Building Professional Training – Day 2

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Agenda

Day 2: Wednesday, October 27th, 10:00 AM to 1:00 PM

- Fundamentals of Building Science, cont.
- Building Science and Health
- 2018 Residential Energy Code
- Efficient HVAC Systems
- Relative Humidity
- A bit about Resilience

The movement of:

- Heat
- Air
- Moisture

Air Control

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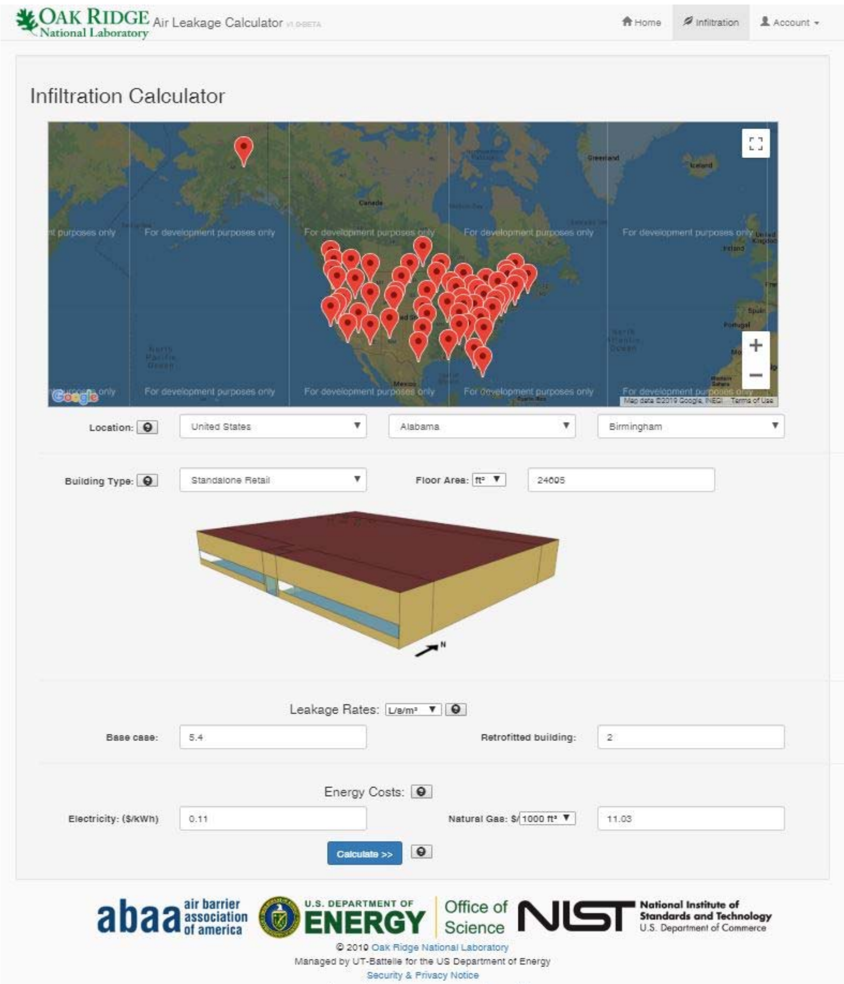
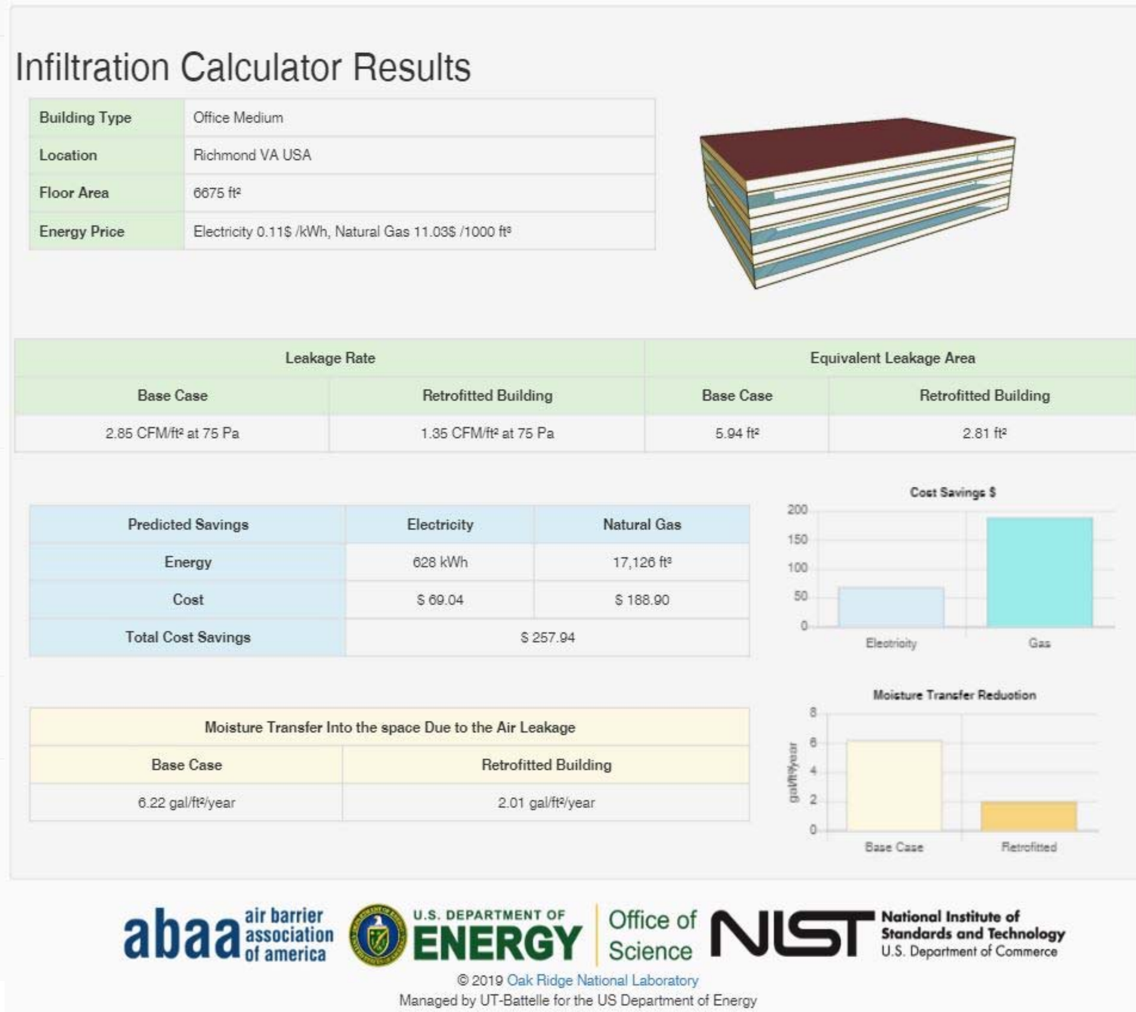
Why Air Control?

