MAD-AIR 2015

Mechanical Air Distribution and Interacting Relationships

John Tooley

Advanced Energy

(919) 857-9000

Tuesday, February 17, 2015

1988 Original Paper

Google search: Mechanical Air Distribution and Interacting Relationships

http://repository.tamu.edu/bitstream/handle/1969.1/6566/ESL-HH-89-10-05.pdf?sequence=3

MAD-AIR Agenda

- System thinking
- A few air flow fundamentals
- 26 house study of pressure differences
- Soil depressurization study
- % of house air originating from the garage
- % of house air originating from the crawl space
- Code changes that effect MAD-AIR
- Real world effects

Dealing With Houses Requires System Thinking

A system is *a whole* that derives its characteristics (good or bad) *from the interactions* of its essential parts…..and *none taken separately*.


The essential parts to make an Oak tree

The essential parts to make an Oak tree

The essential parts to make an Oak tree

+

The essential parts to make an Oak tree


+

+


The essential parts to make an Oak tree


+

+

+


The essential parts to make an Oak tree


+

+

+


All are Essential - None are Sufficient

The essential parts to make an Oak tree


+

+

+


All are Essential - None are Sufficient

Taken separately none will produce a healthy oak tree.

A House Is a System

A house is system that derives its characteristics (good or bad) from the interactions of its essential parts…..and none taken separately.

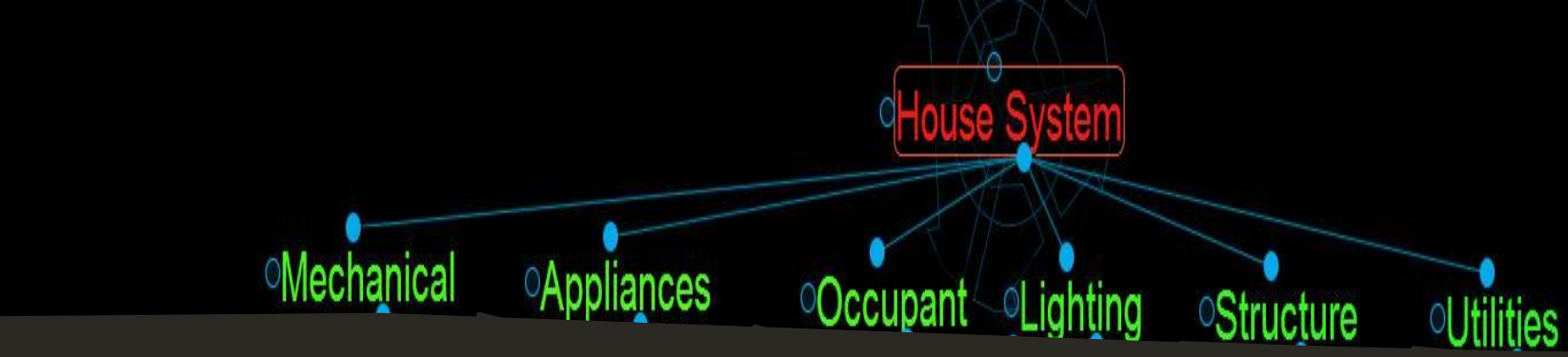
All are essential, none are sufficient

No part of the house is a house; only the whole is

System Thinking

- The defining behavior of a high performance home

1. Healthy and safe
2. Durable
3. Comfortable
4. Energy efficient
5. Environmentally responsible



A system is a whole that derives its characteristics from the interactions of it's essential parts….and none taken separately

MAD-AIR Demands Homes Be Viewed As A System

- A **HOME** is a whole that derives its characteristics or behavior from the interactions of its essential parts……and no part taken separately.

A home's goodness is the interactions of its essential parts

Change has either a…..

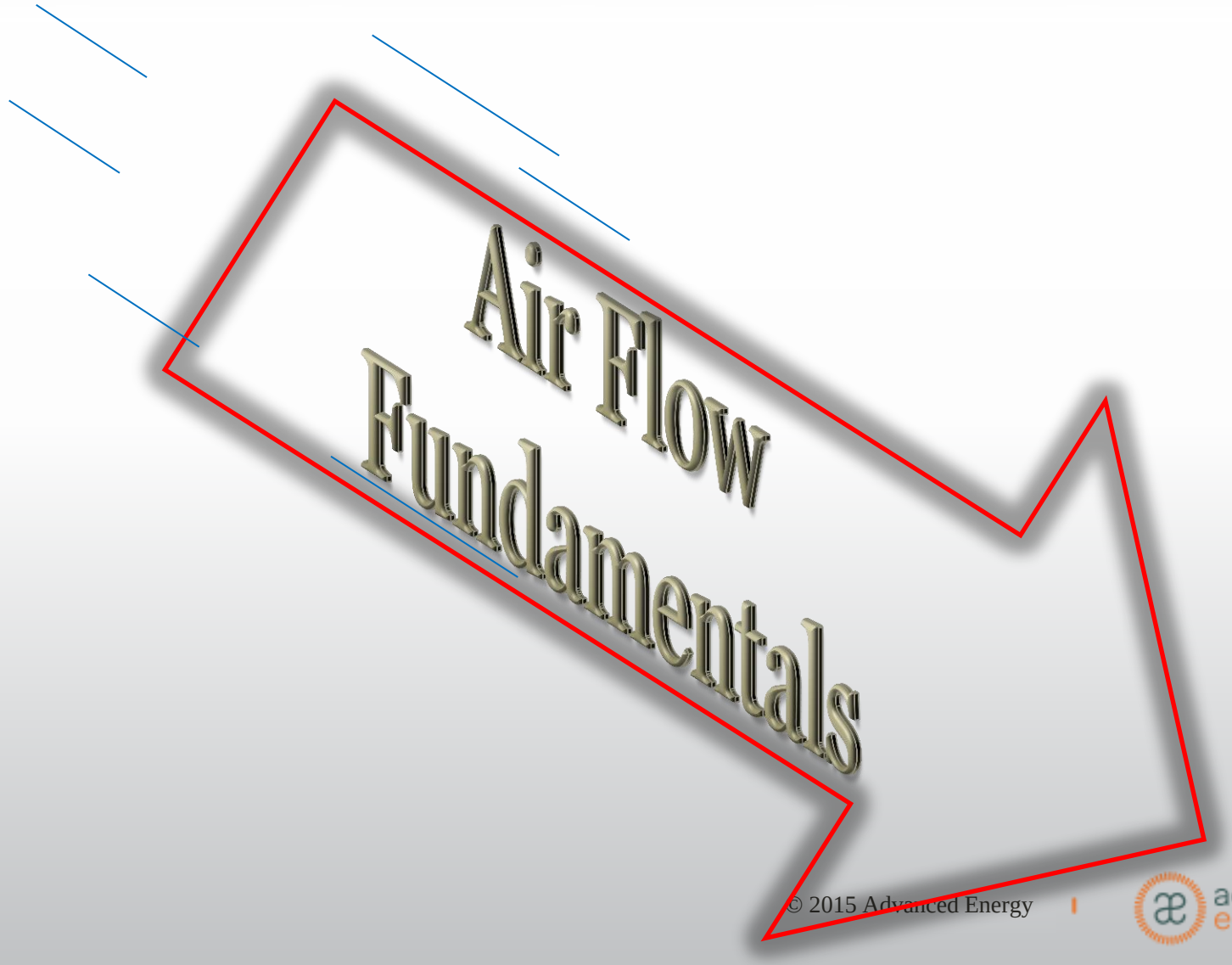
- Building products

- Codes
- Standards
- Specifications

- House tightness
- Duct tightness
- Equipment efficiency
- Fan efficiency

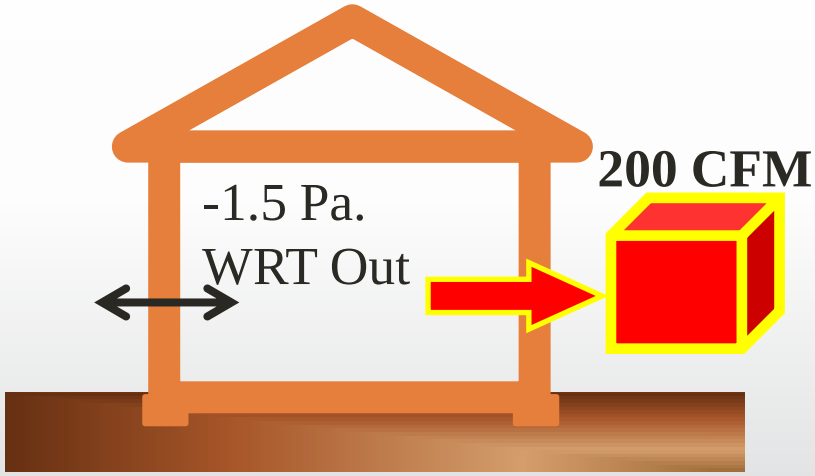
advanced energy

Understanding the importance of applying building science and system thinking

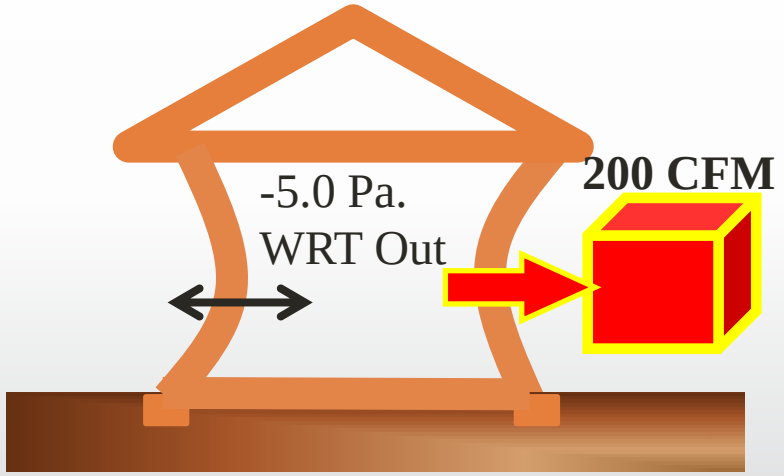


MAD AIR Facts

- The tighter the house envelope, the greater the pressure between inside and out.



Leaky House
2,200 ^{CFM50}
7 ACH^{50}



Tighter House
800 ^{CFM50}
4 ACH^{50}

Assumes 1500 square feet with average ceiling height of 8’

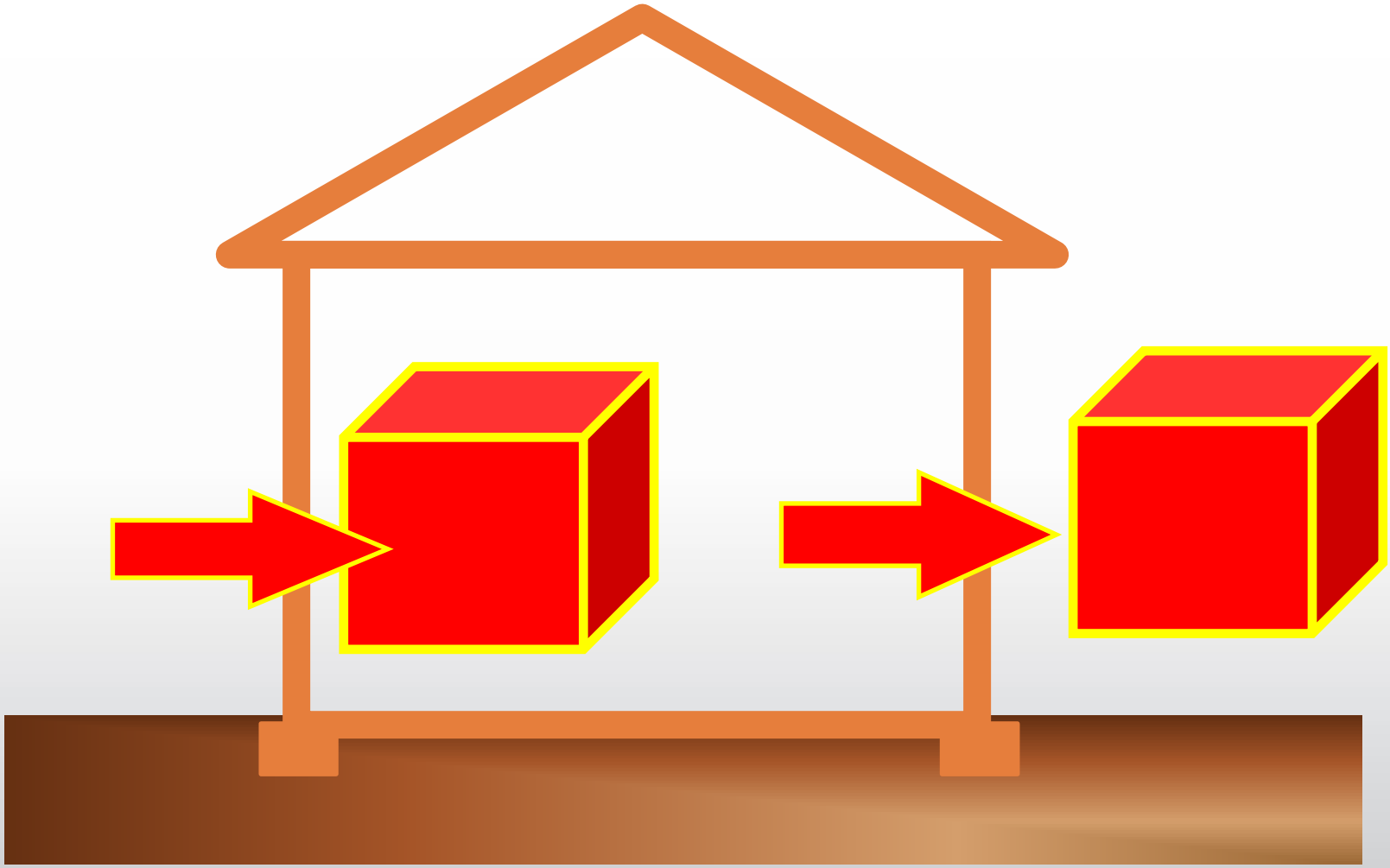
3 Driving forces

1. Wind

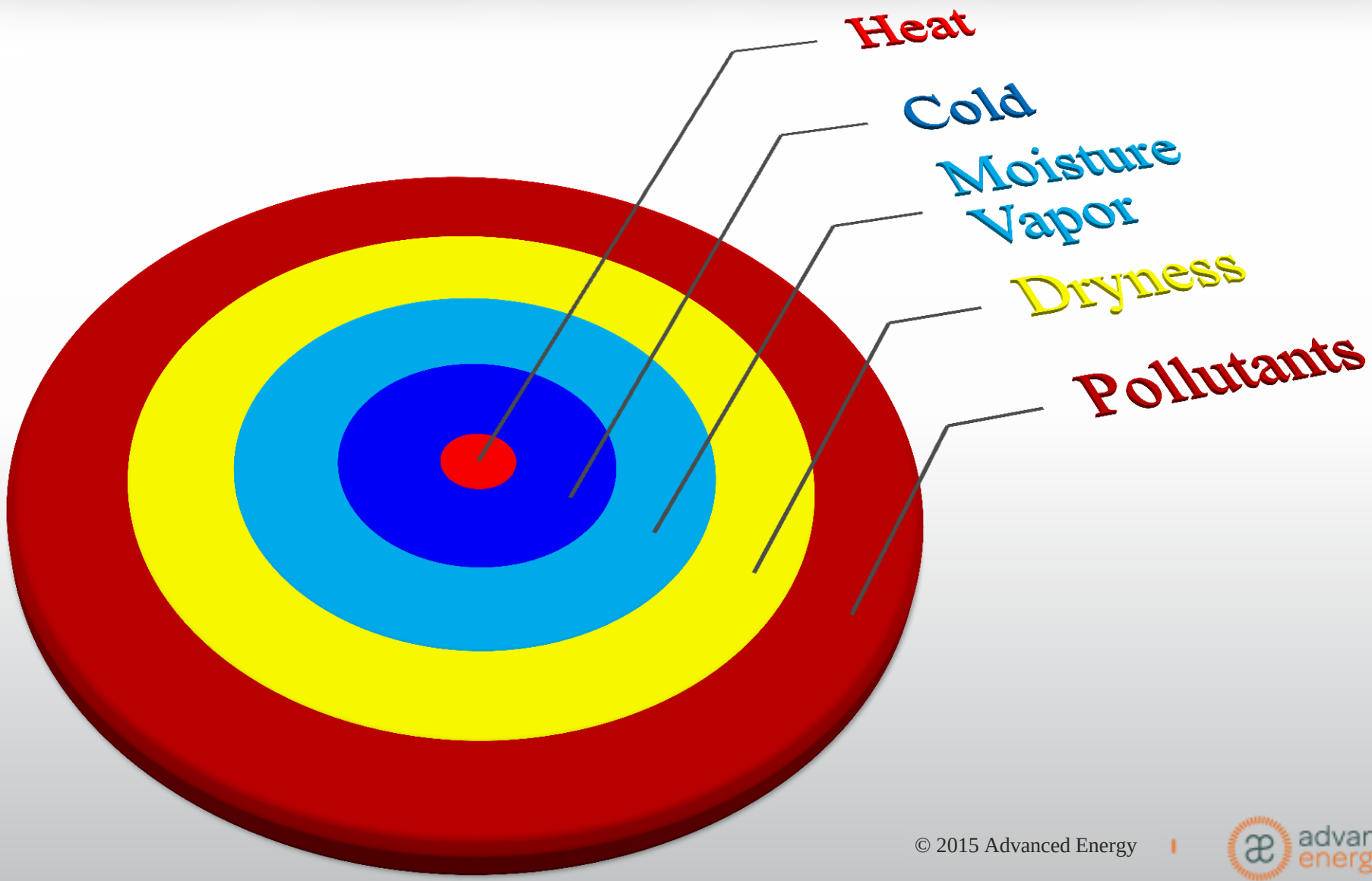
2. Heat (stack pressure)

