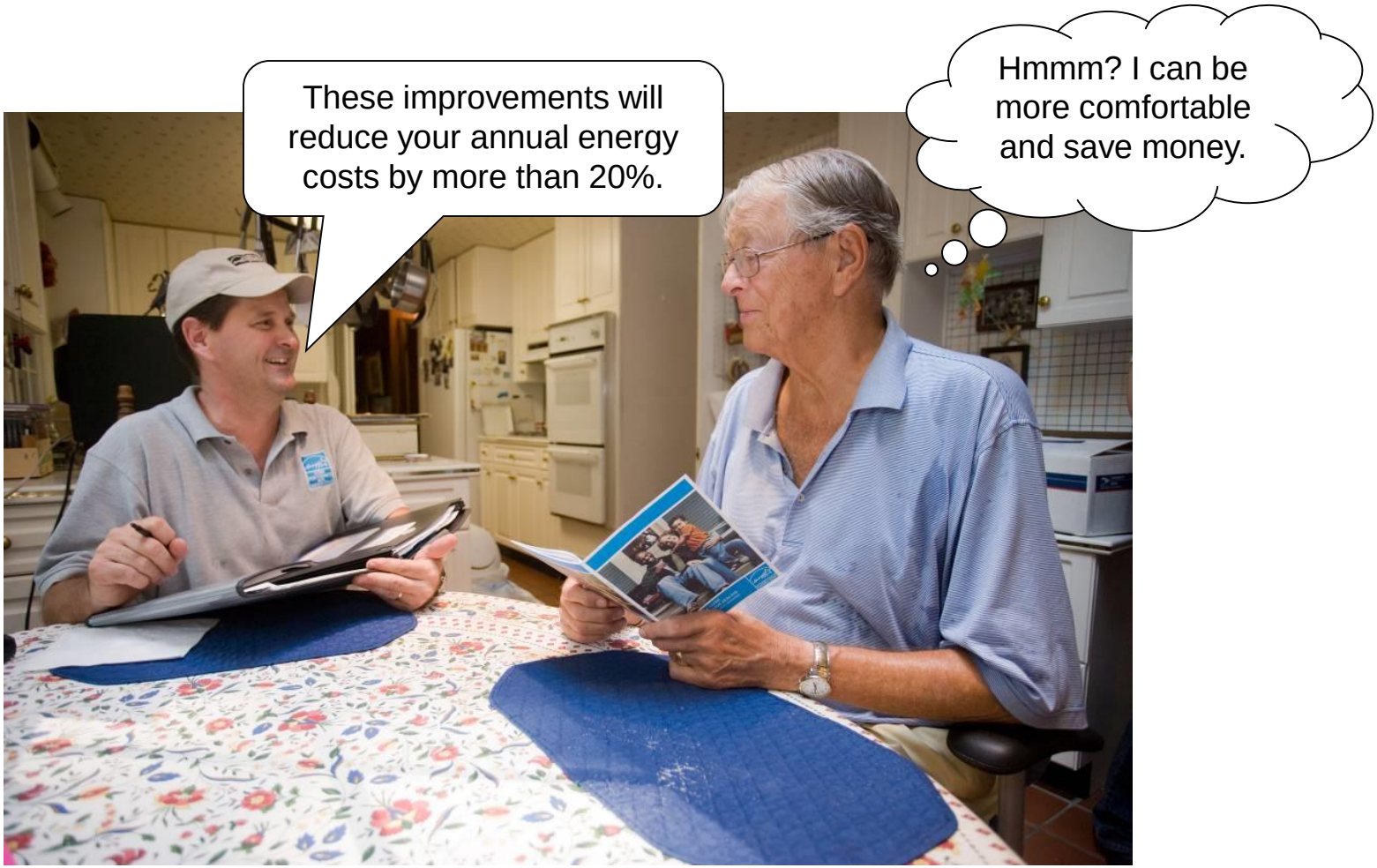
Common Improvements: Adding Insulation

Common Improvements: Duct Sealing and Repair

Common Improvements: New HVAC Equipment

Common Improvements: Lighting, Appliance, and Window Upgrades

Present Results and Proposal



How do you find a qualified pro?

- Look for BPI certification
- Look at local programs for participating contractors
- Ask around

Three Key Take-Aways

- Home energy assessments allow one to look at the entire system of a home and diagnose the real issues, rather than the symptoms.
- Guessing, or looking at only one piece of the puzzle, can produce undesirable and potentially dangerous effects.
- Look for a BPI-certified contractor with a sound reputation in your area when considering home performance upgrades.