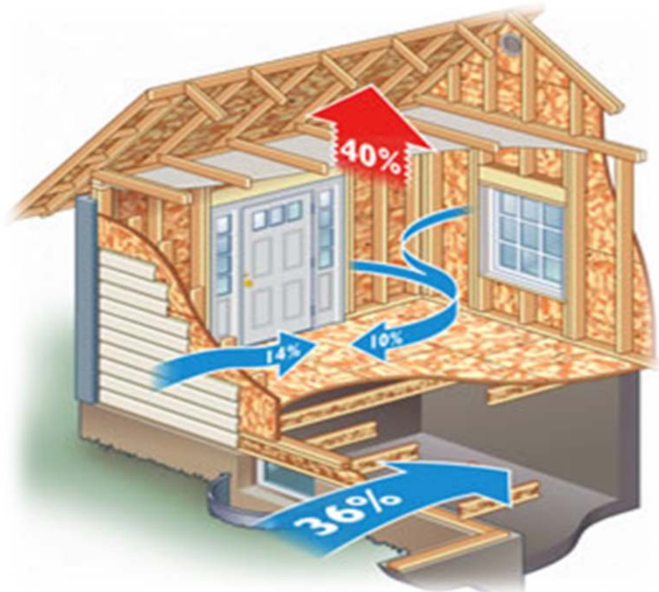




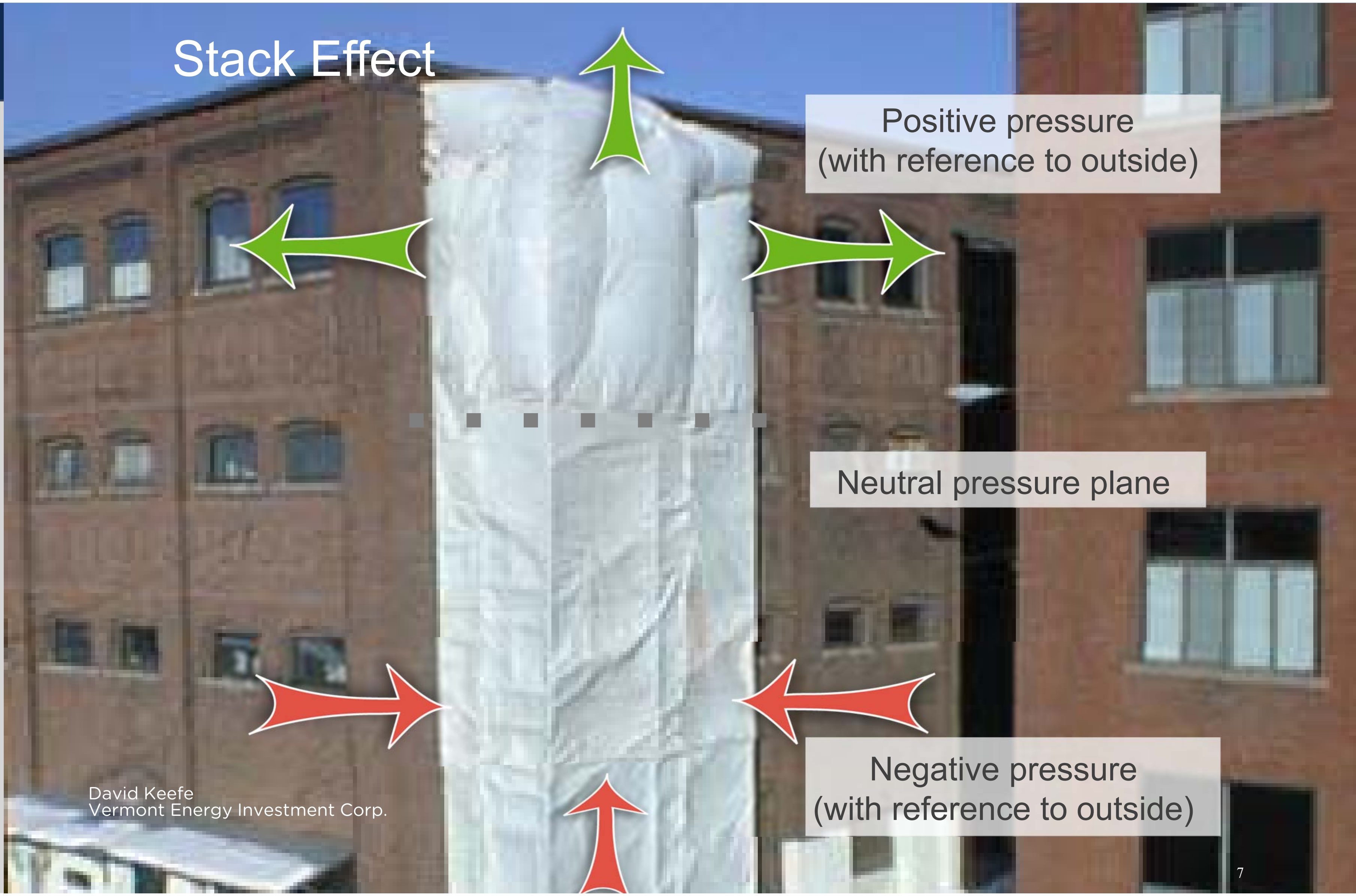
Air Leakage Conditions in Buildings

- Hole
  - Penetrations in the building enclosure
  - Seams in building products
  - Punched Openings

- Driving force
  - Pressure Moves from High to Low
  - What Creates Driving Forces?