3. Fans
   - Duct leakage
   - Interior door closure
   - Exhaust and supply fans
   - Imbalanced flow in zones

One portion of air out equals One portion of air in



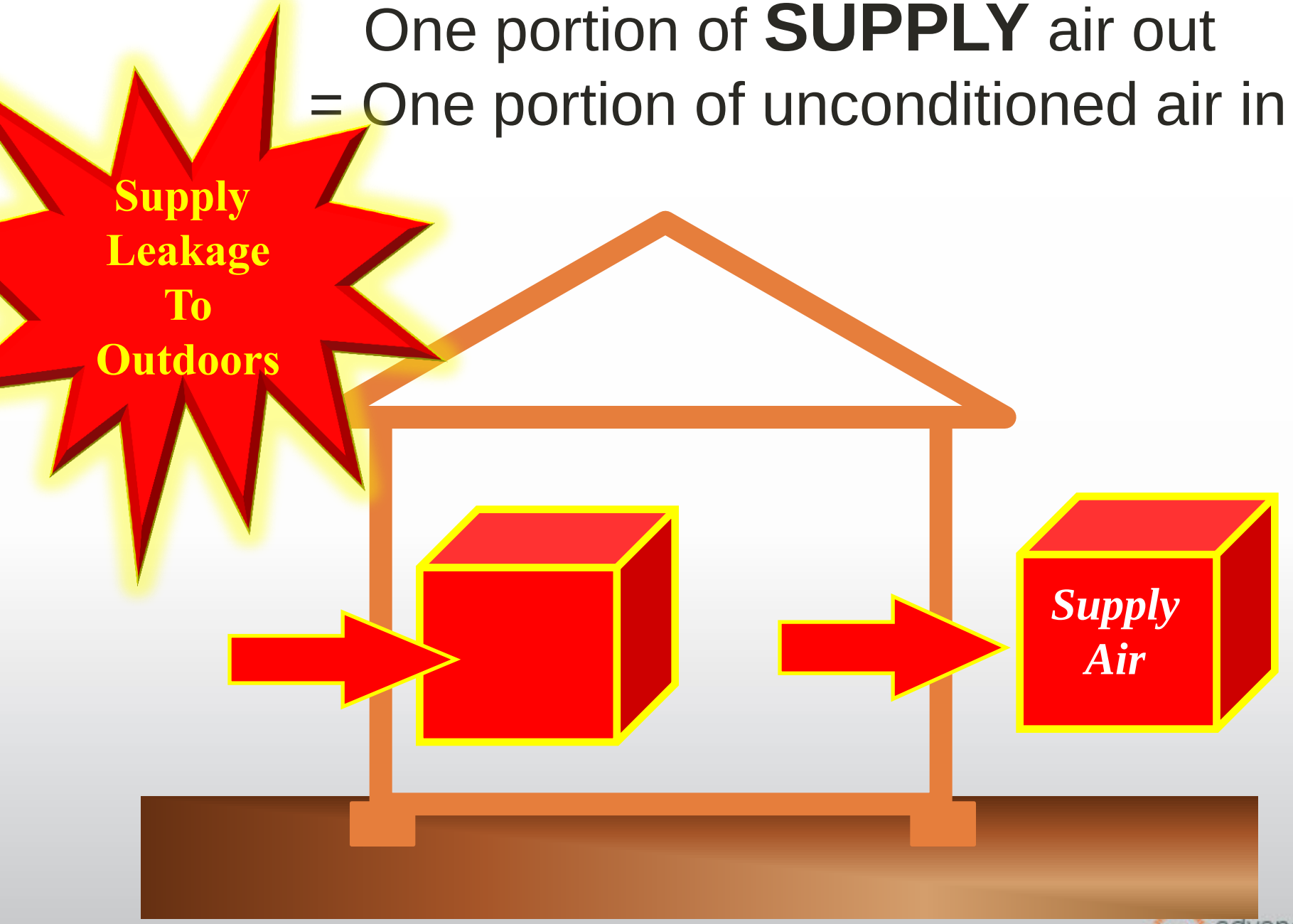
Air Is A Carrier



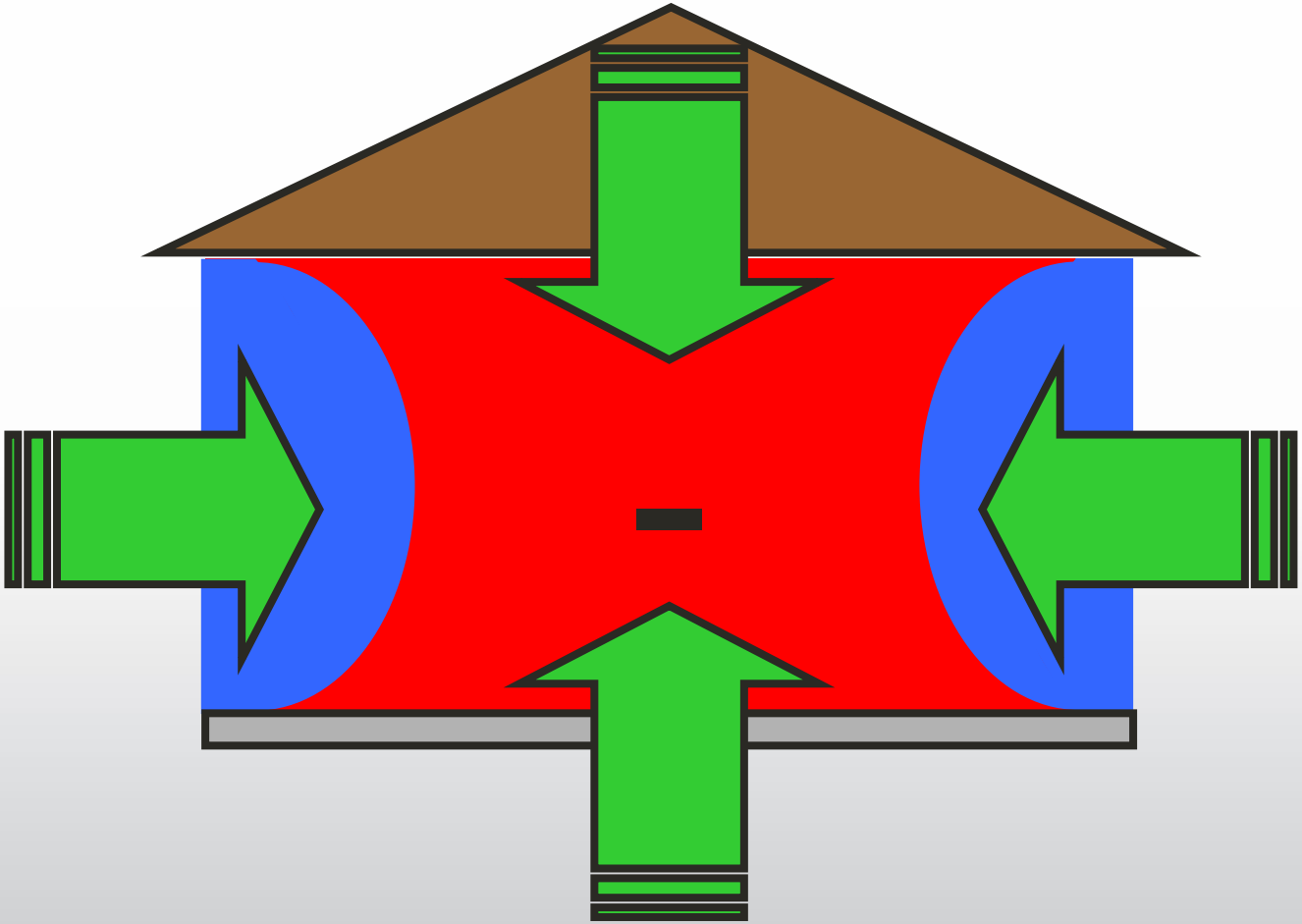
Duct leakage

3. Fans
   - Duct leakage
   - Interior door closure
   - Exhaust and supply fans
   - Imbalanced flow in zones

One portion of **SUPPLY** air out
= One portion of unconditioned air in

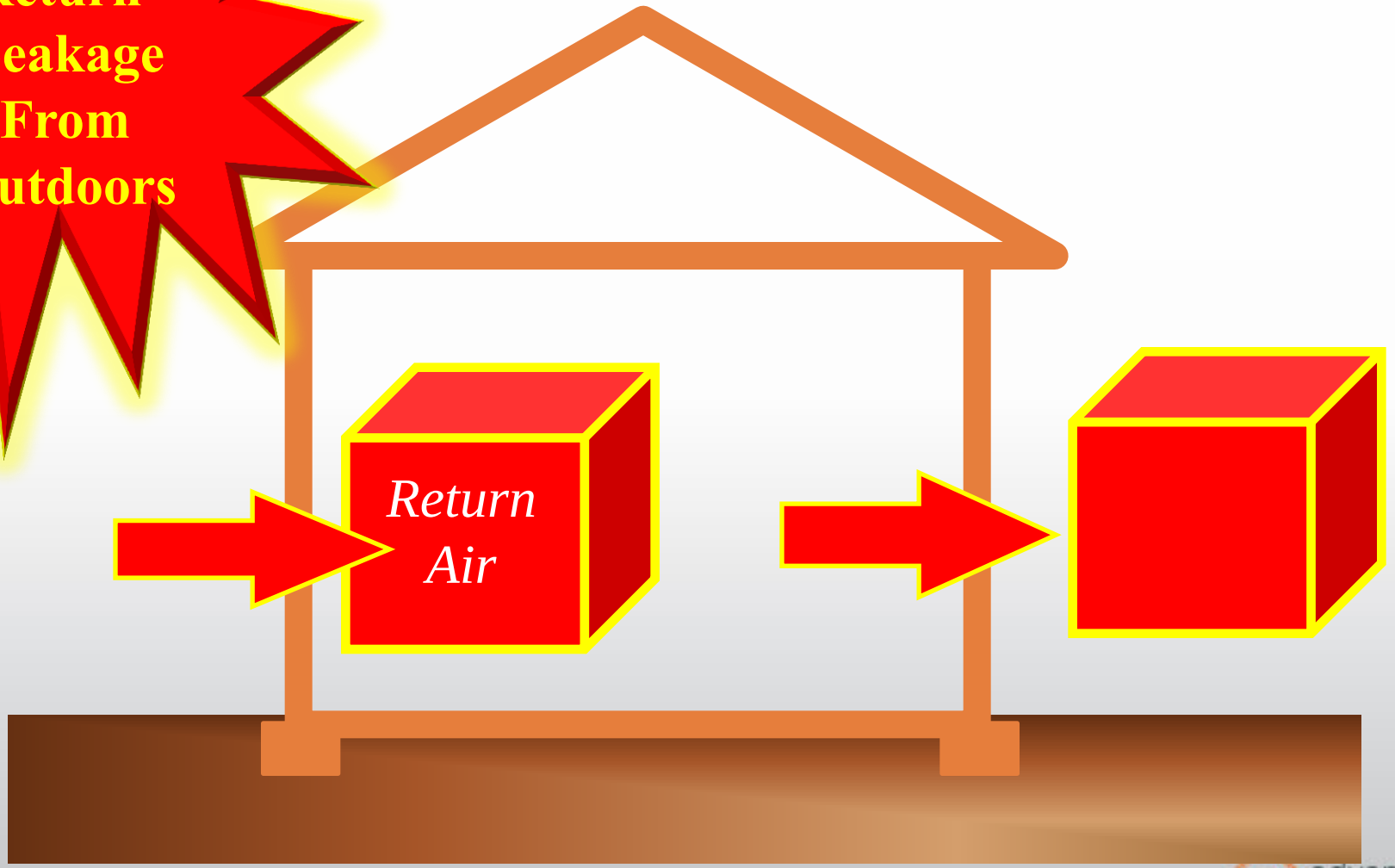


Supply Leakage To Outside Can Cause A Negative Pressure In The House

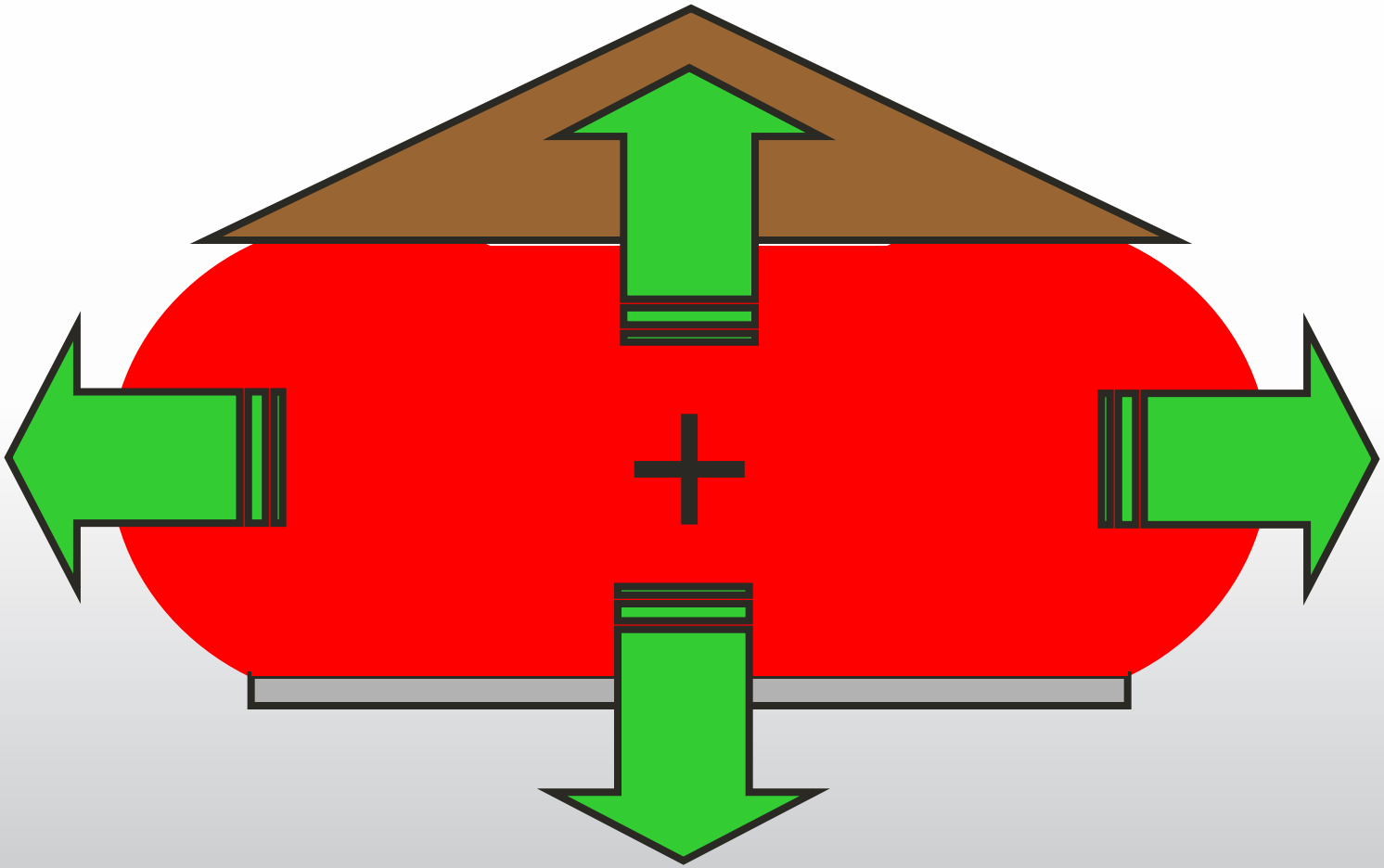


One portion of **RETURN** air in = One portion of conditioned air out

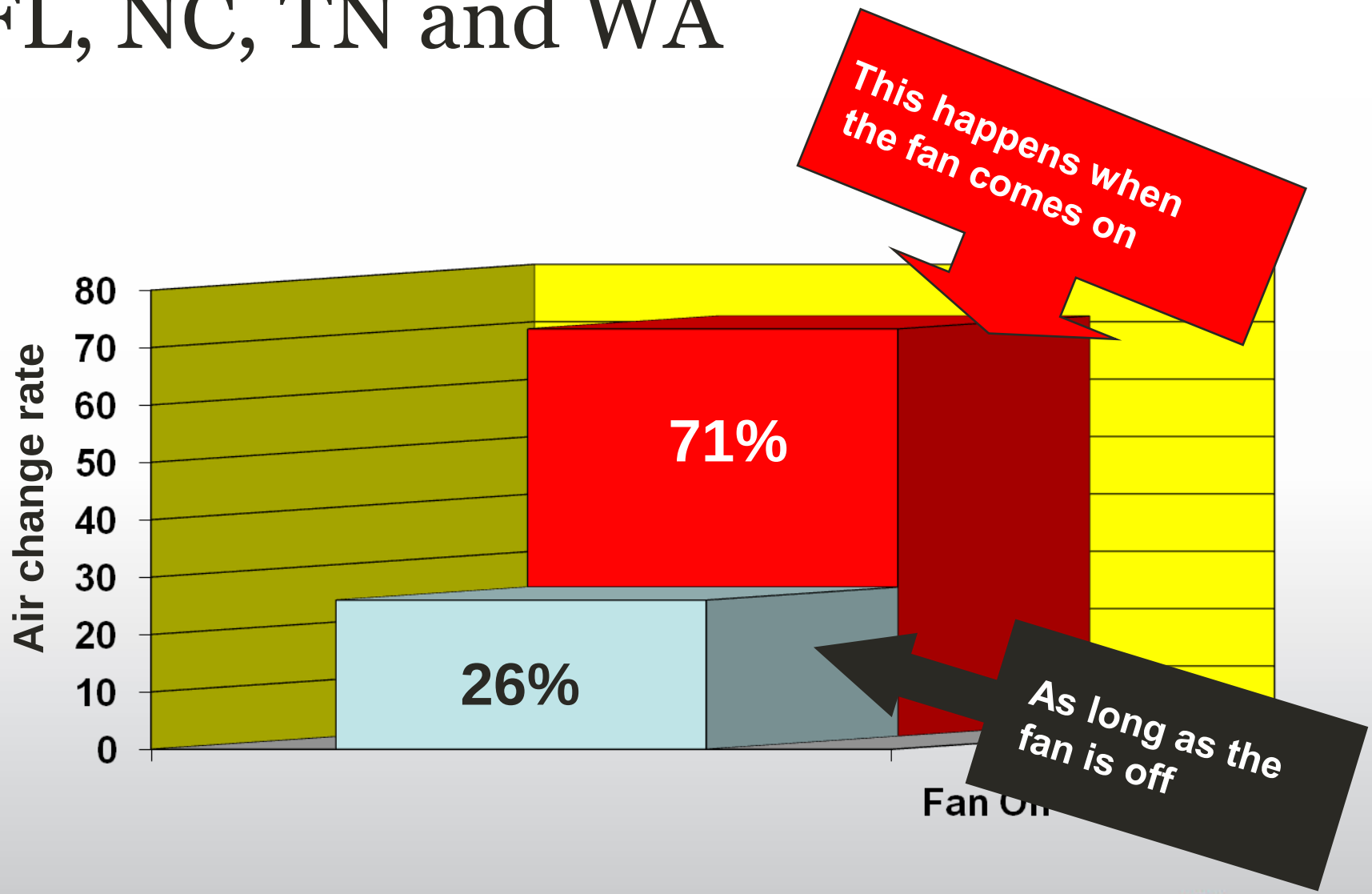
Return Leakage From Outdoors



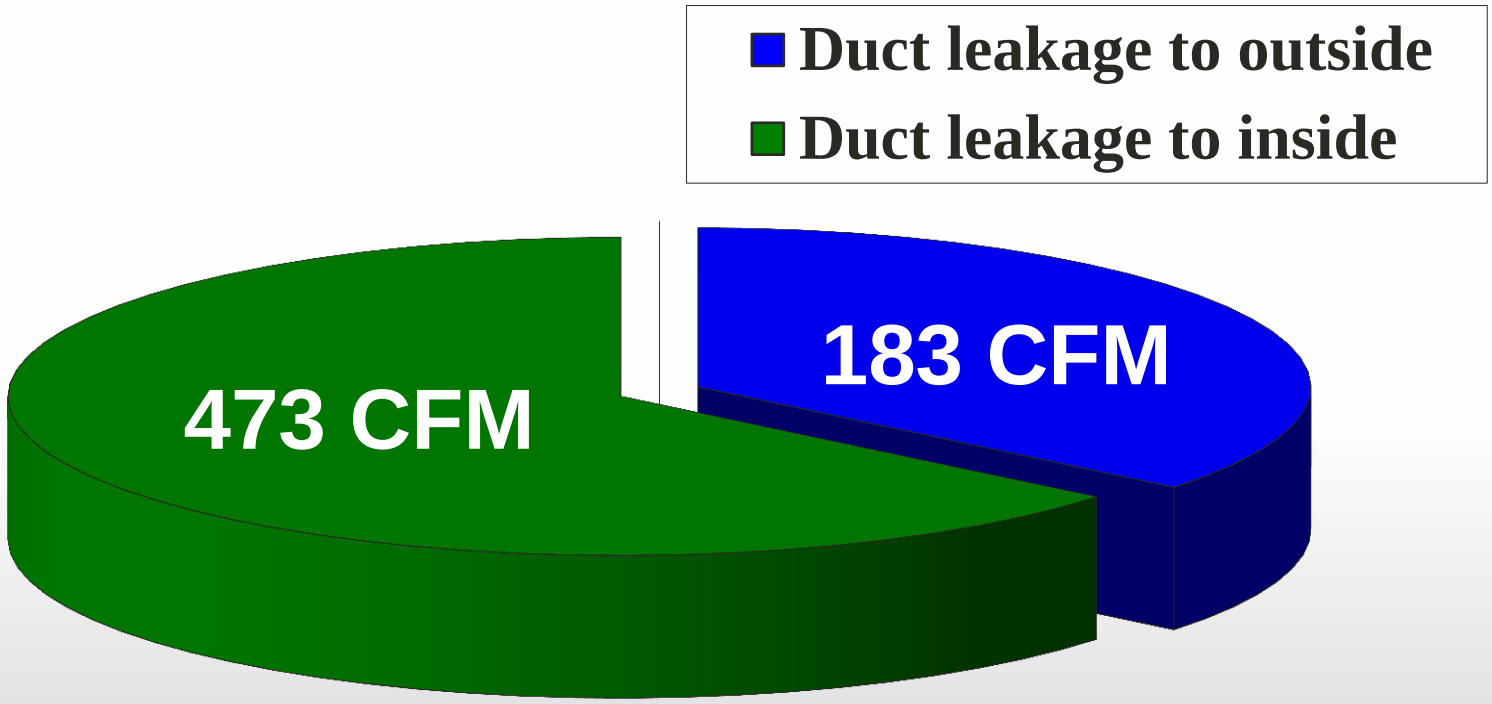
Return Leakage Can Cause Positive Pressure In The House