Upcoming Seasonal Messaging Opportunities

Images: The Energy Group

Energy Efficiency Day

Take Action!

Join the thousands of people & businesses across the U.S. taking action to save energy and money today.

October 5, 2018

It's #EEDay2018

ENERGY EFFICIENCY DAY

Save energy. Save money.

Better Buildings

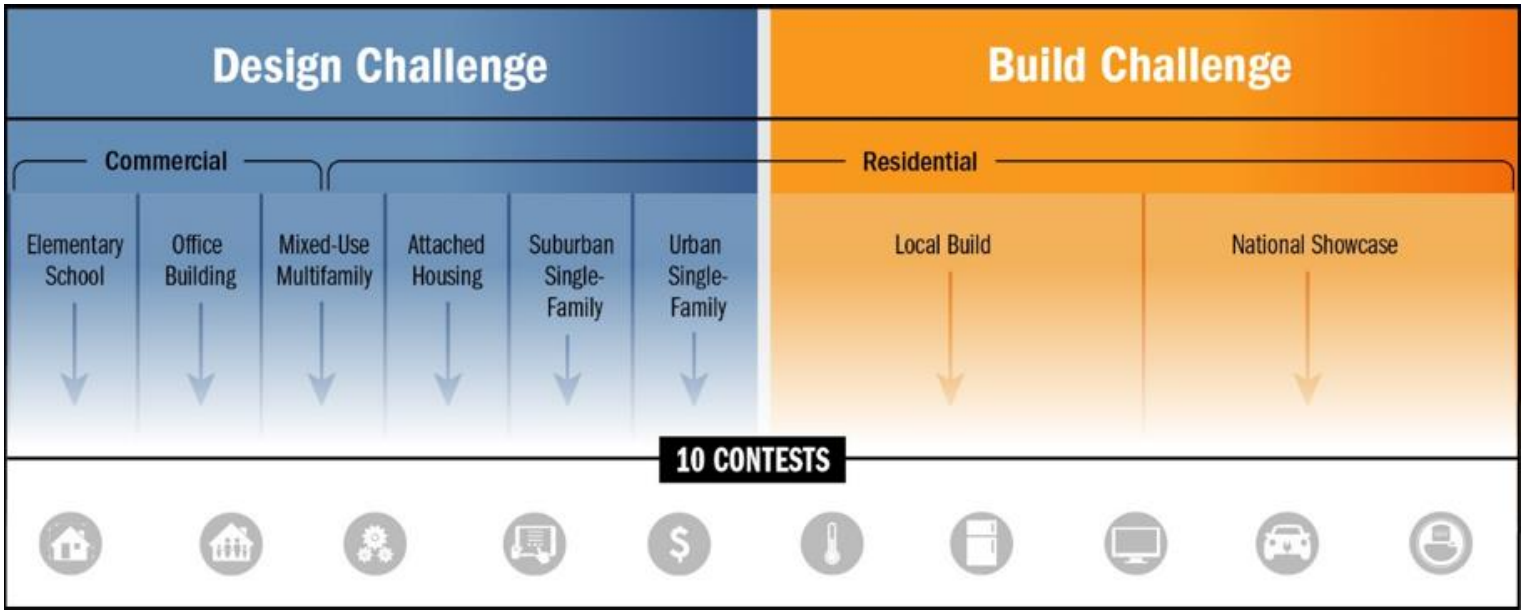
U.S. DEPARTMENT OF ENERGY

U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON

The Solar Decathlon:

1 Competition, 2 Challenges, 10 Contests

The U.S. Department of Energy Solar Decathlon® is a collegiate competition, comprising 10 contests, that challenges student teams to design and build highly efficient and innovative buildings powered by renewable energy.



Apply by November 6, 2018 at www.solardecathlon.gov





Explore the Residential Program Solution Center

Resources to help improve your program and reach energy efficiency targets:

- Handbooks - explain *why* and *how* to implement specific stages of a program.
- Quick Answers - provide answers and resources for common questions.
- Proven Practices posts - include lessons learned, examples, and helpful tips from successful programs.
- Technology Solutions NEW! - present resources on advanced technologies, **HVAC** & **Heat Pump Water Heaters**, including installation guidance, marketing strategies, & potential savings.

https://rpsc.energy.gov

Thank You!

Follow us to plug into the latest Better Buildings news and updates!

Better Buildings Twitter with #BBResNet

Better Buildings LinkedIn

Office of Energy Effiency and Renewable Energy Facebook

Please send any follow-up questions or future call topic ideas to:
bbresidentialnetwork@ee.doe.gov