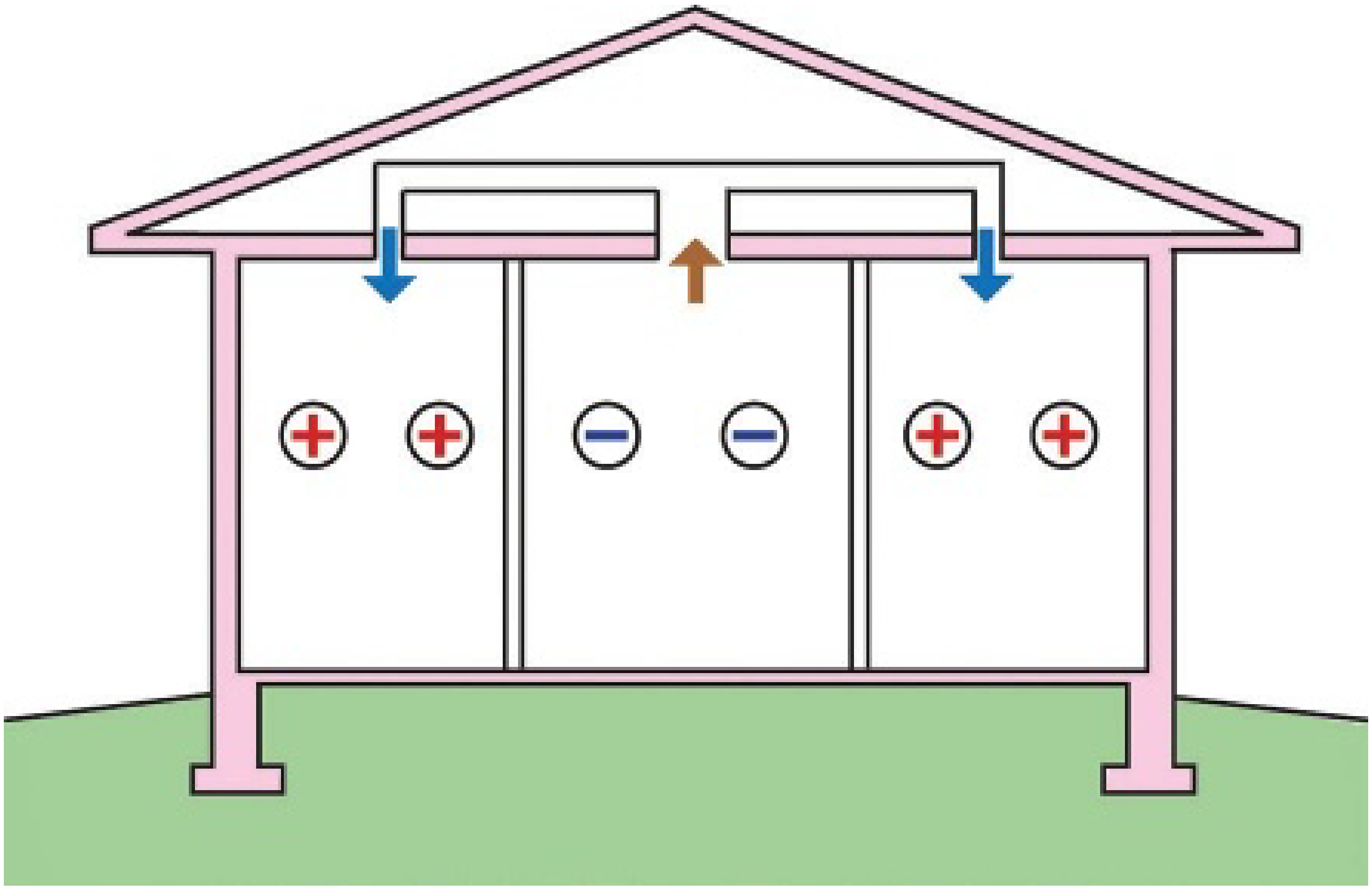


Stack Effect



David Keefe
Vermont Energy Investment Corp.