236 Houses
FL, NC, TN and WA



22 Two Story Colonials With Basement Ducts



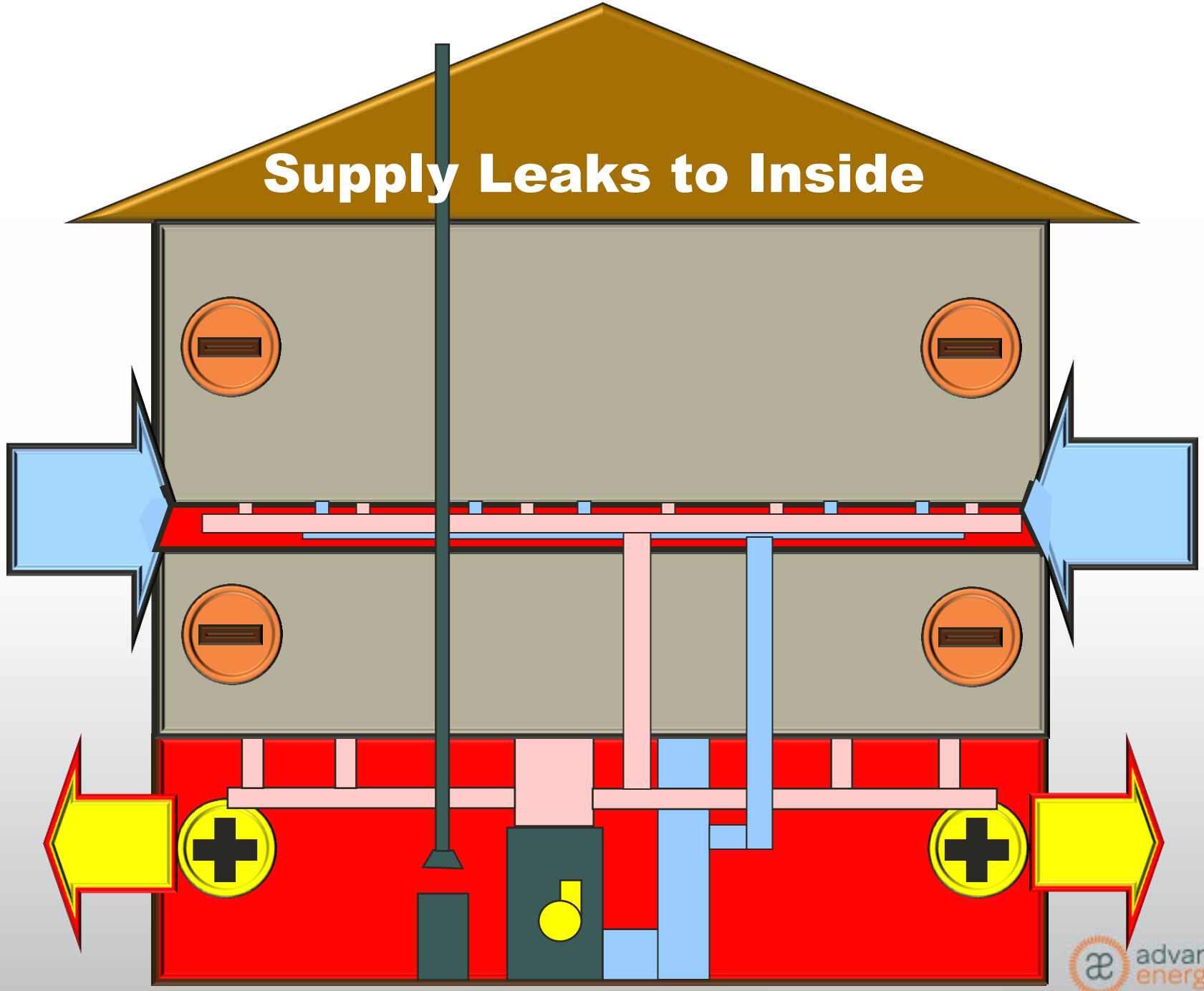
Source: NAHB Research and EPA

8 Basements House Air tightness Versus Duct Air tightness

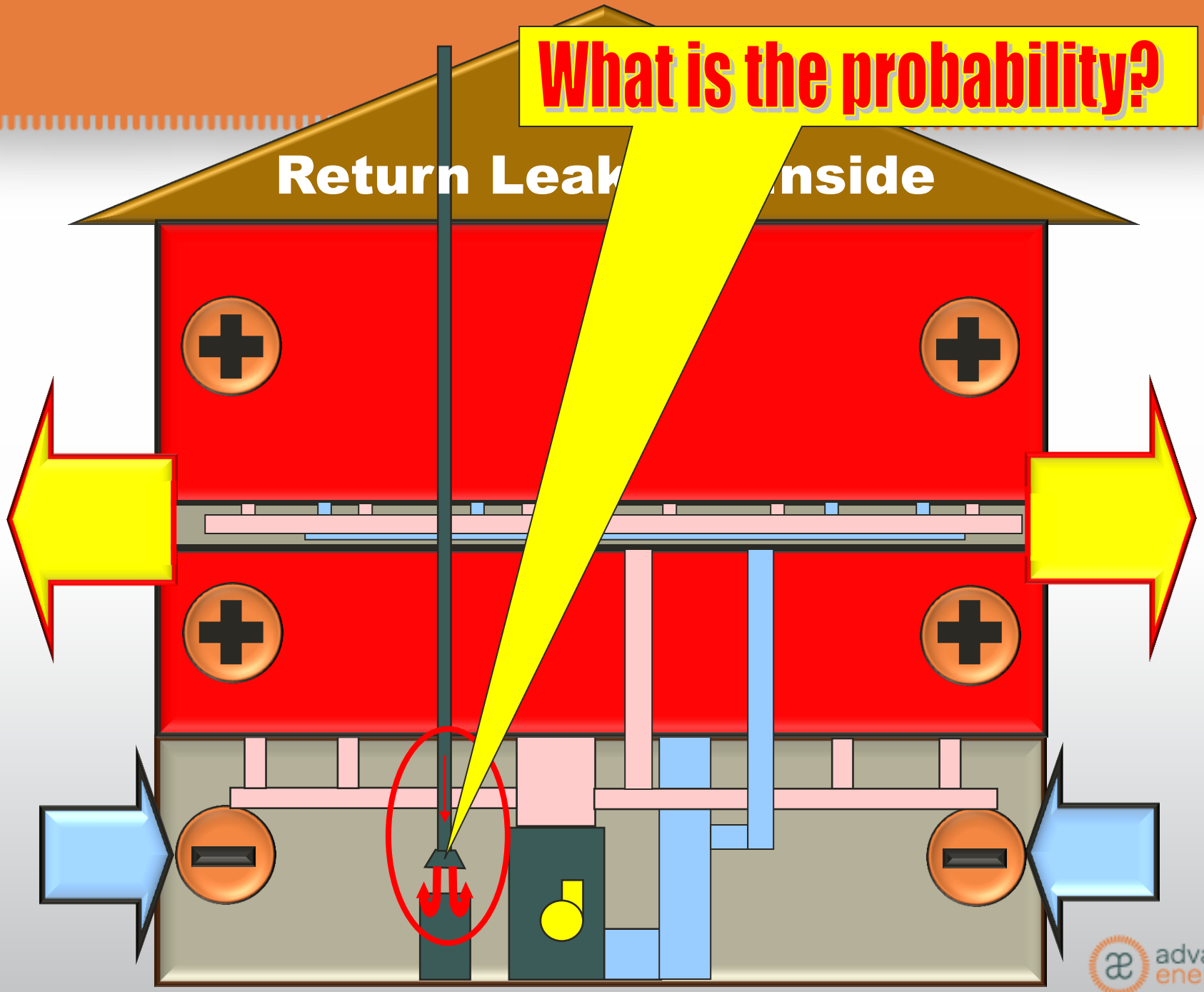
House Number	House Sq. in.	Duct Sq. in.	House Volume	House ACH50	House ACH (Nat)
1	228	NA	32,000	3.27	0.21
2	290	349	34,500	4.05	0.26
3	237	399	27,000	4.04	0.26
4	147	177	15,400	5.06	0.33
5	179	250	16,200	5.09	0.33
6	192	271	24,600	3.60	0.24
7	215	249	20,500	4.83	0.32
8	309	610	41,000	3.48	0.23
AV	229	288	26,400	4.18	0.27

Source: Energy Conservatory and NFR

Supply Leaks to Inside



advanced energy



advanced energy

MAD-AIR 1992

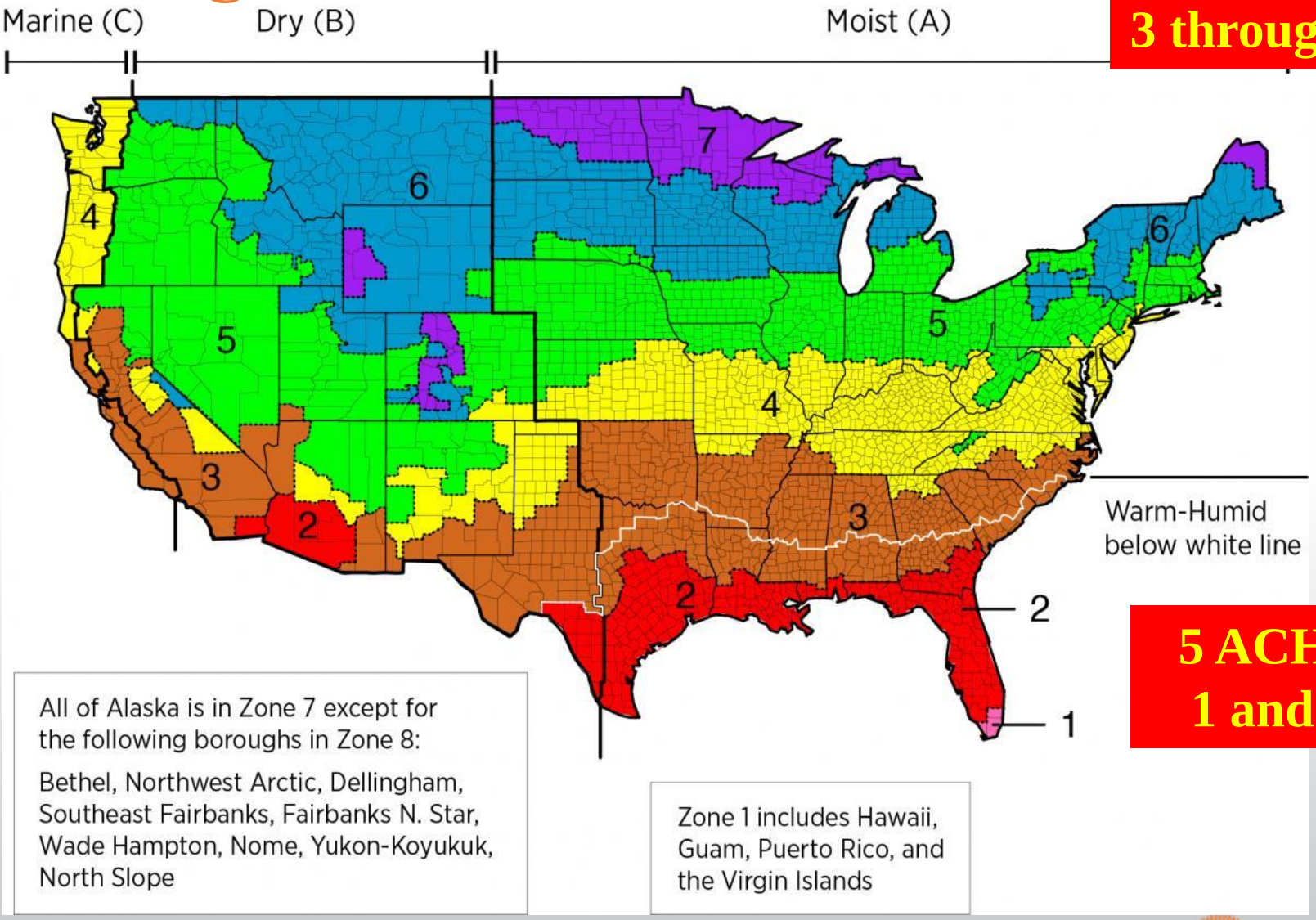
- 26 house study to show interactions
- House age 1-5 years
- Duct leakage
- Interior door closure
- Exhaust devices
- Combination

MAD-AIR is a function of…

1. Tightness of the home
2. Tightness of rooms
3. Flow to rooms and house
4. Existence or the free flow of return air (single zone houses)
5. Exhausted air from the house
6. Supply air to the house
7. Occupant behavior

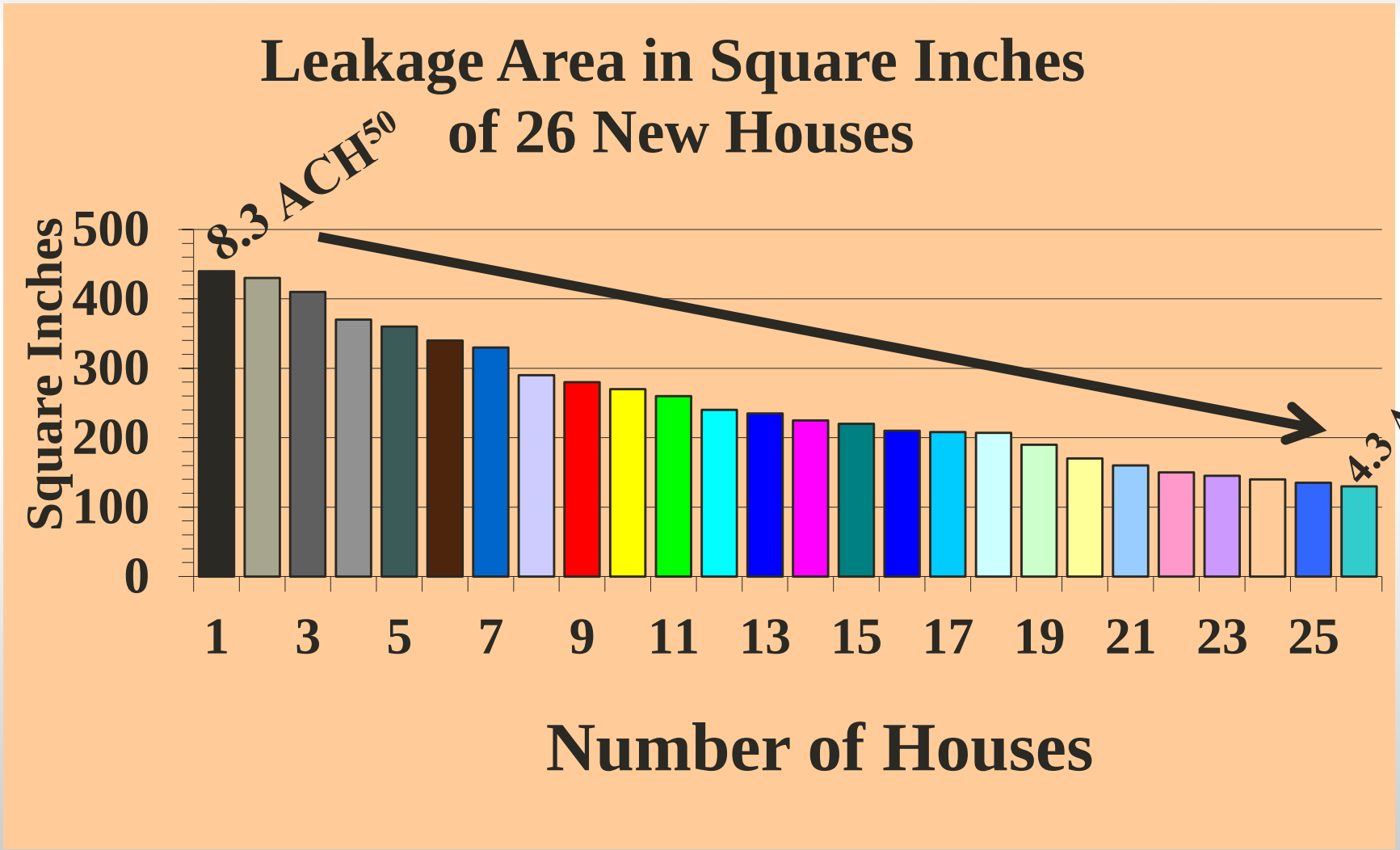
2015 IECC Climate Map & House Tightness

3 ACH^{50}
3 through 8



5 ACH^{50}
1 and 2

All houses leakier than 2015 IECC



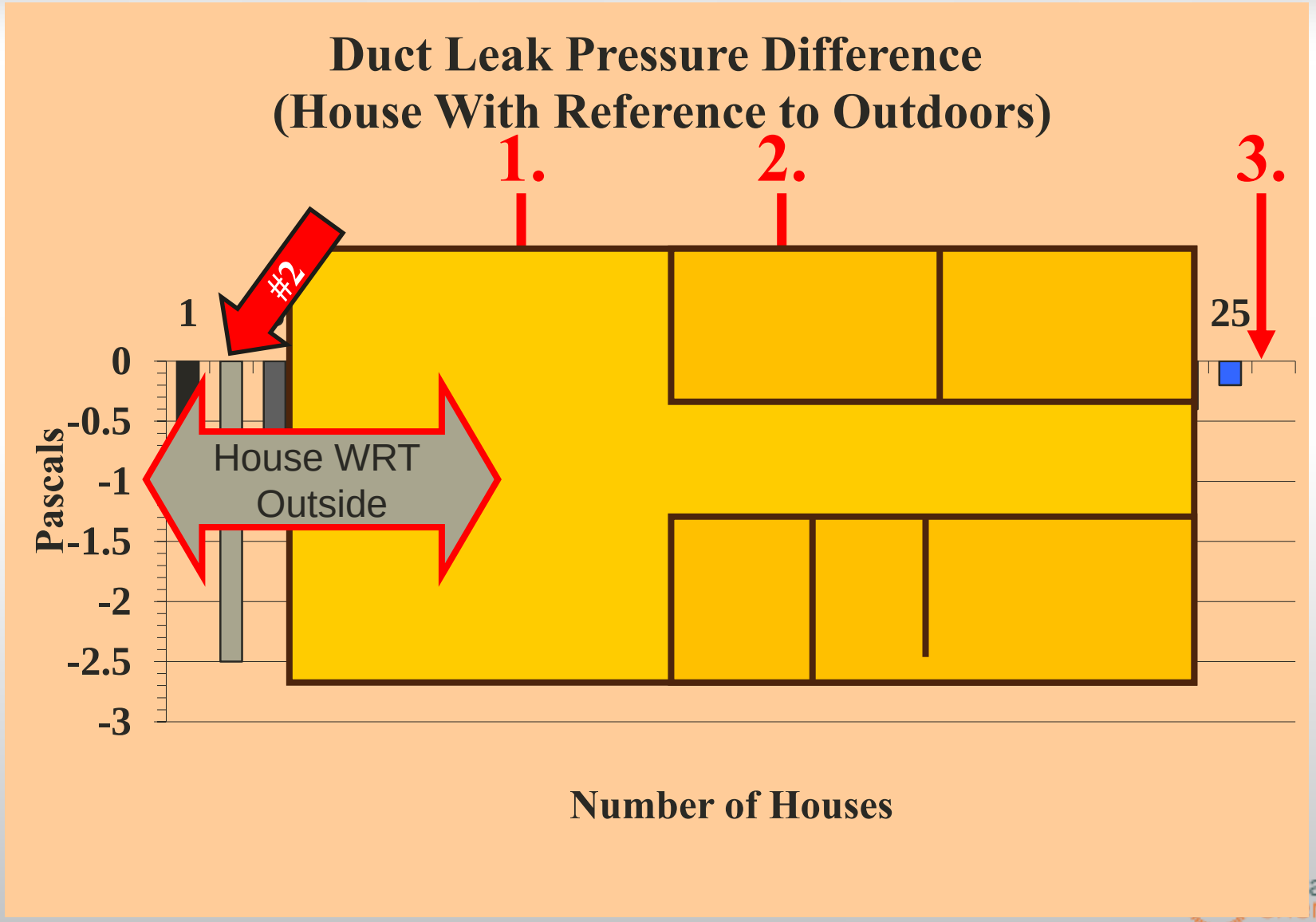
Duct Leakage Effects

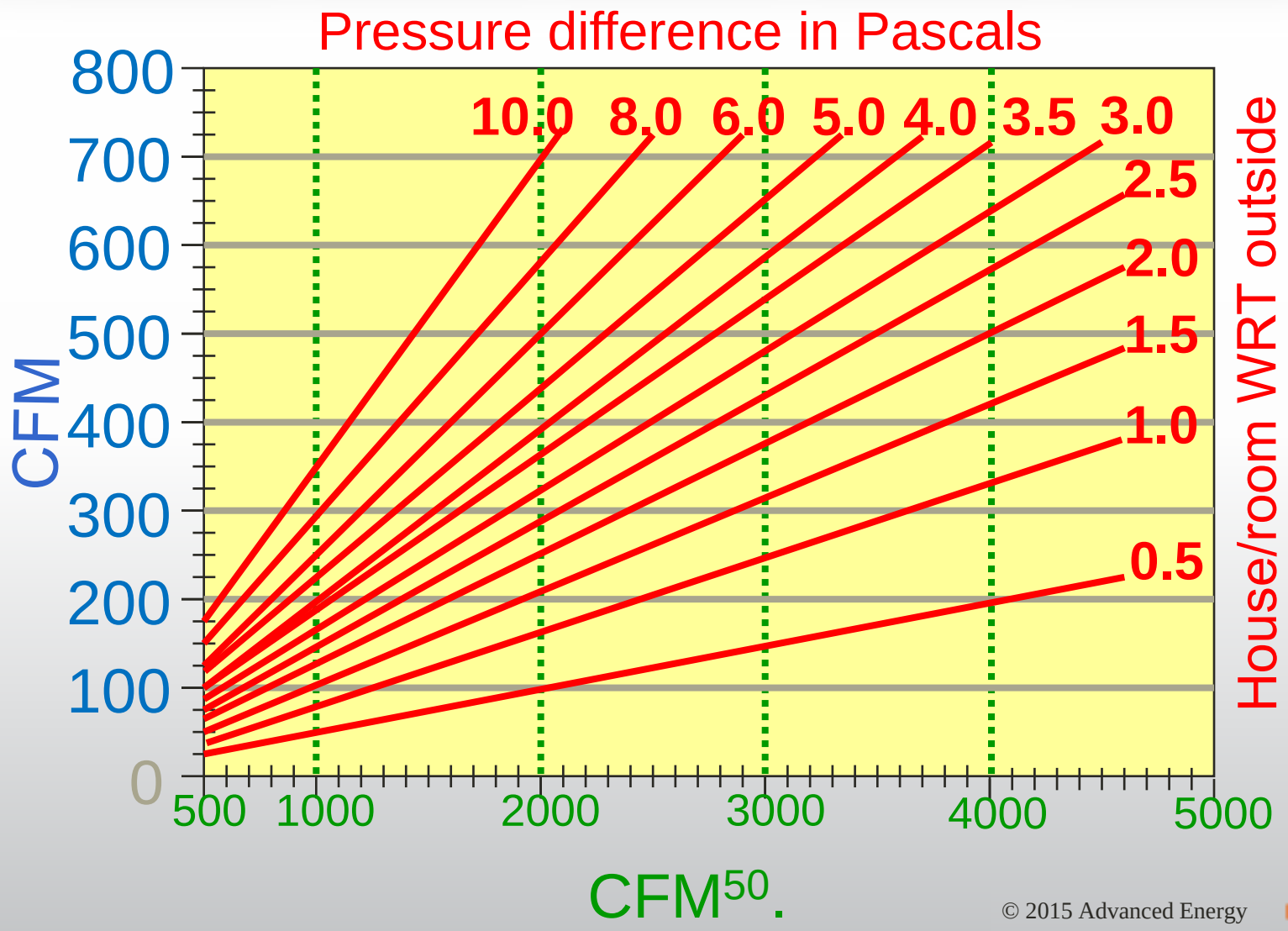
- Duct leakage
- Interior door closure
- Exhaust devices

Metal

Flex

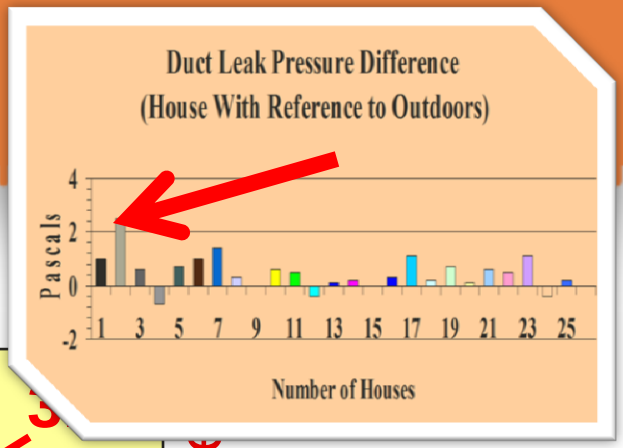
Duct Leakage To Outside Effects

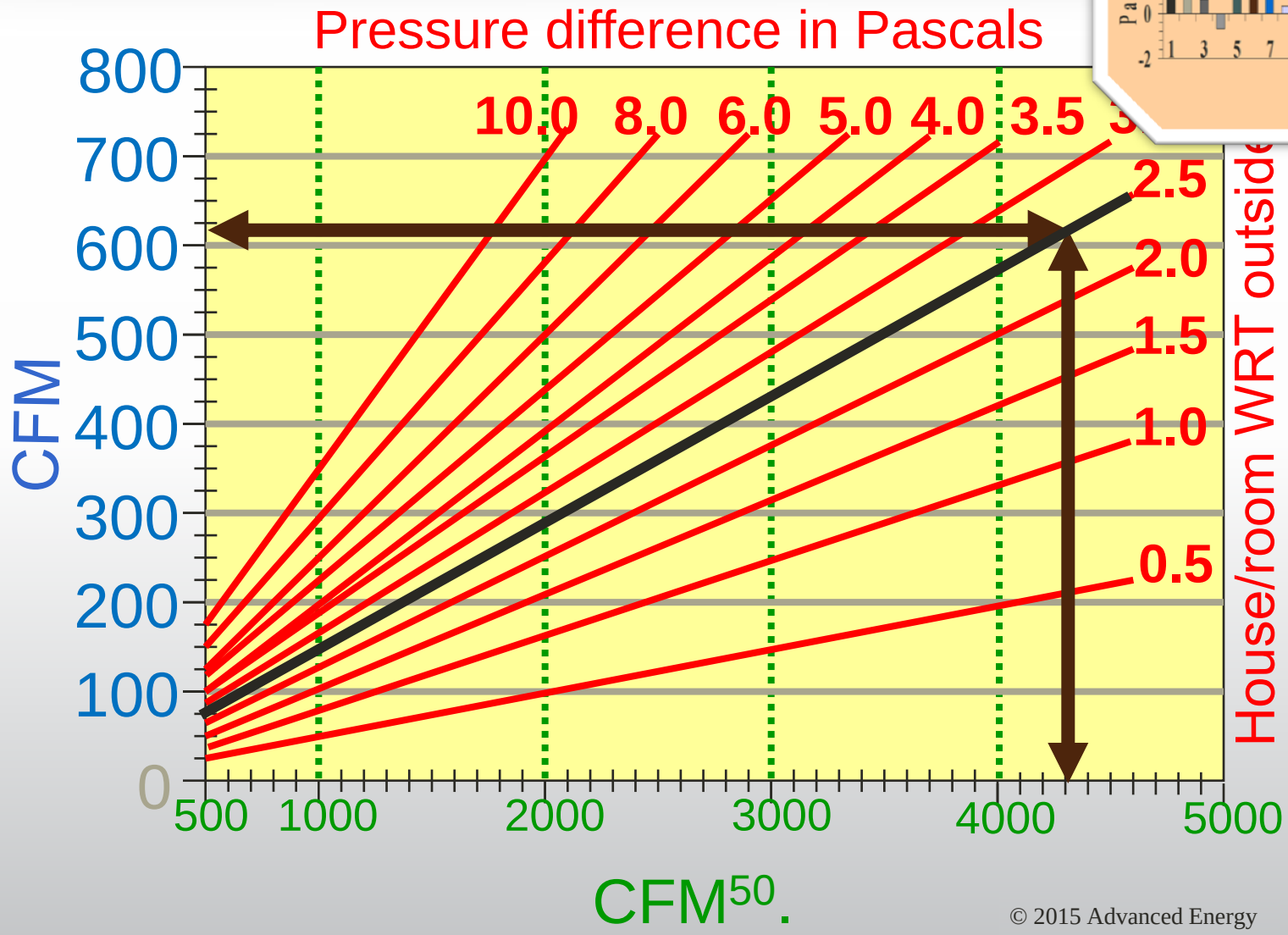




advanced energy

House #2

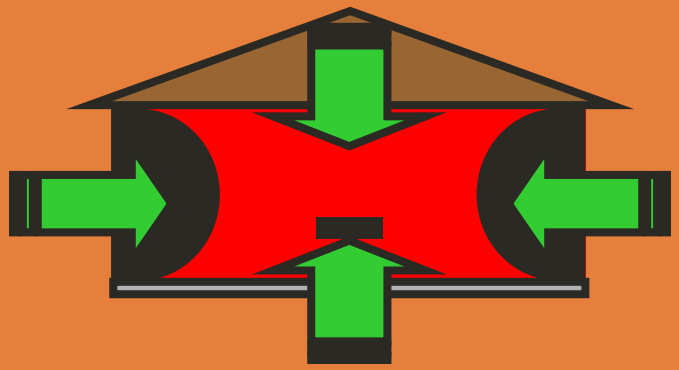


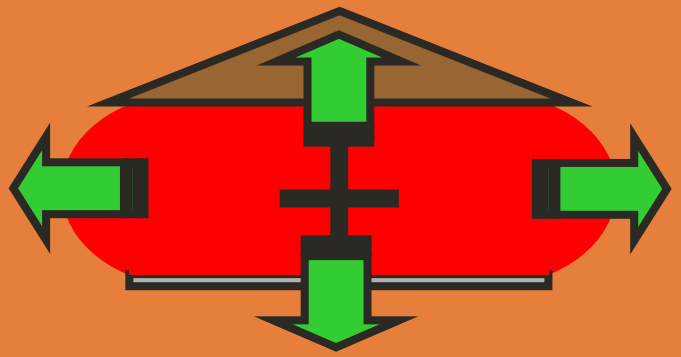


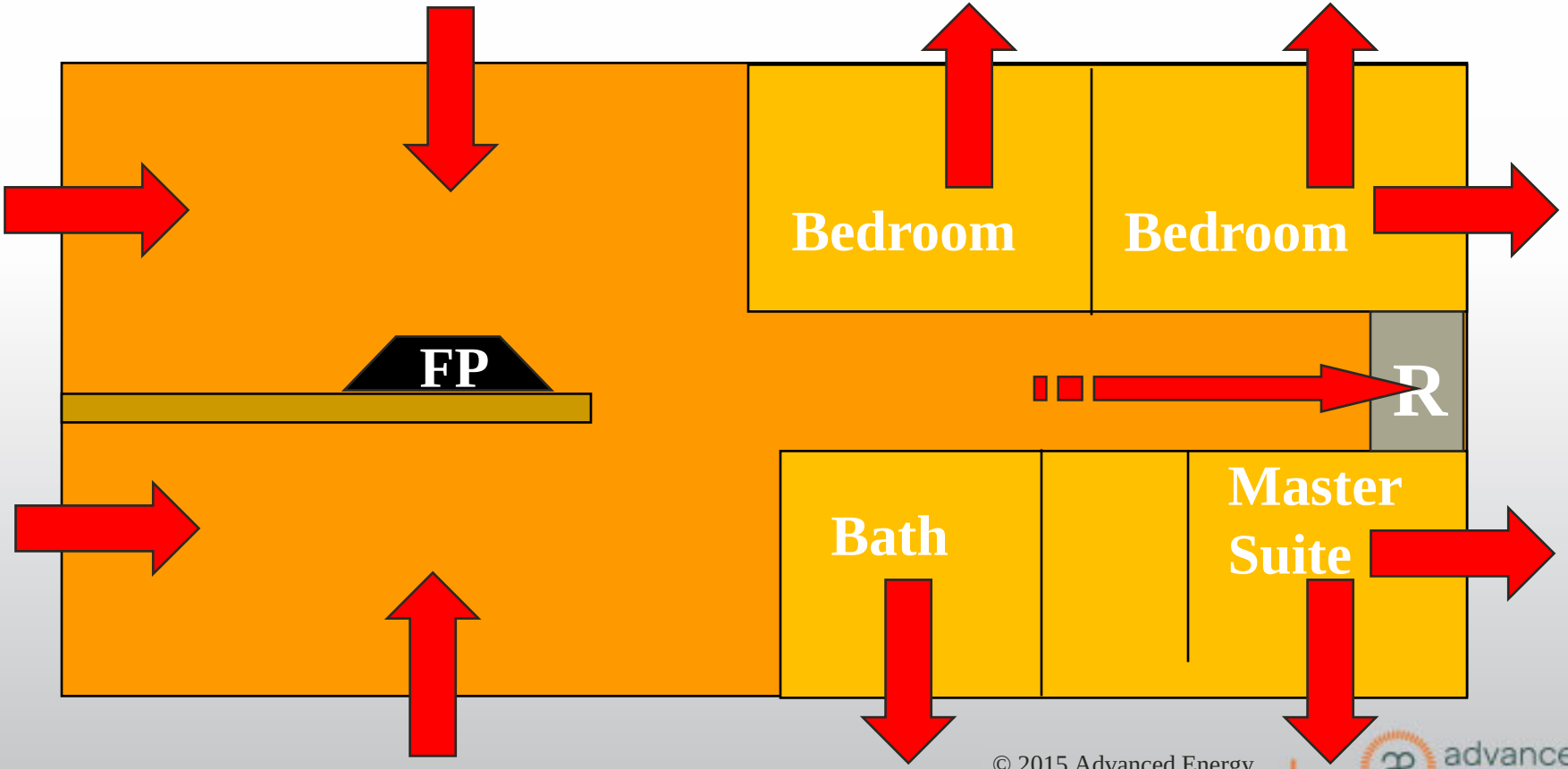
advanced energy

Interior Door Closure Effects

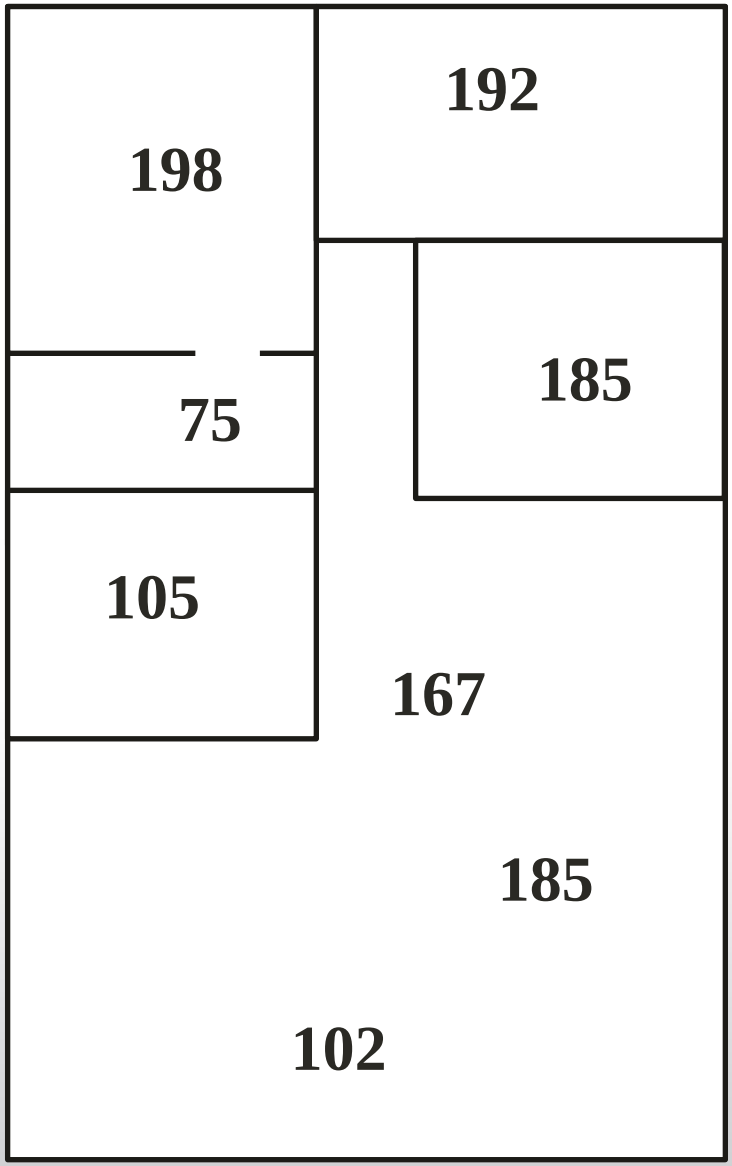
- Duct leakage
- Interior door closure
- Exhaust devices



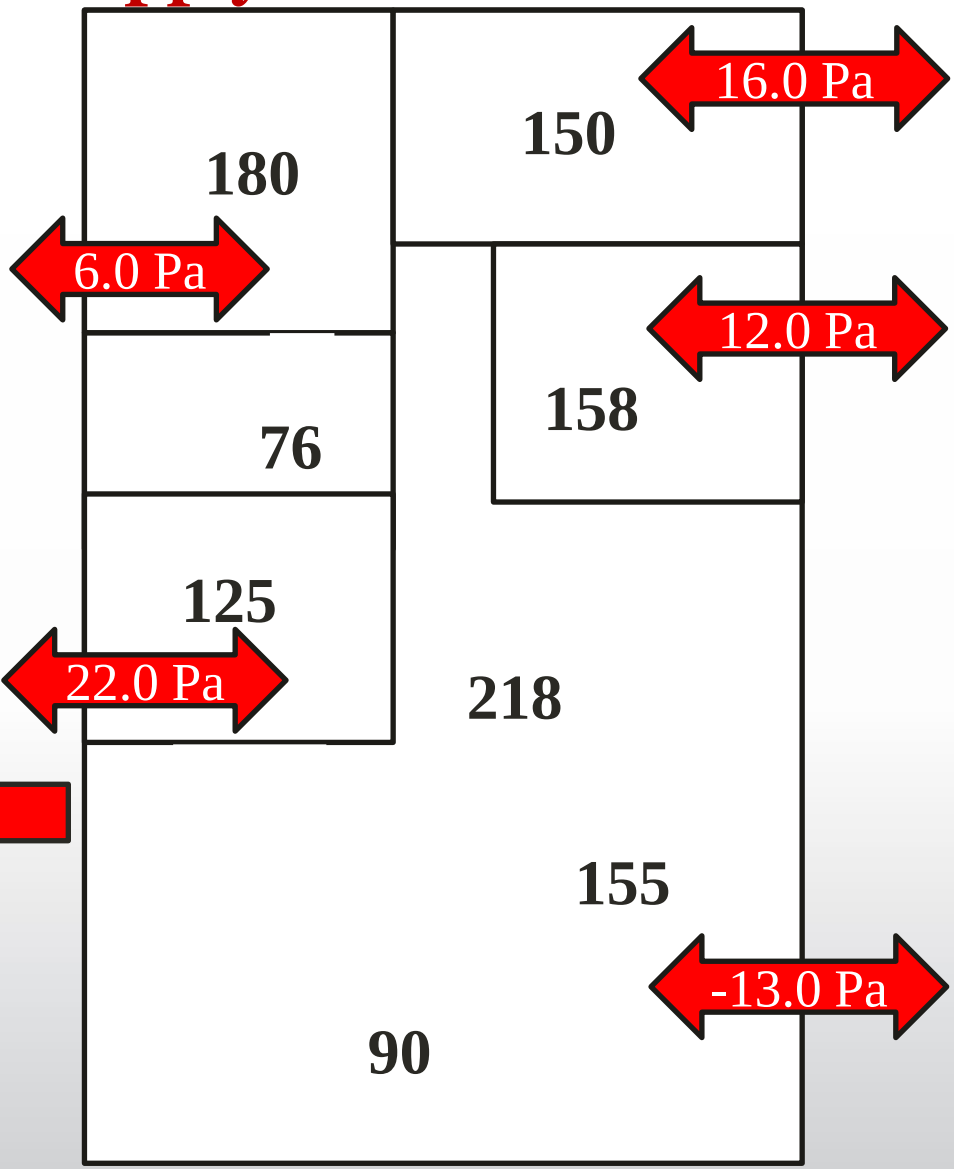




Supply CFM Doors Open



Supply CFM Doors Closed



Pa.

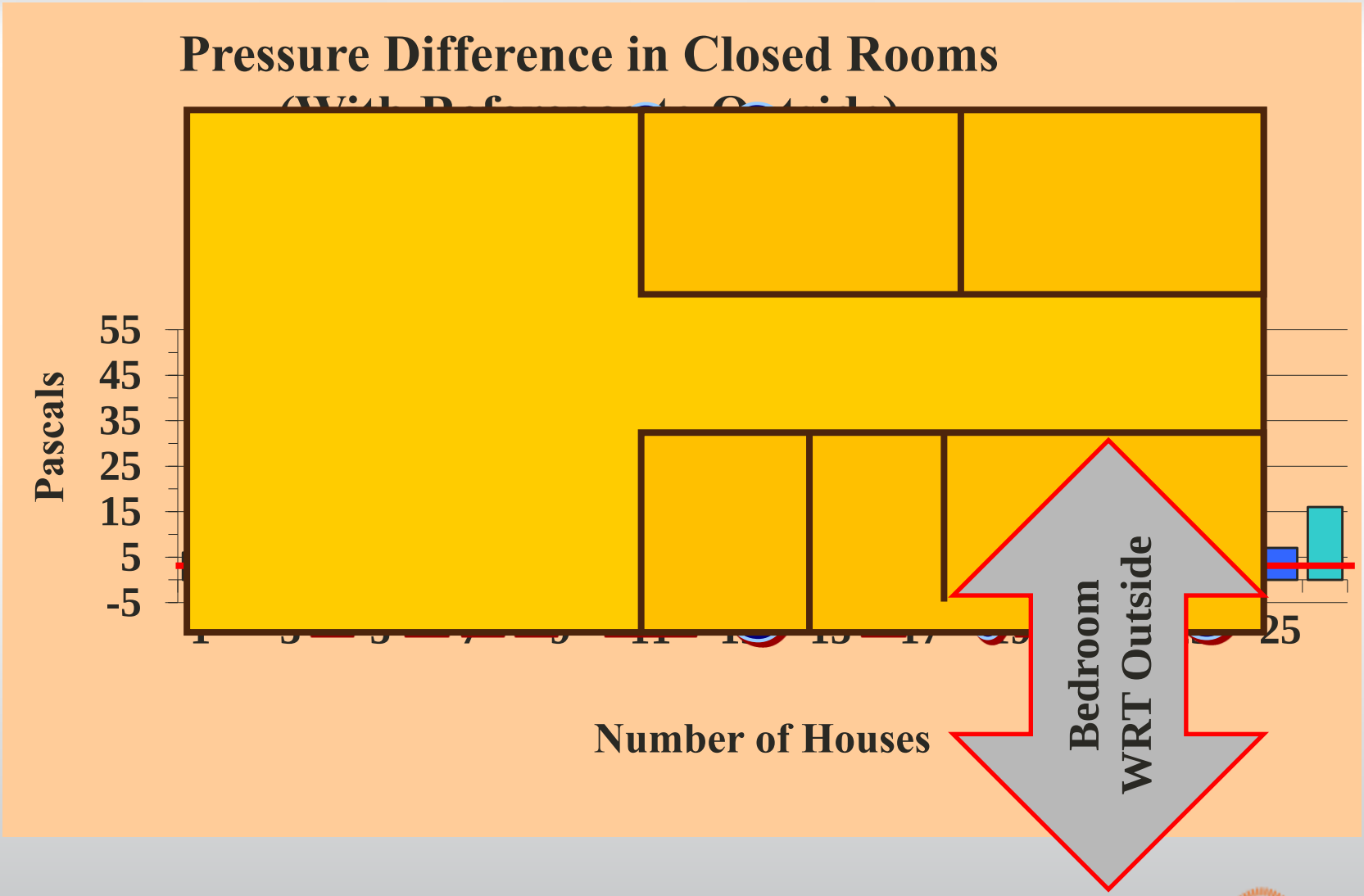
1208 CFM delivered flow

1152 CFM delivered flow

Source: Infiltration Rates and Pressure Differences in Florida Homes Caused by Closed Interior Doors When The Central Air Handler is On FSEC James B. Cummings and John J. Tooley