Driving Forces



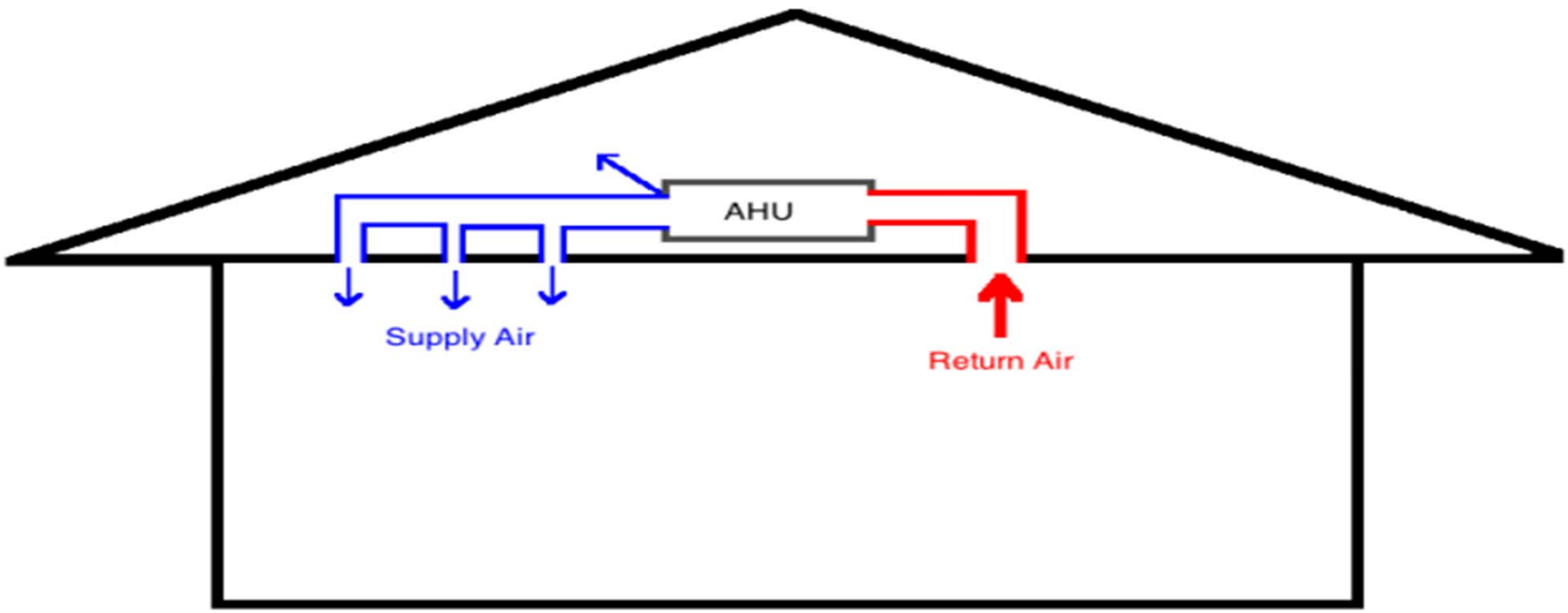
Source: www.buildingscience.com

Driving Forces - Mechanical

Observation 1: The unit with the air handler inside the bedroom had a pressure differential of -34.4 Pa with reference to the central living space. Transfer grills/jumper ducts are not installed between the bedroom and the central living space.

The House is a System

A Price So Nice, You'll Pay it Twice



Supply Duct Leakage

http://www.greenbuildingadvisor.com/blogs/dept/building-science/how-duct-leakage-steals-twice