advanced energy

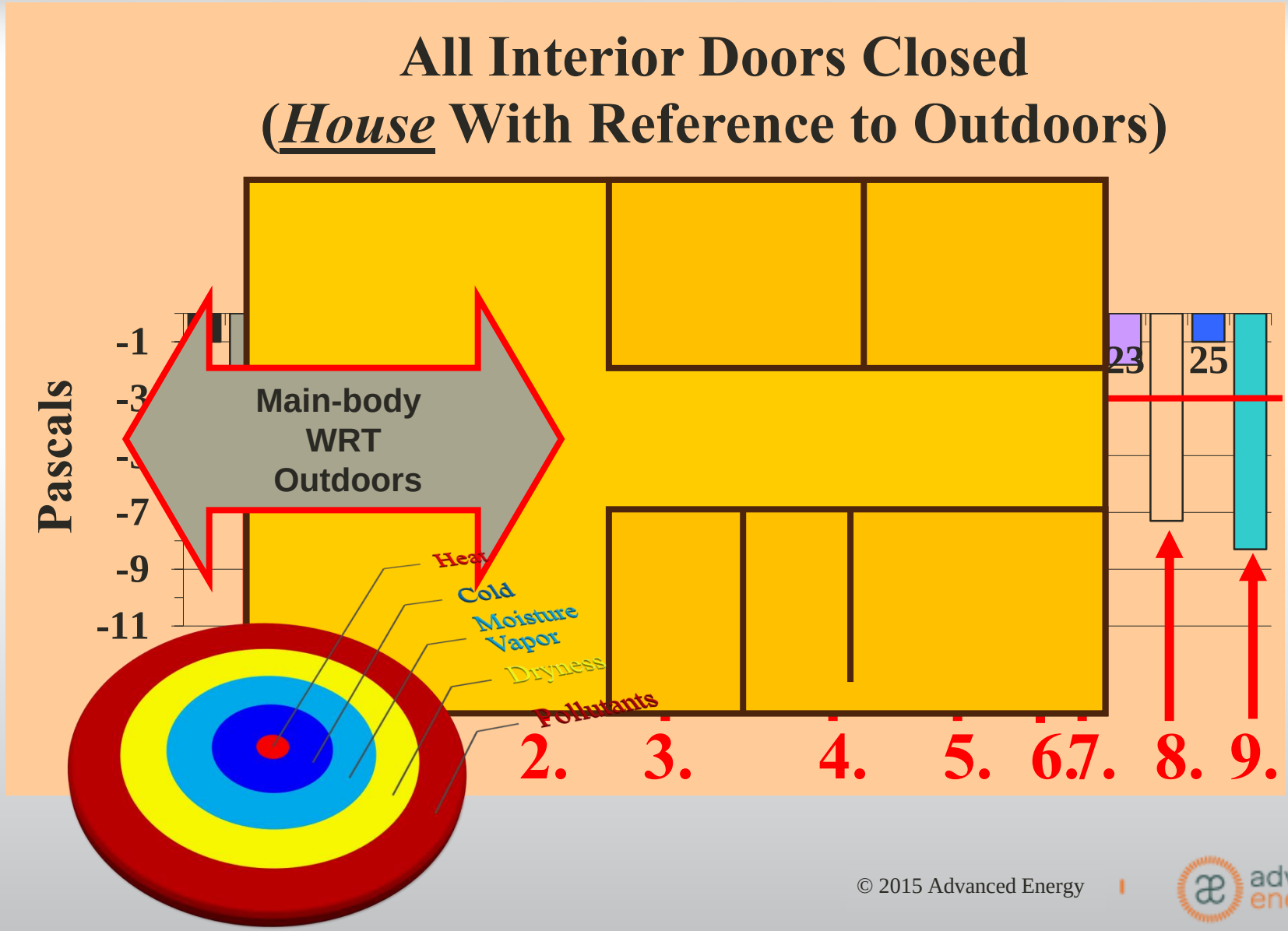
Closed Bedroom WRT Outside



Door Closure Pressure Effect Test

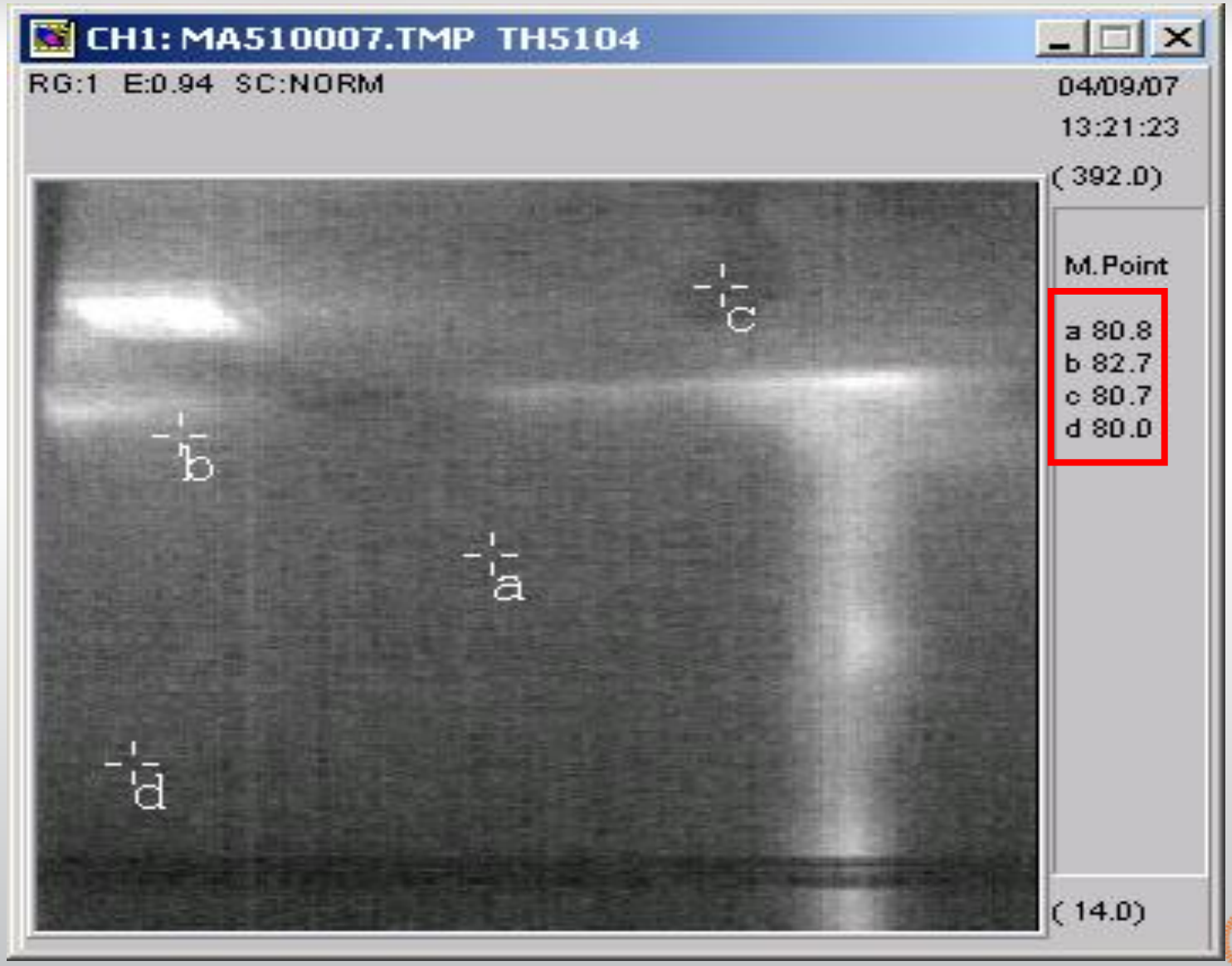
No more than 3 pascals of pressure difference between the inside and outside with all bedroom doors closed and the heating or cooling system on high speed.

House Main Body WRT Outdoors



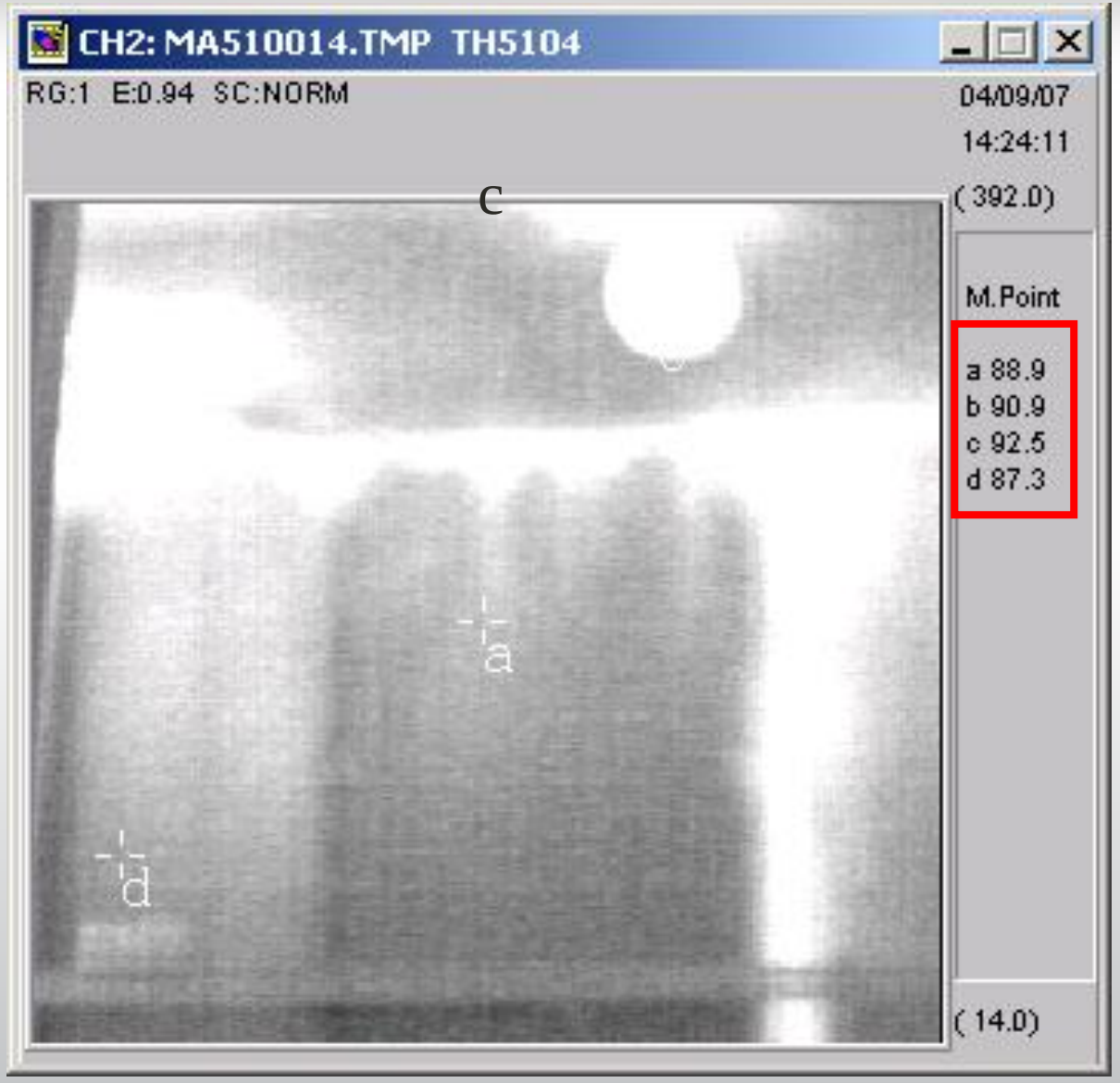
advanced energy

Start of Scan



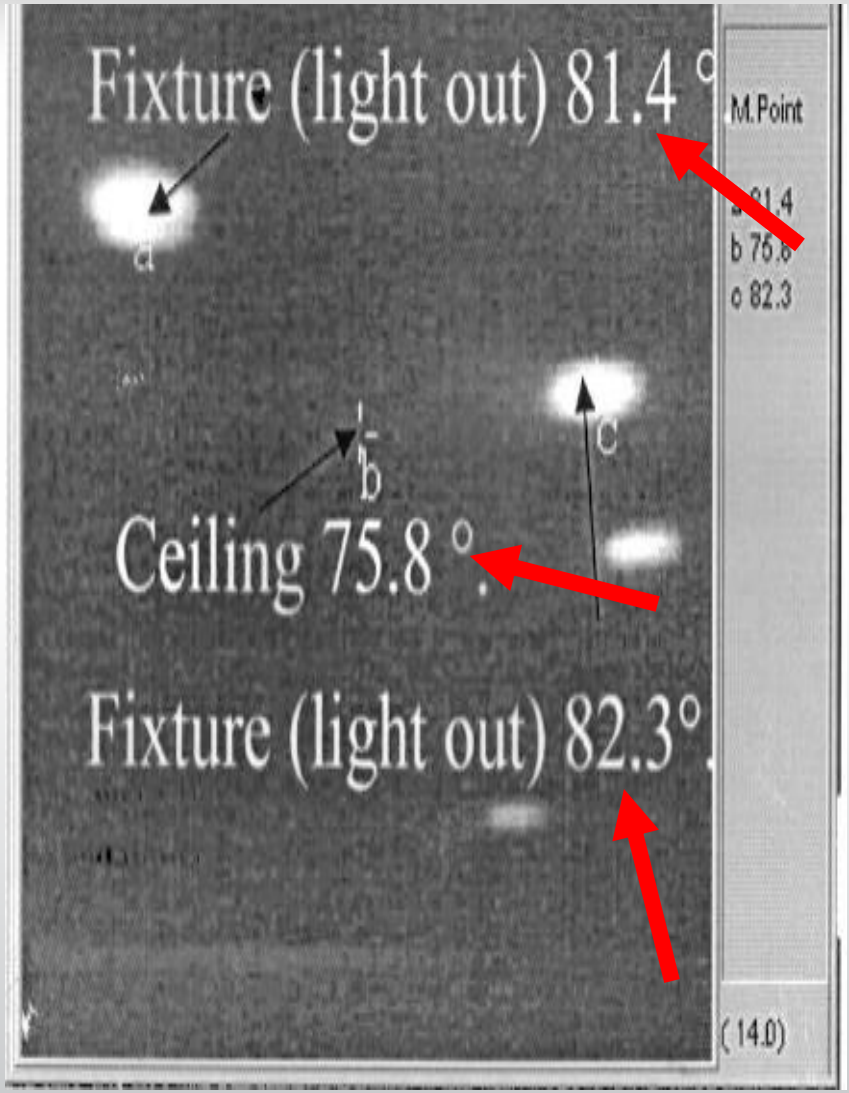
advanced energy

End of filming-20 minutes at 3 Pascals

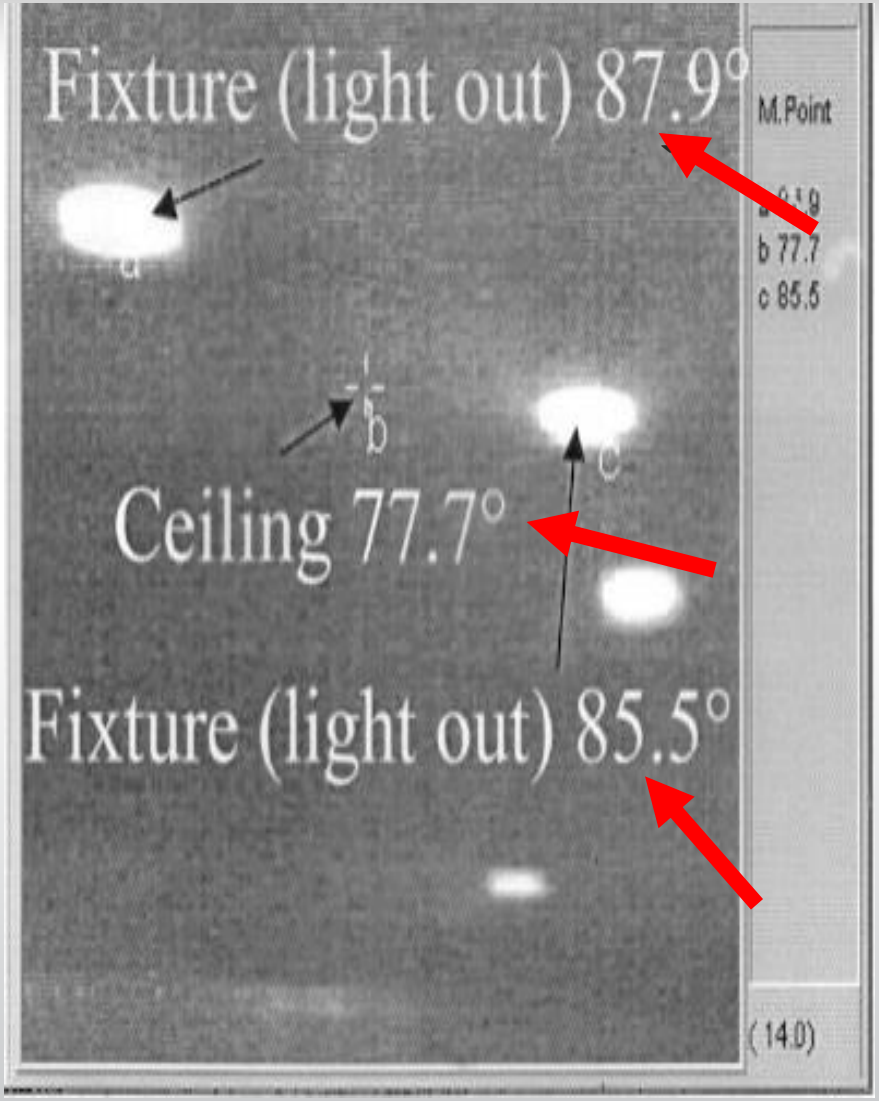


advanced energy

Doors Open Then Closed 20 Minutes



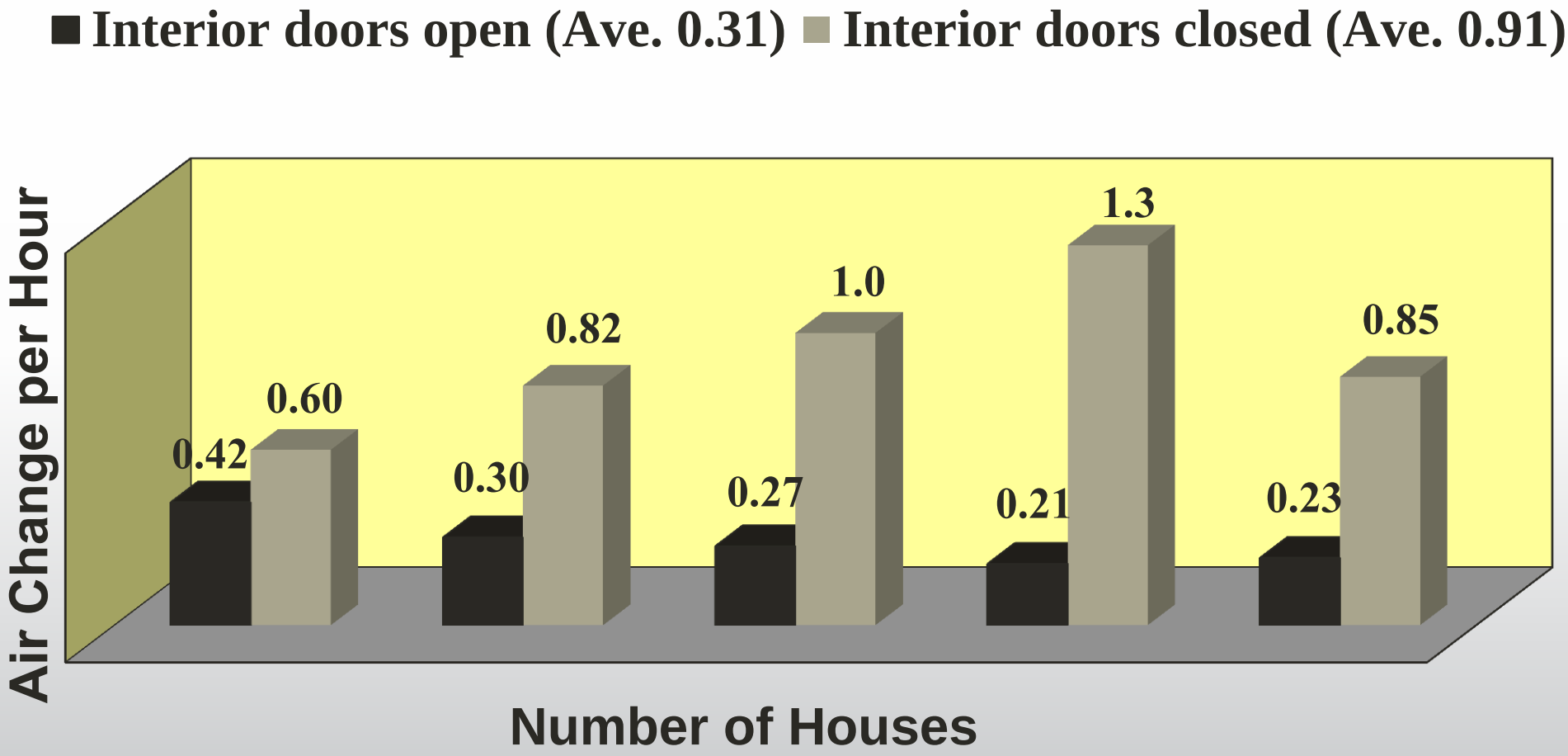
Open



Closed

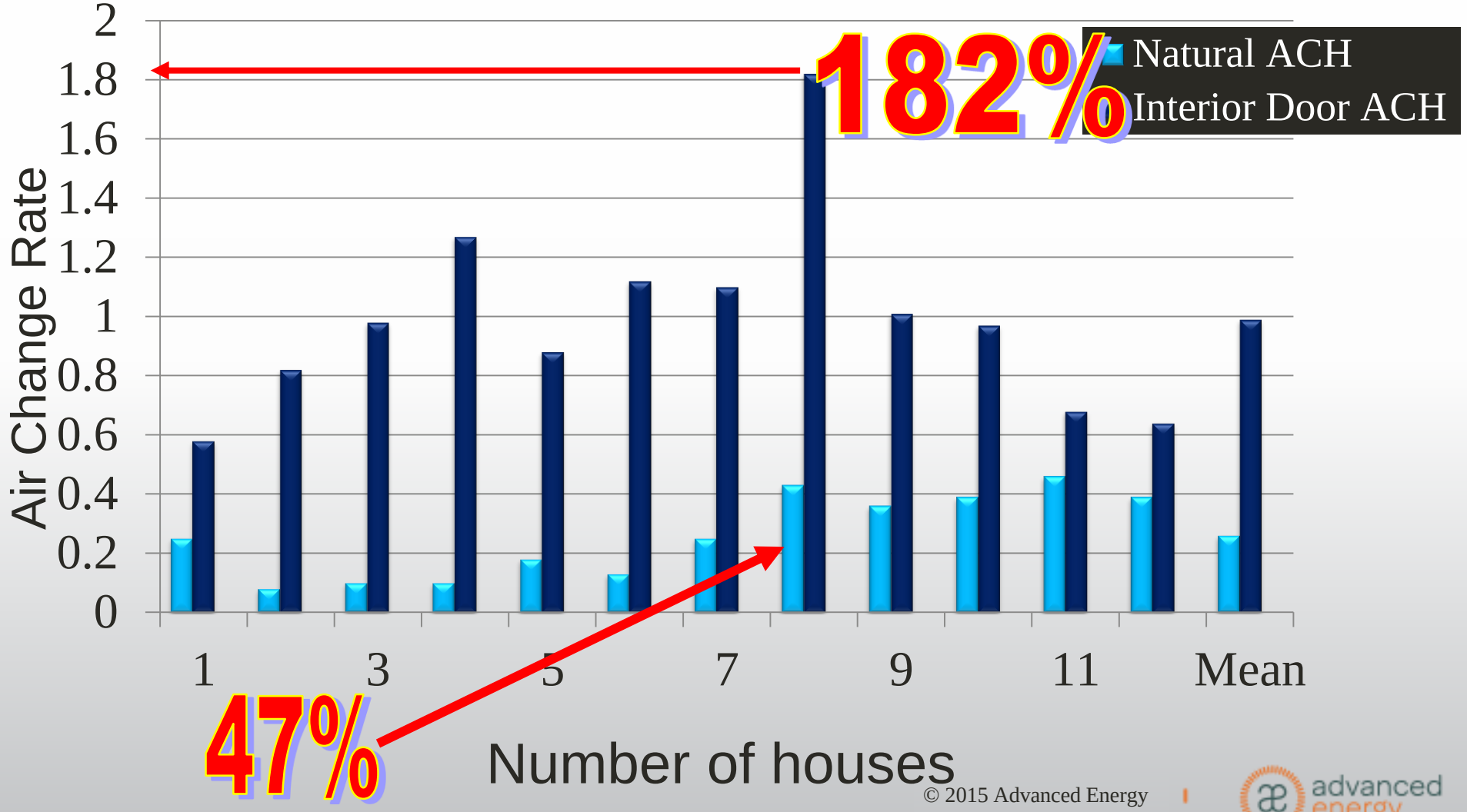
Source: Cherlie Goman, AEO

Infiltration Rates In 5 Houses With Interior Doors Open and Closed (Tracer gas)



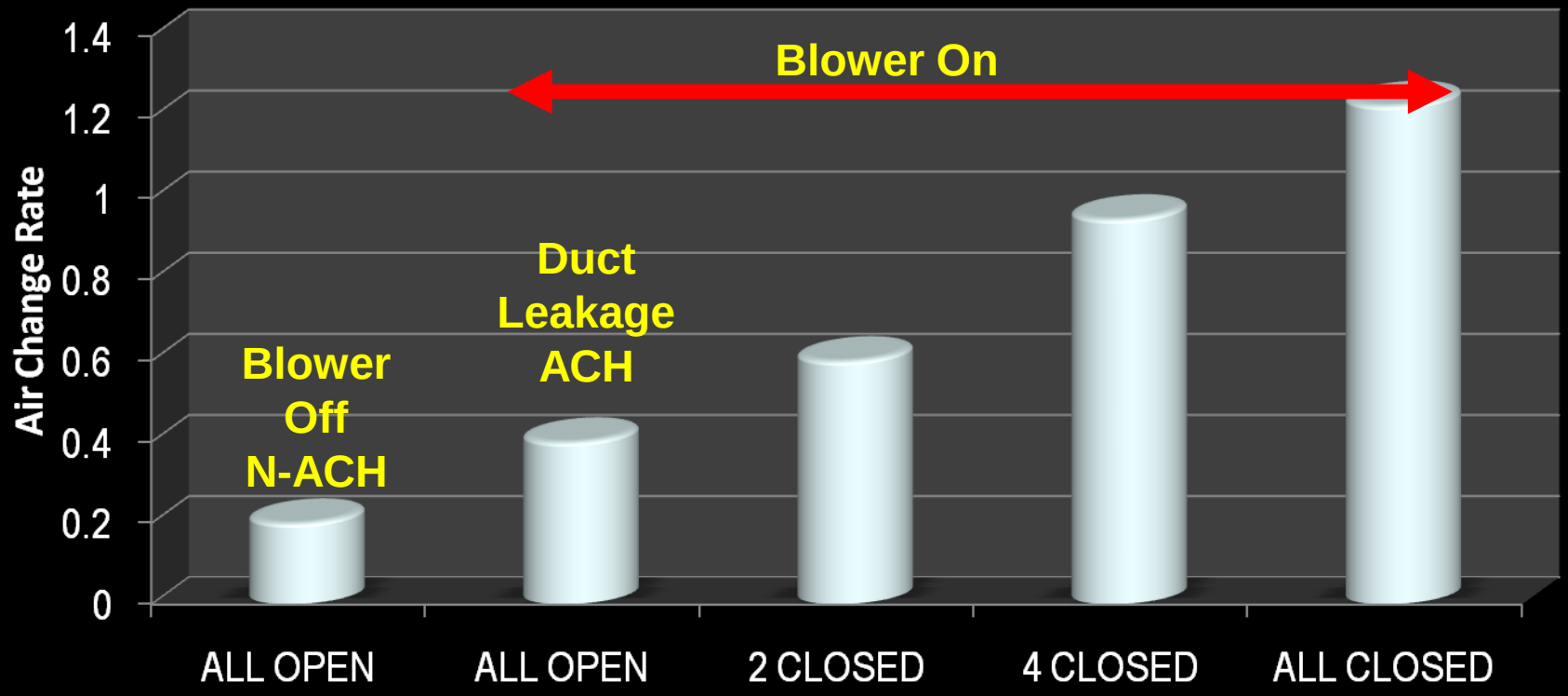
Source: Infiltration Rates and Pressure Differences in Florida Homes Caused by Closed Interior Doors When The Central Air Handler is On FSEC James B. Cummings, John J. Tooley and Neil Moyer

Natural Infiltration Rate Vs. Interior Door Closure Air Change Rate

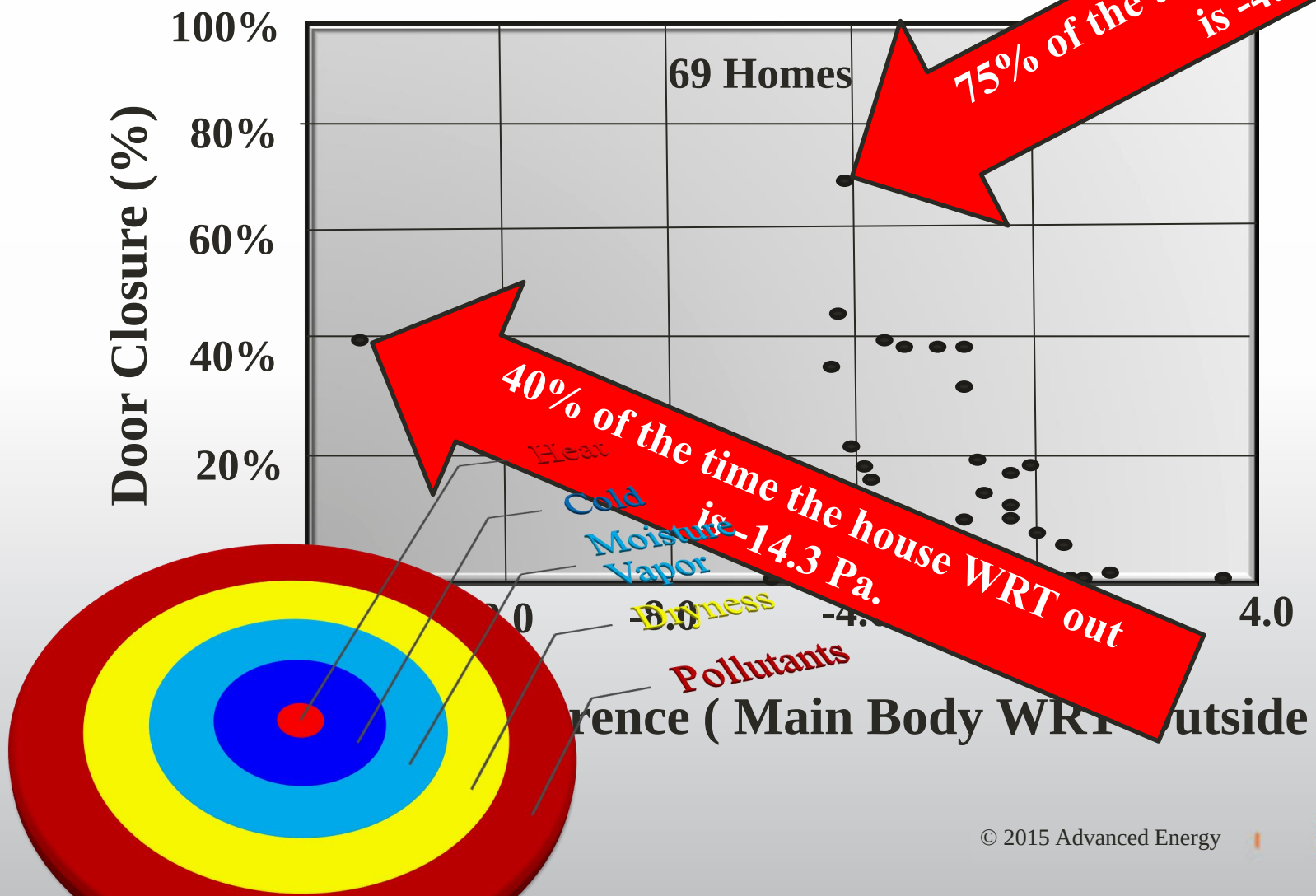


advanced energy

Measured Infiltration Rates In One Home With Various Interior Door Positions (Tracer Gas)



Depressurization (Pa) of the Main Body Caused by Interior Doors Closed and AHU Operation V
Estimated Time Occupants Close Do



advanced energy

Pressure Balance Defined

- All rivers that are dammed, release water in order to manage water levels behind the dam
- Allowing adequate water to the river below, neither too much nor too little

- All air dammed behind a closed interior door must be released to manage levels of comfort, energy use, moisture condensation and mold
- Allowing proper air flow from the **closed room** to the **main portion** of the house, neither too much nor too little

A Good Building Code 1997:

- 1902.5 Return Air Intake:

- "Return air may travel through the living space to the return air intake if there are no restrictions, such as **doors**, to the air movement."

2015 IMC and ACCA Manual D

- **2015 IMC - 601.5.3 Return Air Openings**

The amount of return air taken from any room or space shall not be greater than the flow rate of the supply air delivered to such room or space.

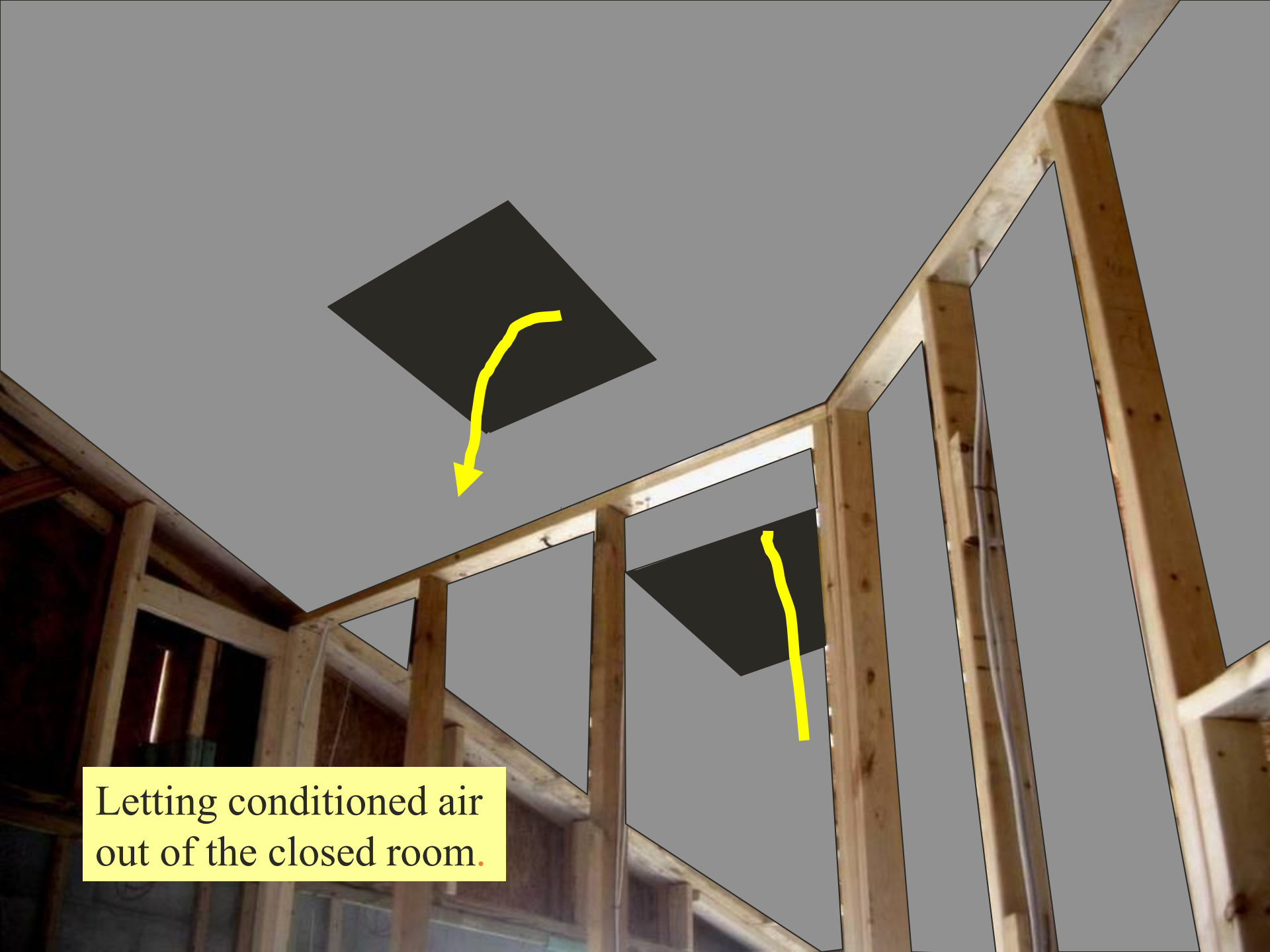
- **ACCA Manual D – Returns**: A low-resistance return path is required for each zone. If a room is isolated from one of the returns, transfer grills can be used to establish a circulation path between the isolated room and the return

Pressure Relief?

ACCA Manual T

Transfer grilles are typically sized at 200 fpm face velocity or 300 fpm core velocity and in some cases a value of 150 fpm face velocity is used to minimize the pressure drop. If door undercuts are used in lieu of door grilles, allow 1 inch of undercut for each 60 CFM of return air. Also note that privacy (sight and sound) should be maintained. A line of grilles specifically designed for this application is available from many manufacturers.

11-1

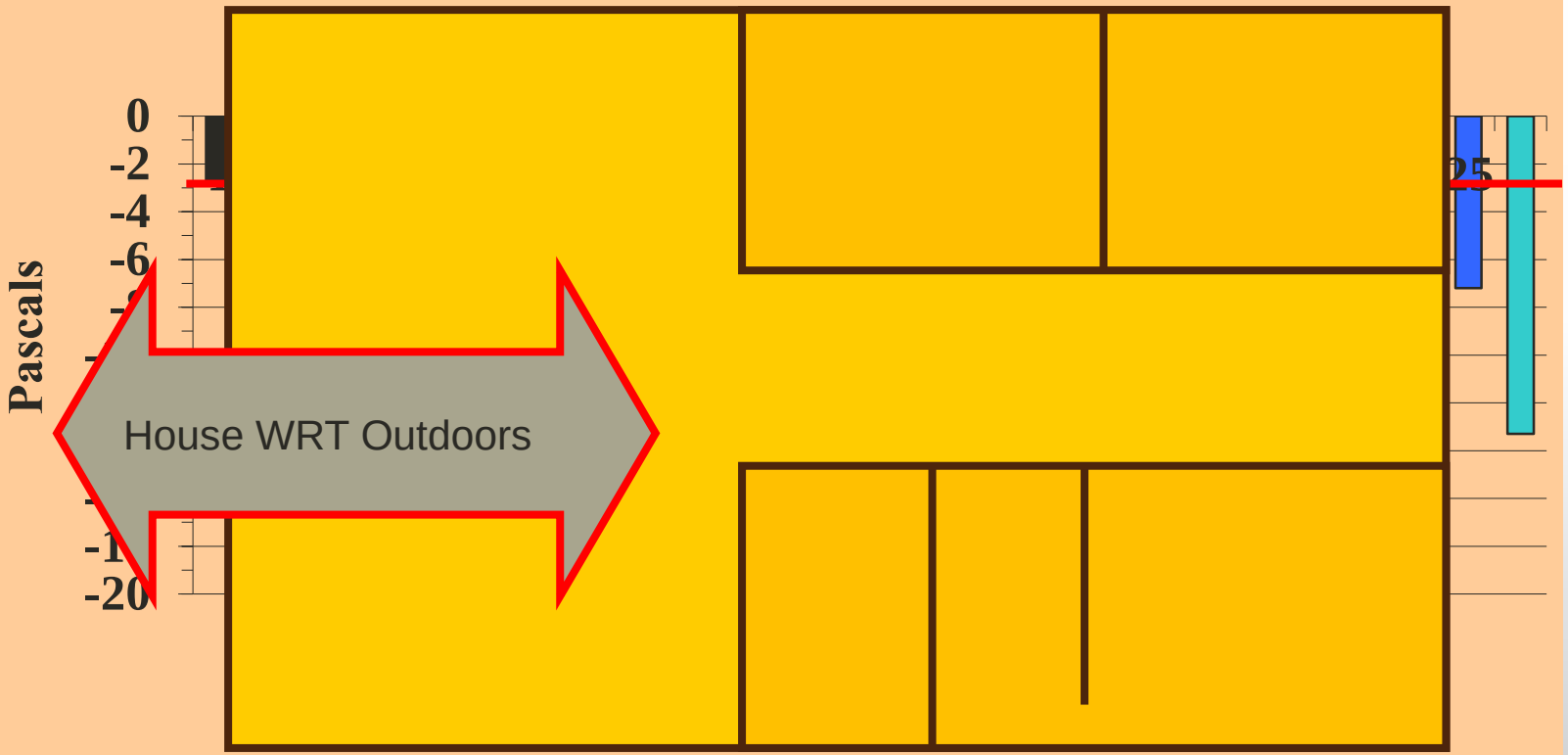

Letting conditioned air
out of the closed room.

Fan Effects

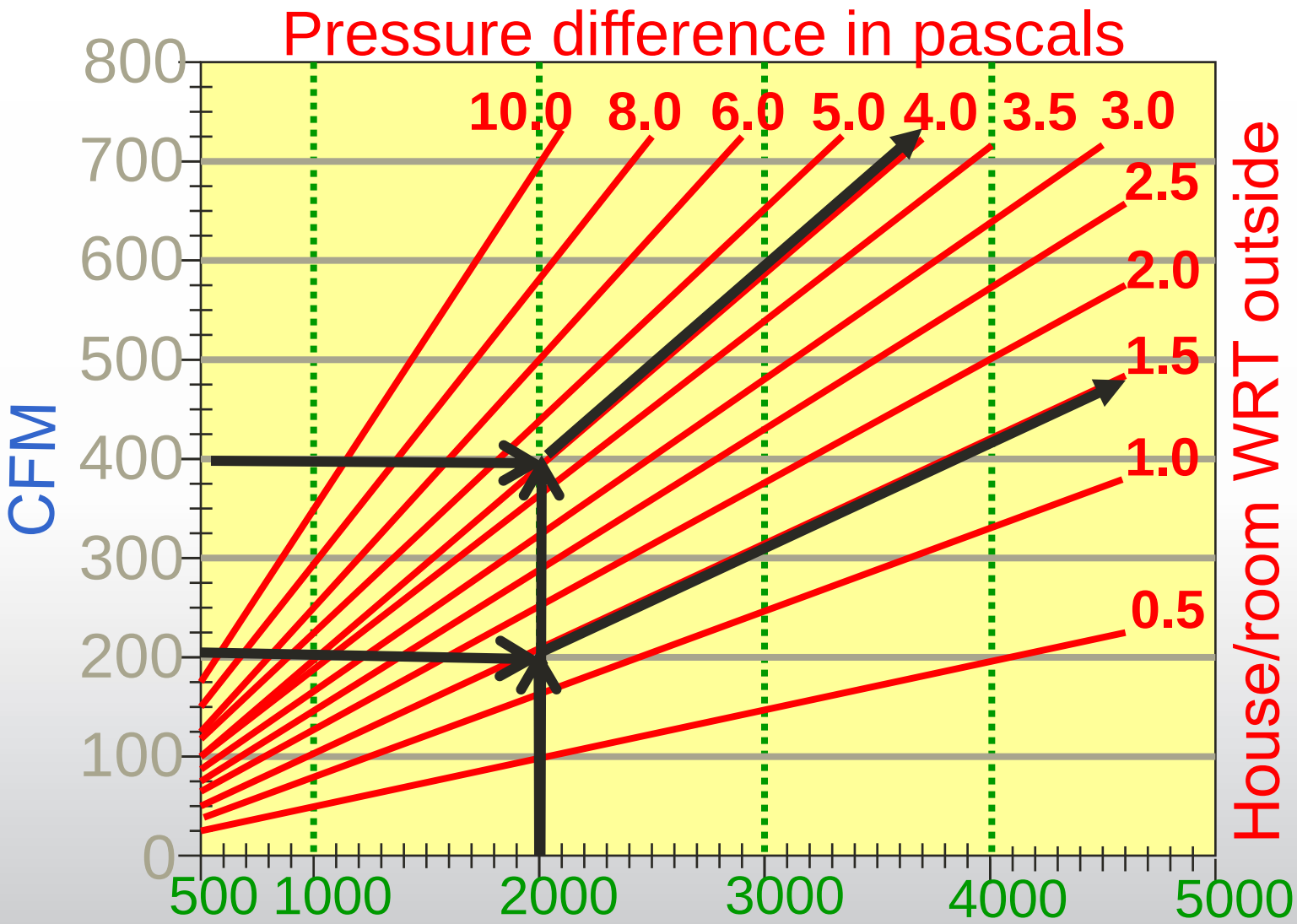
- Duct leakage
- Interior door closure
- Exhaust devices

More Flow Out of Tighter Houses?