Compartmentalization

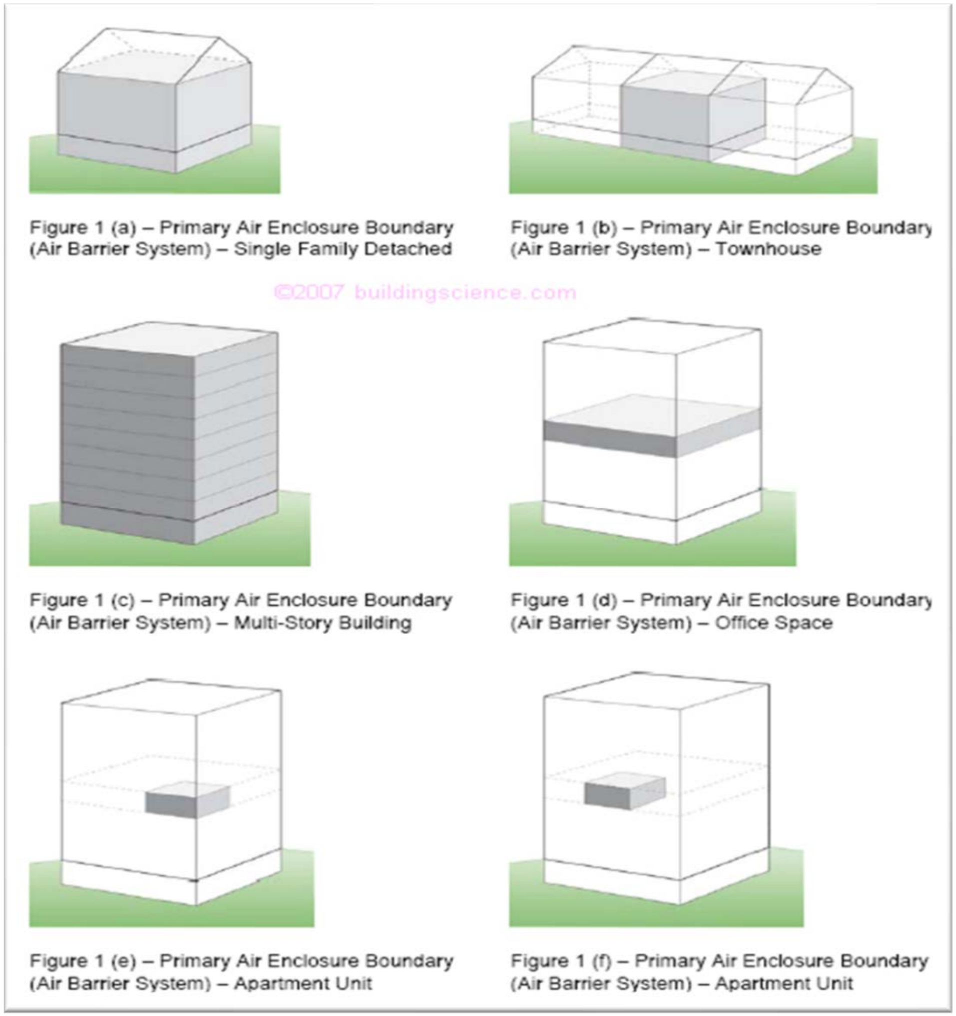


Figure 1 (a) – Primary Air Enclosure Boundary (Air Barrier System) – Single Family Detached