Interior Doors Closed and Exhaust Fans On (House With Reference to Outside)



Doubling the flow does not double the pressure



advanced energy

House #21 (Tighte one)

Call backs and claims

advanced energy

House #22 (Tigh ter e)

Call backs and claims

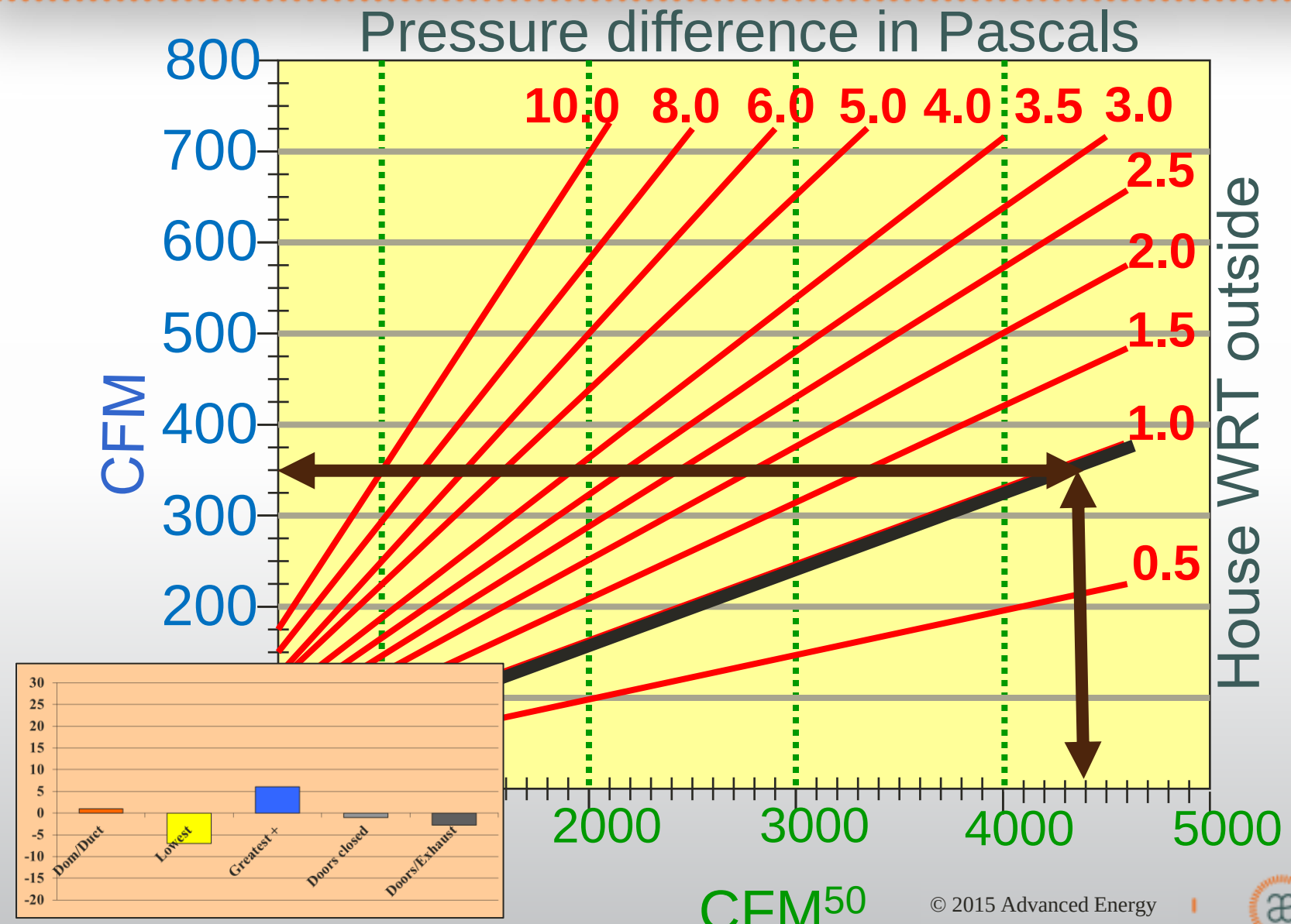
advanced energy

House #1 Leakiest

Call backs and claims

advanced energy

House #1 Dominate Duct Leak Pressure



advanced energy

House #2, Secon M leaky

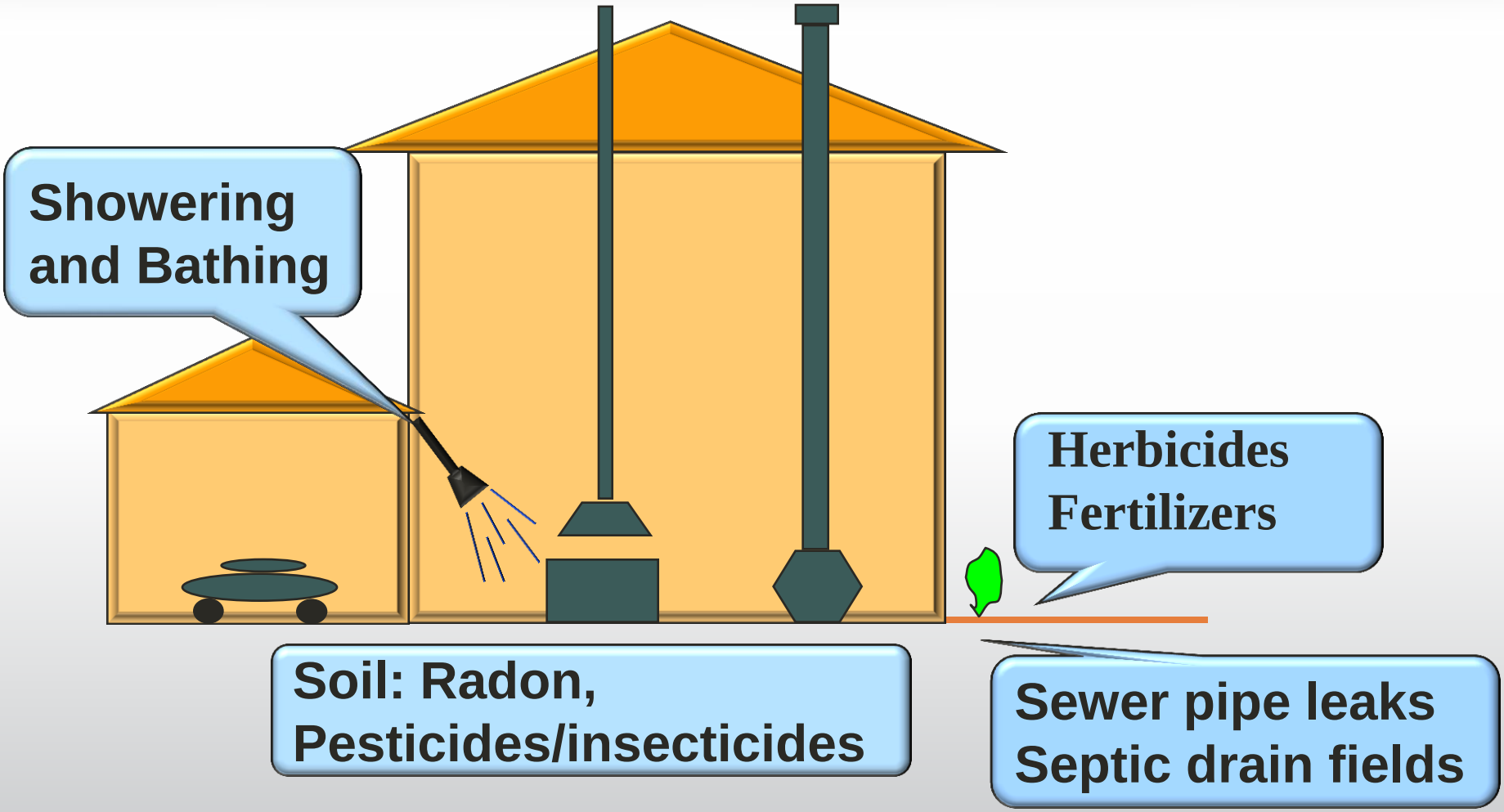
Call backs and claims

advanced energy

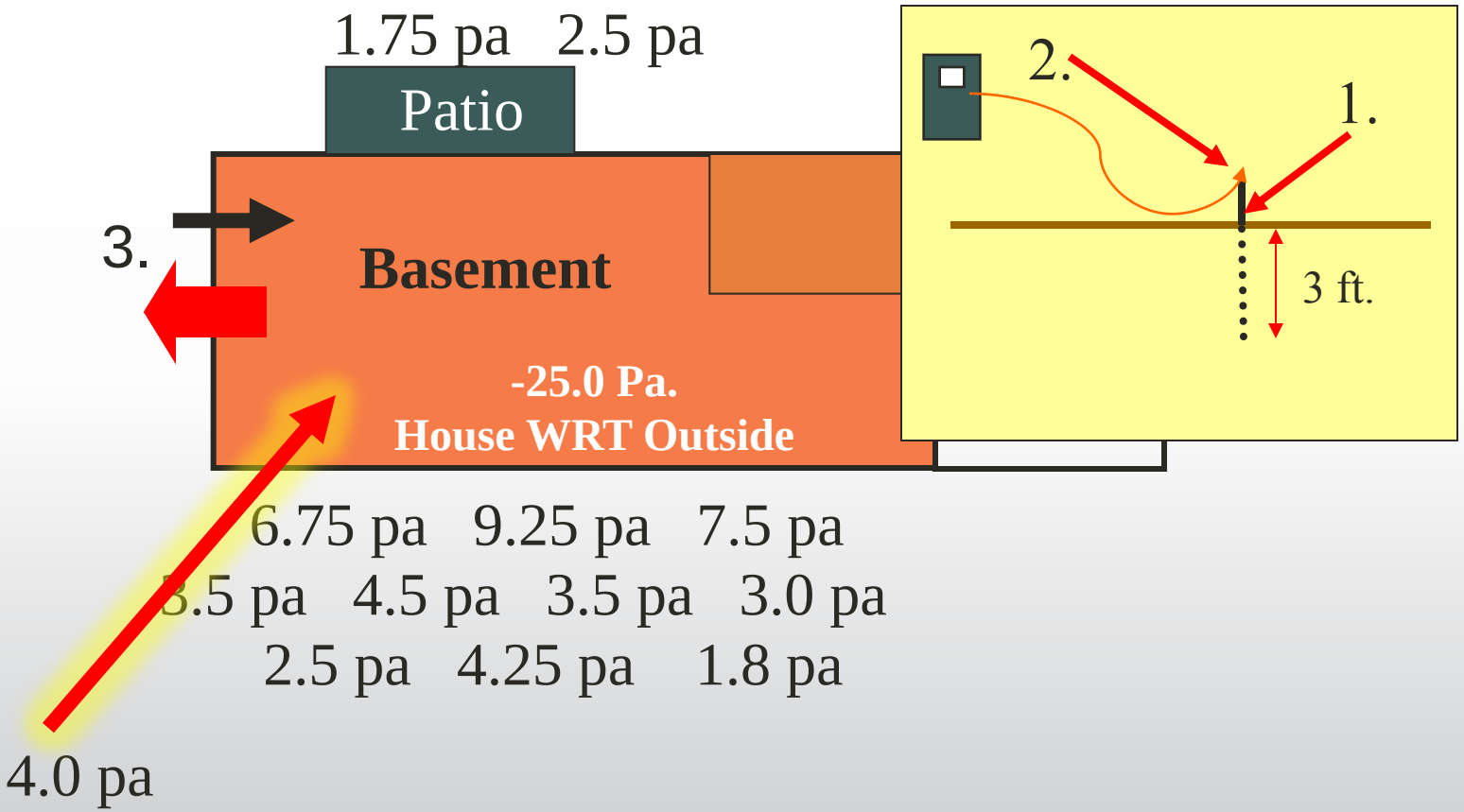
Pressures can cause

- Soil gas entry
- Garage vapor entry
- Combustion problems
  - Spillage
  - Back-drafting
  - Flame roll-out
- Moisture damage and mold

Soil Gas Sources and Pathways Into The House



Soil Depressurization Study

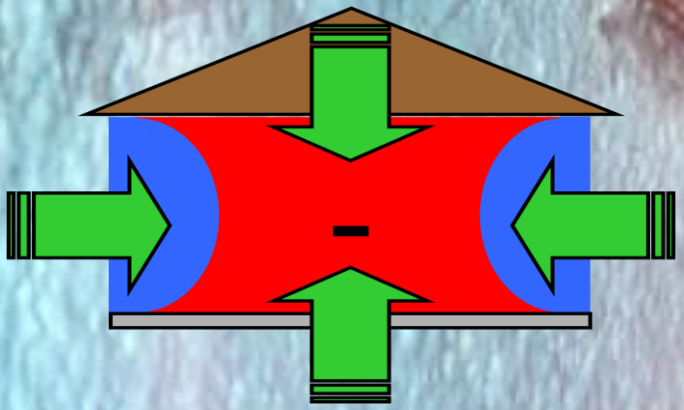


Pest Control

Spray Fertilizer

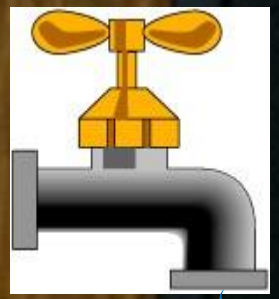
Septic Drain Field

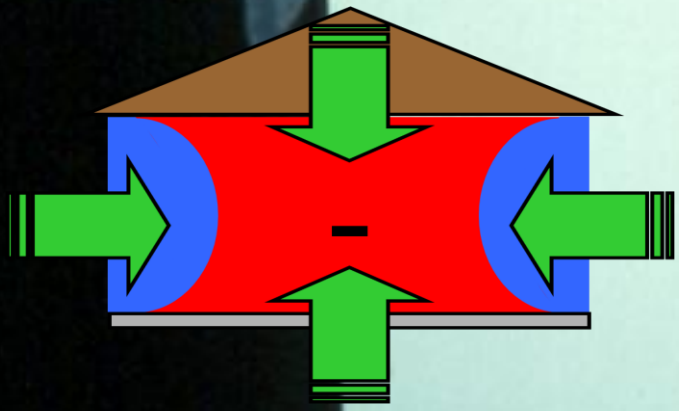
Air Transported



This house is depressurized

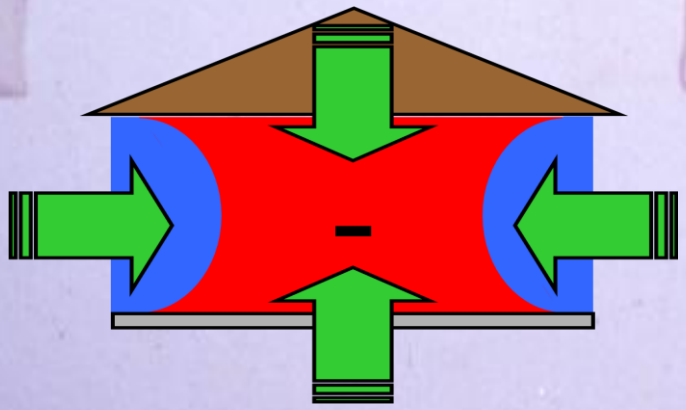
Air Transported





This house is depressurized

Air Transported

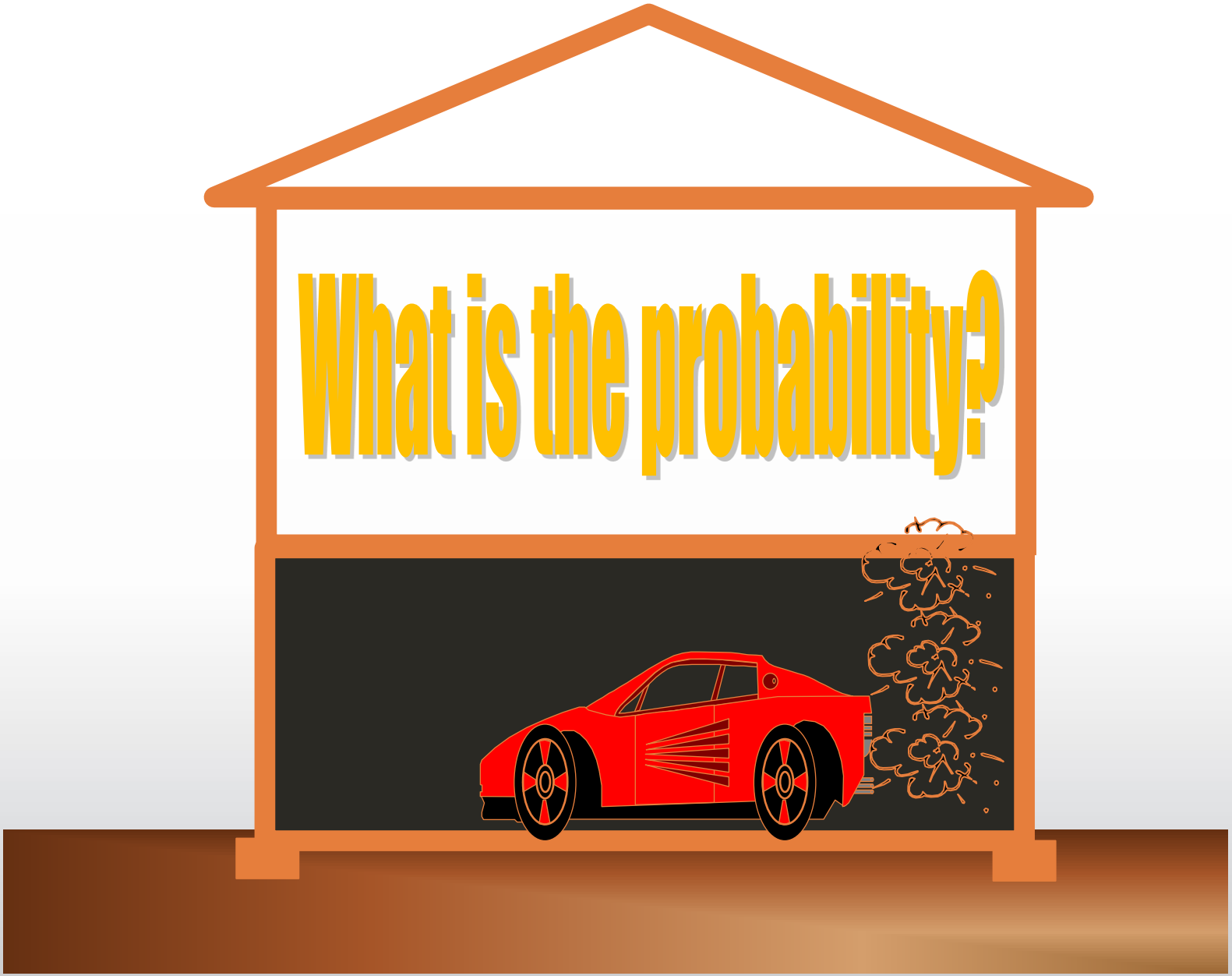


This house is depressurized

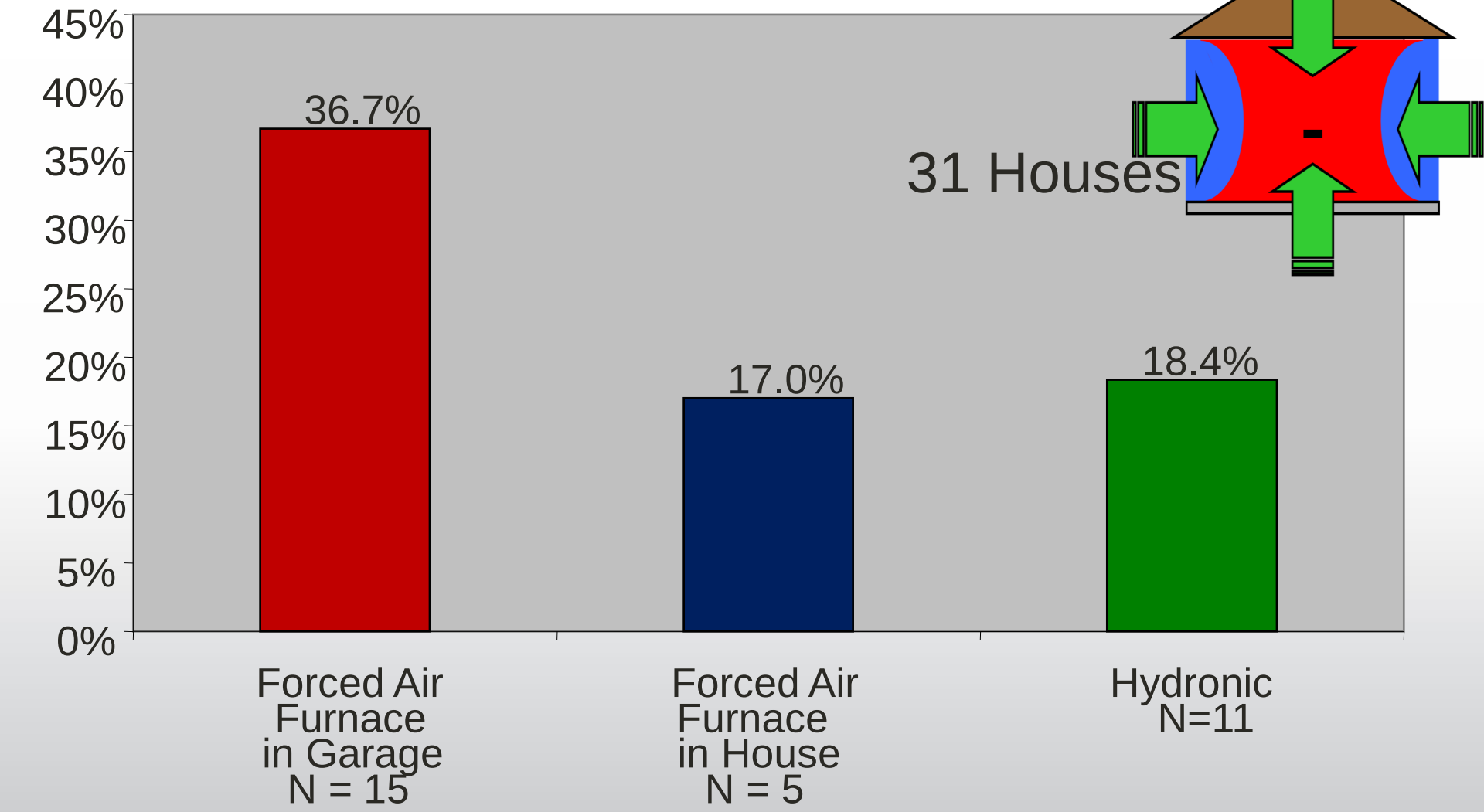
Often We Don’t Know We Are In Trouble


Air
Transported
Condensation

What is the probability?



Comparison of Median Infiltration Rates
Proportion of House Air Originating from Garage



Stephen S. Morris, P.E.
Municipality of Anchorage
Department of Health and Human Services

69 House Study (Alaska) Benzene

- **Class A carcinogen**
  - US Govt. Minimal Risk Level (MRL = 4 ppb)
  - **One of the Top Ten Most Hazardous Air Pollutants**
- **Gasoline**
  - **3-5% *benzene***

60% of homes with attached garages had benzene levels that exceeded the US Govt. Minimal Risk Level (MRL = 4 ppb)

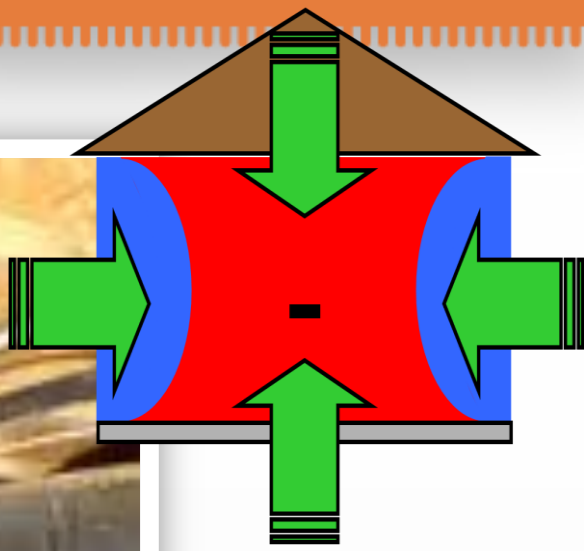
Source: Phil Kaluza, ABSN, Alaska

Carbon Monoxide Testing 50 Houses

What's in the garage can end up in the house

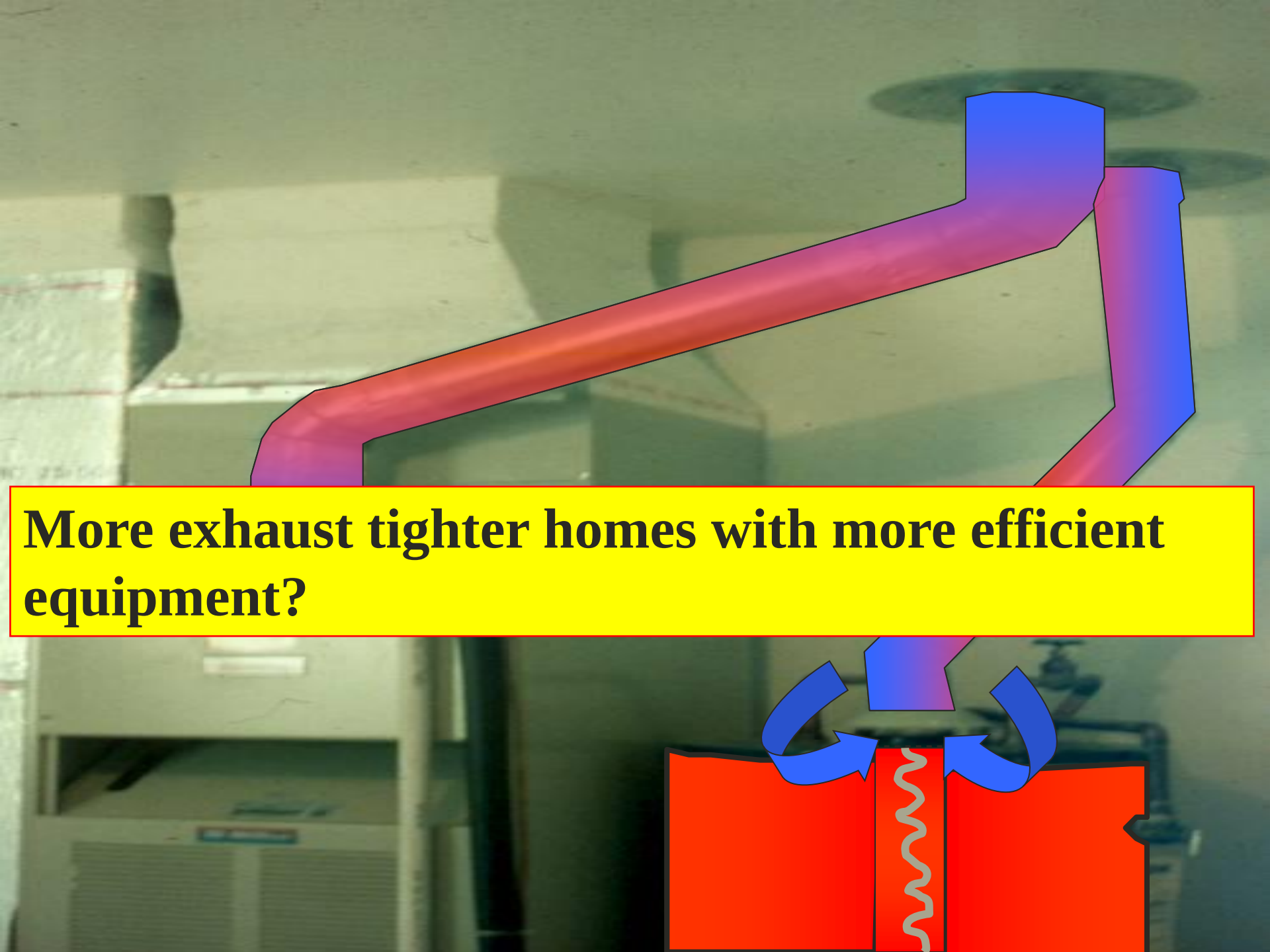
advanced energy

Proportion of House Air Originating from Crawl Space

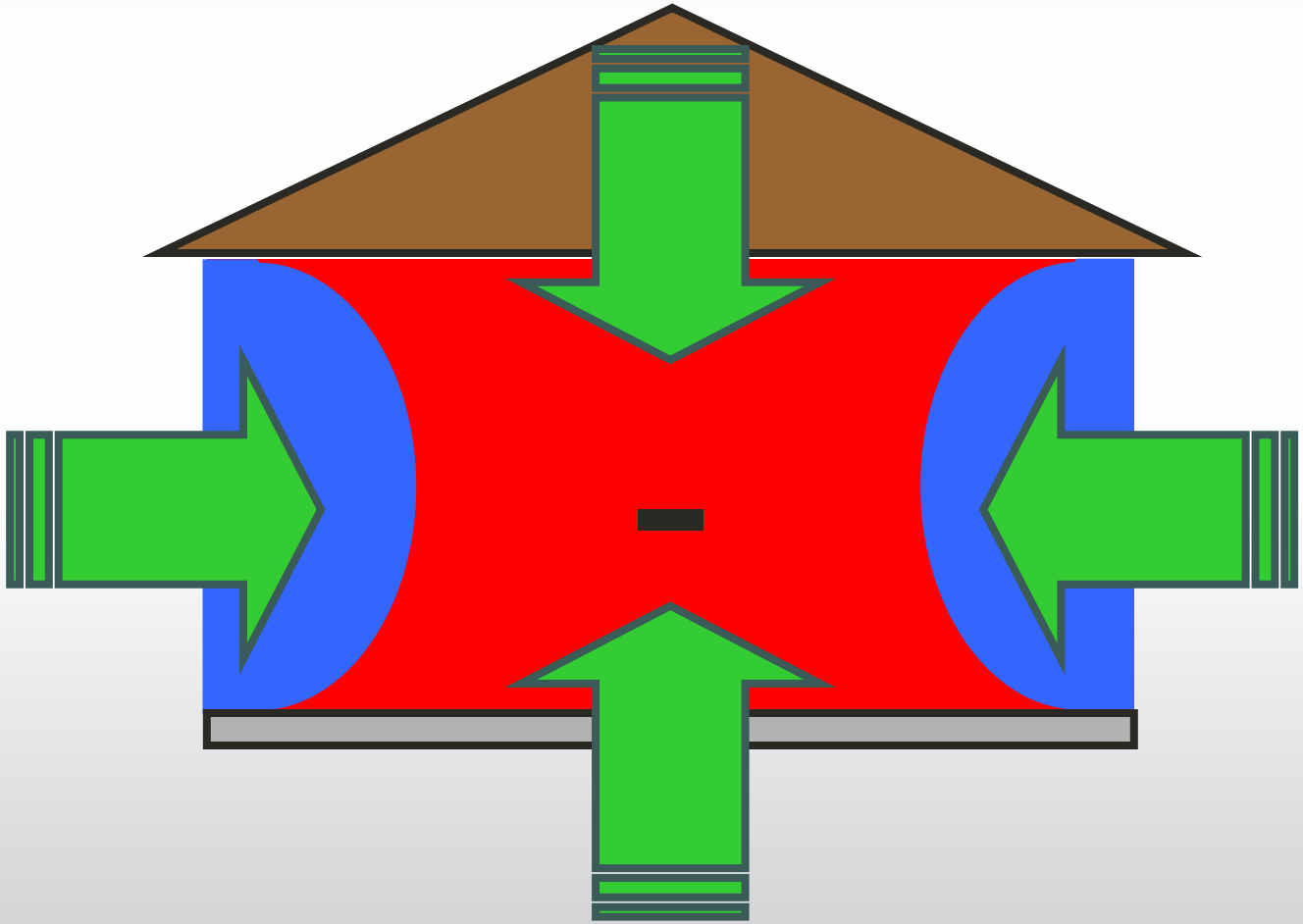


Source: www.crawlspaces.org Advanced Energy

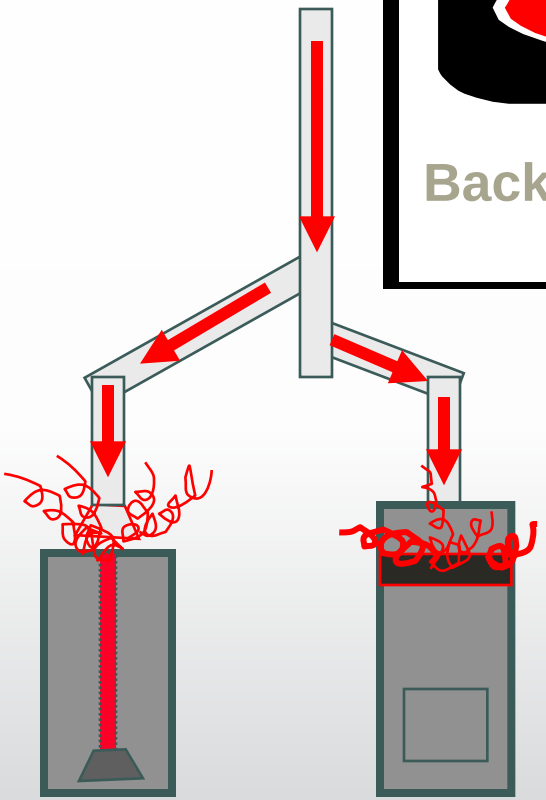
advanced energy


More exhaust tighter homes with more efficient equipment?

Negative Pressure

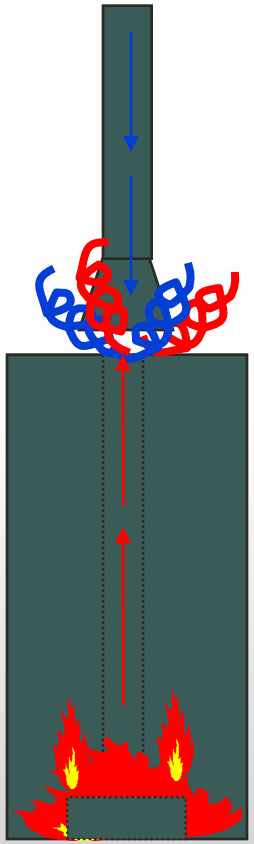


Backdrafting



Negative pressure
CAZ WRT outdoors

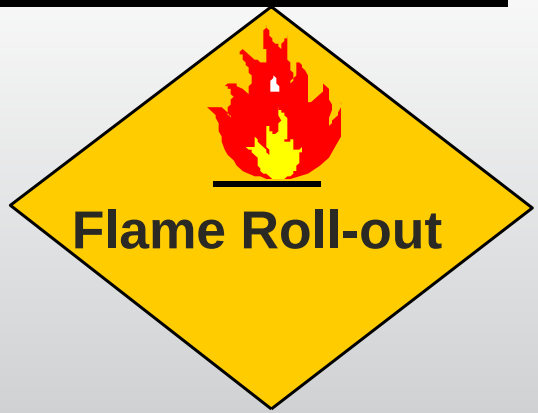
Pressure Induced Flame Roll-Out

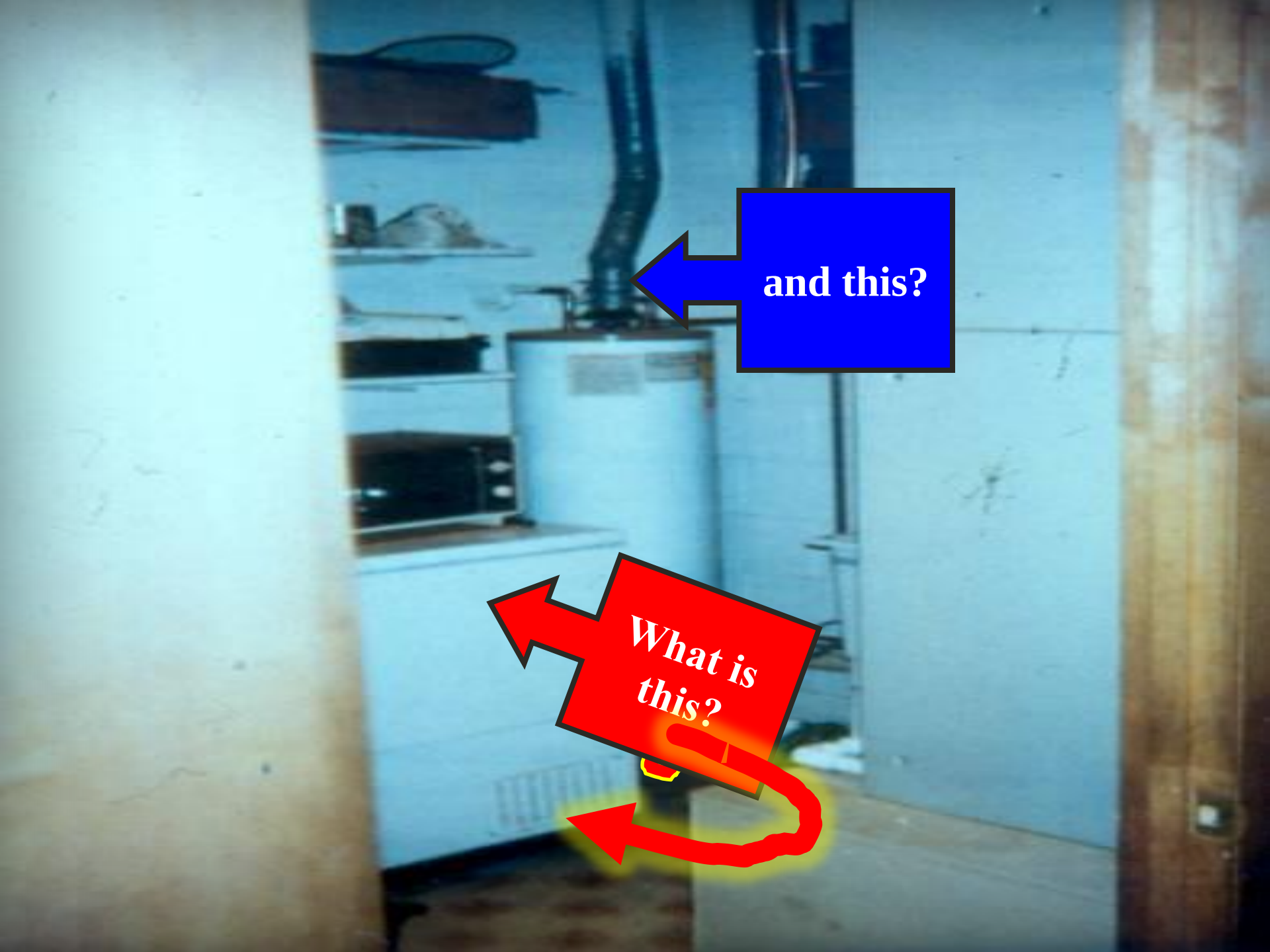


DANGER

Pressure induced flame roll-out
is a **hazardous situation!**

Negative pressure CAZ WRT outdoors




and this?
What is this?


Kitchen sinks
What's behind the door?

Flame Roll-out

Pressure Induced Flame Rollout

Energy Design Update®

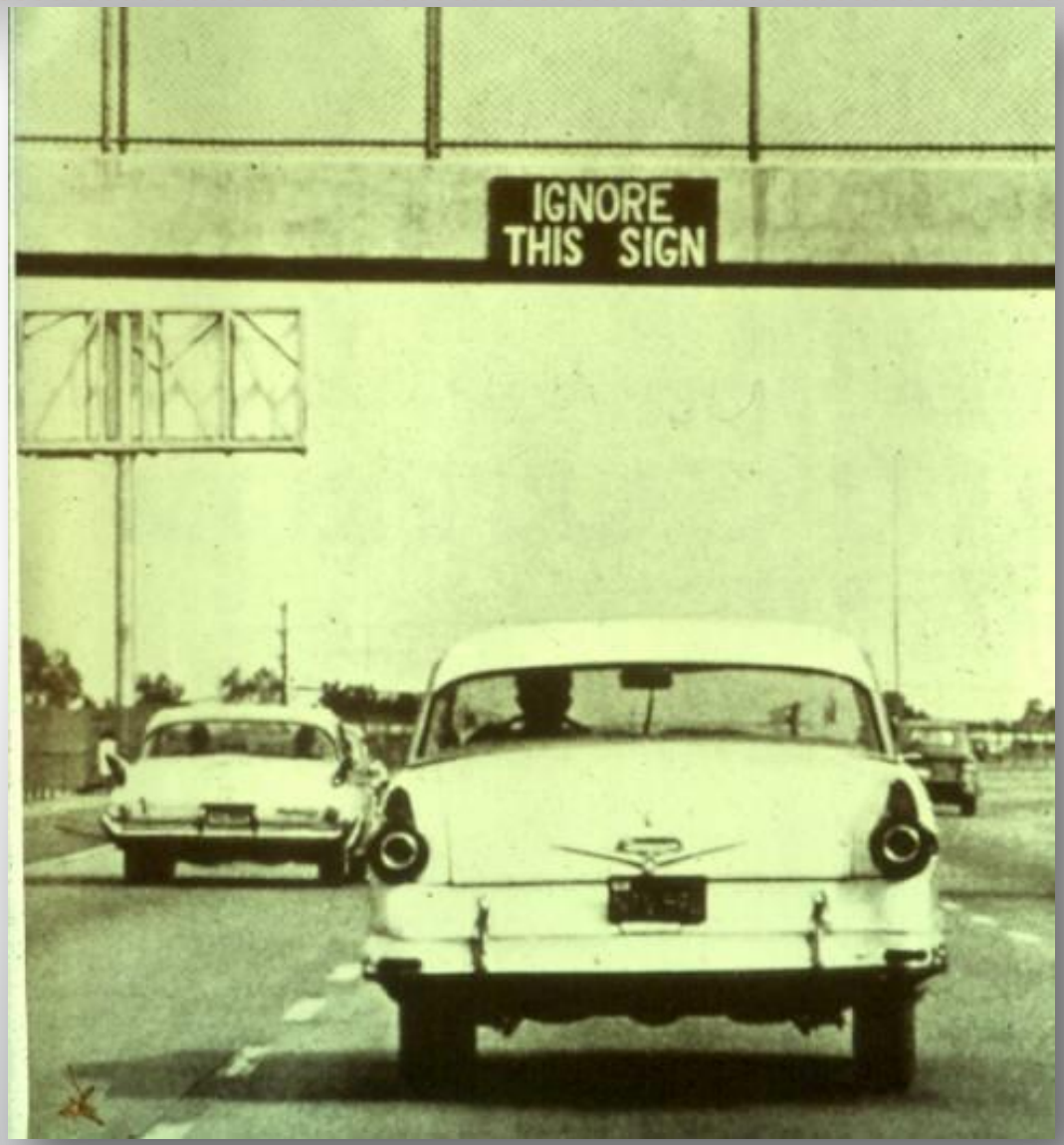
The Monthly Newsletter on Energy-Efficient Housing, from CUTTER INFORMATION CORP.

"Homebuilders are having problems keeping the pilot lights burning in gas-fired water heaters. Their complaint to manufacturers is that when exhaust fans or central air handlers are turned on in some homes, outdoor air flows down the water heater flue and blows out the pilot light."

"In response...at least one manufacturer, A.O. Smith, has decided to modify its water heaters to eliminate the standing pilot light."

Vol. 12, No. 7

What normally happens



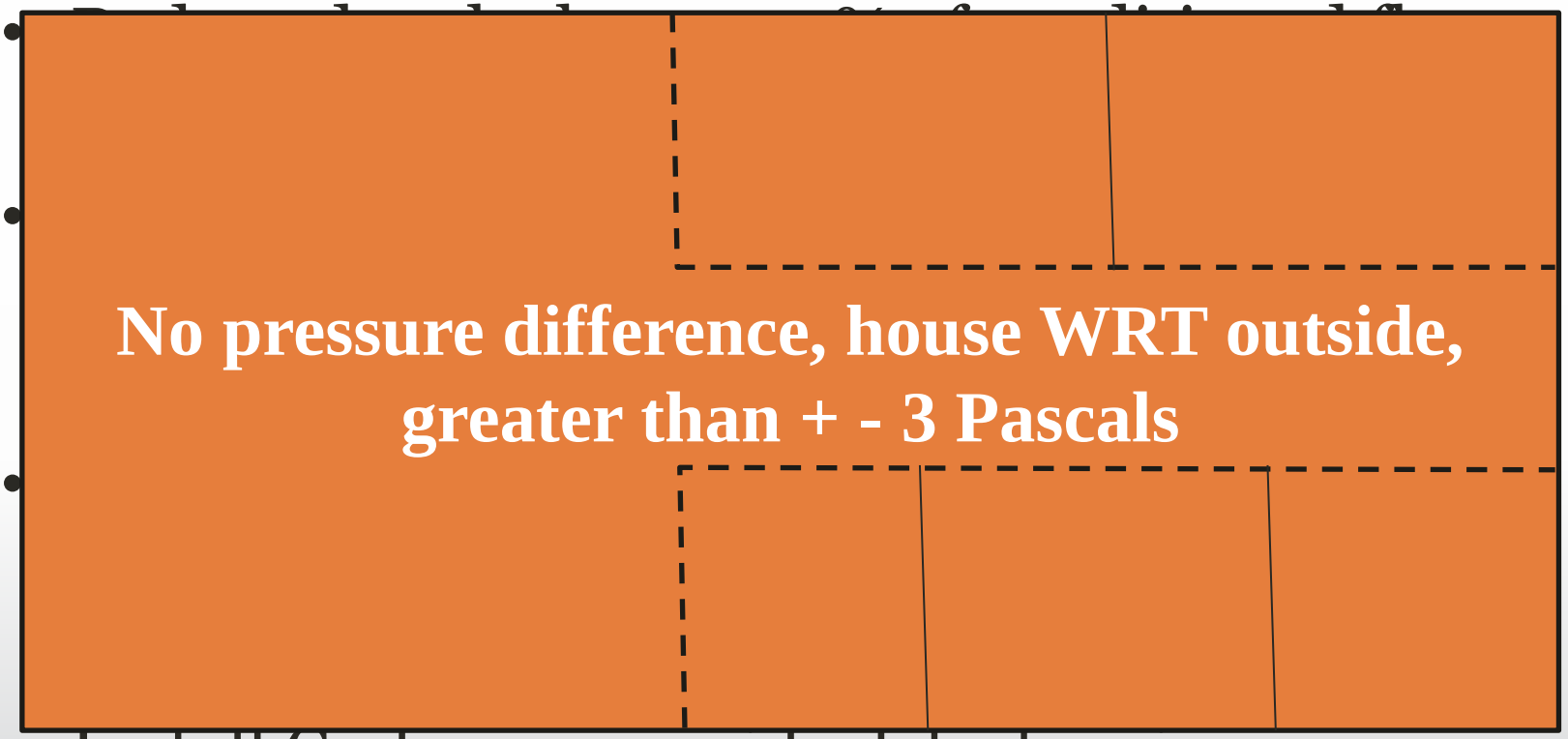
Solution: Sealed combustion or power vented inside living space or all electric.

3 Questions

1. Is **Energy Efficiency** more important than health, safety and durability?
2. Should we cure one problem without creating another?
3. Can we continue to treat buildings as incremental parts, improving one part without considering the whole?

MAD-AIR Demands Codes and Standards….

- Use a system approach to pressure
- Install Carbon monoxide detectors in every house
- Installing fresh air ventilation as called for in 2015 IECC



QUESTIONS ?


Thank You