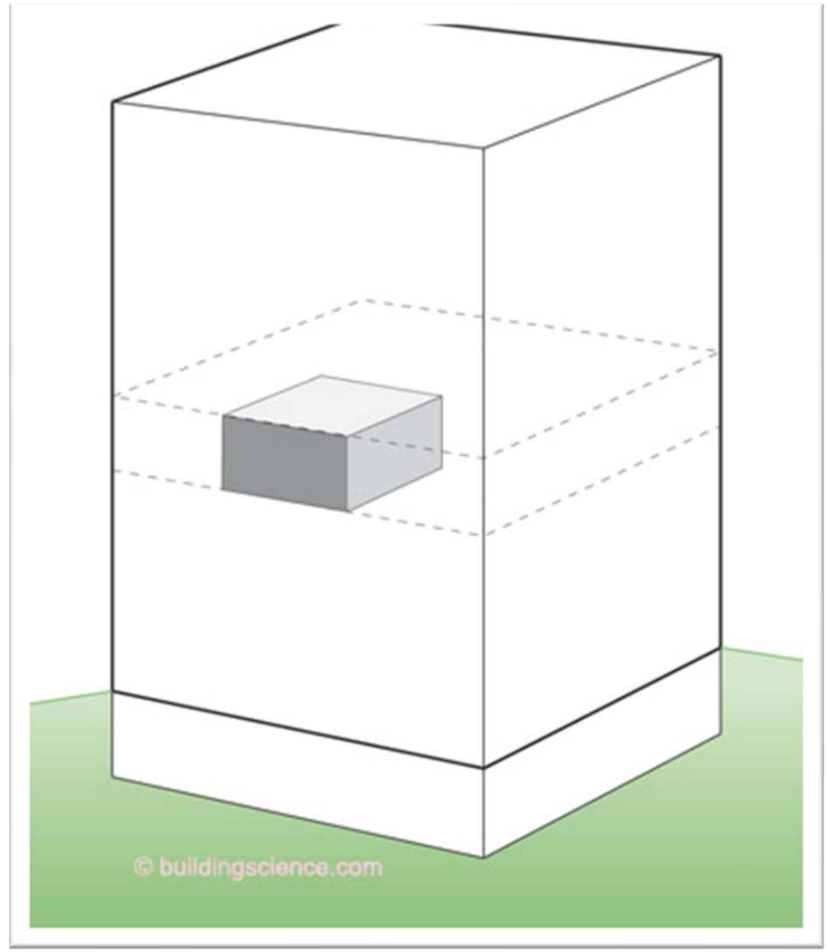
Figure 1 (b) – Primary Air Enclosure Boundary (Air Barrier System) – Townhouse

Figure 1 (c) – Primary Air Enclosure Boundary (Air Barrier System) – Multi-Story Building

Figure 1 (d) – Primary Air Enclosure Boundary (Air Barrier System) – Office Space

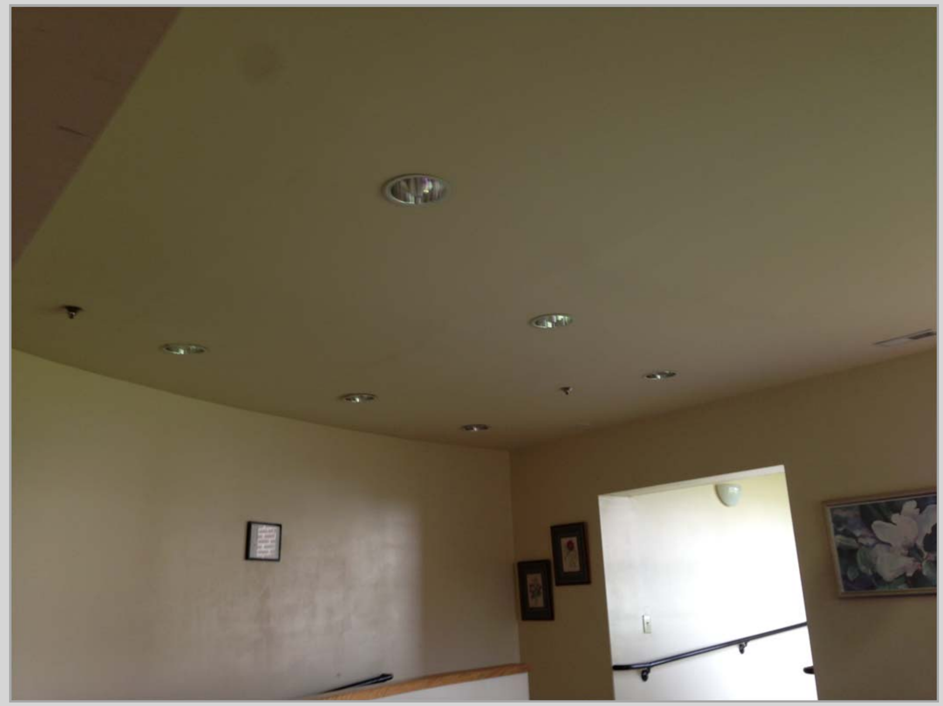
Figure 1 (e) – Primary Air Enclosure Boundary (Air Barrier System) – Apartment Unit

Figure 1 (f) – Primary Air Enclosure Boundary (Air Barrier System) – Apartment Unit



Source: www.buildingscience.com

Common Enclosure Opportunities



Common Enclosure Opportunities

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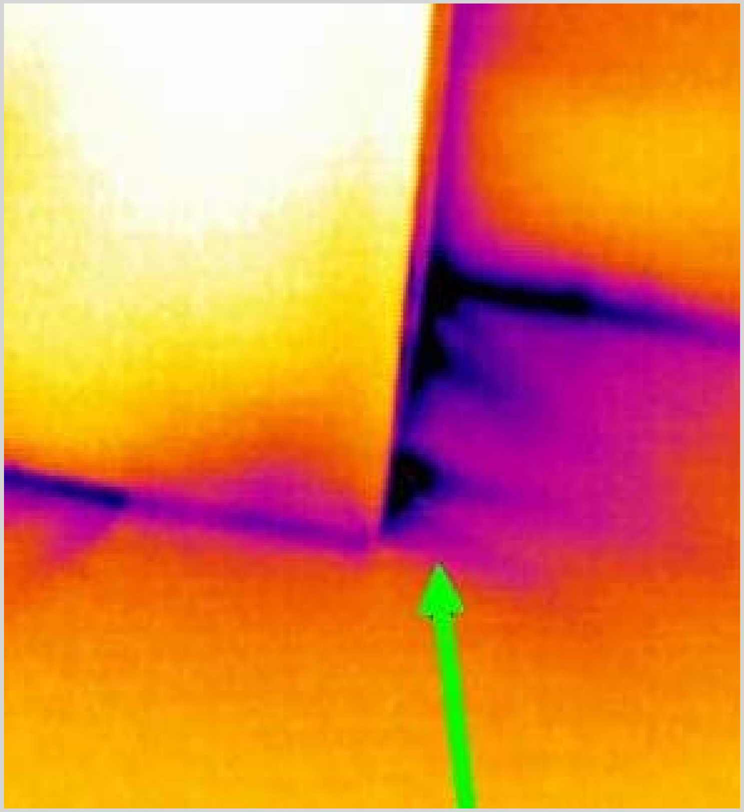


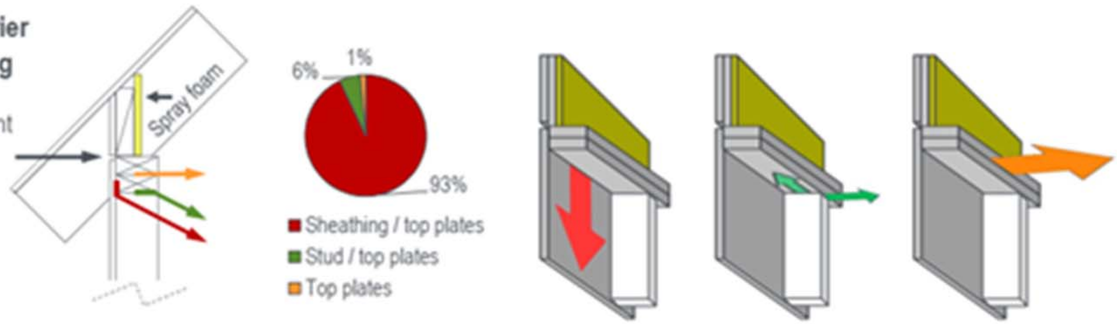
Common Enclosure Opportunities

Air Leakage Distribution

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Exterior air barrier
Cathedral ceiling

Sheathing / roof joint
1.1 cfm/ft @ 50 Pa



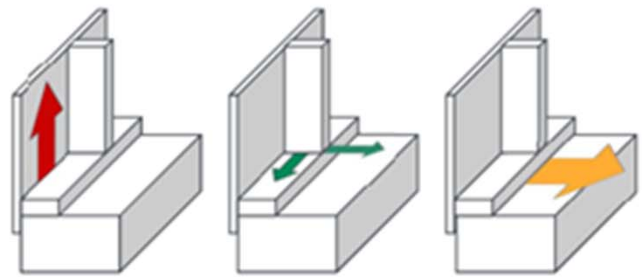
2-Story house (Floor area = 2,000 ft²)
Sheathing / roof joint unsealed ≅ 0.5 ACH_{50}

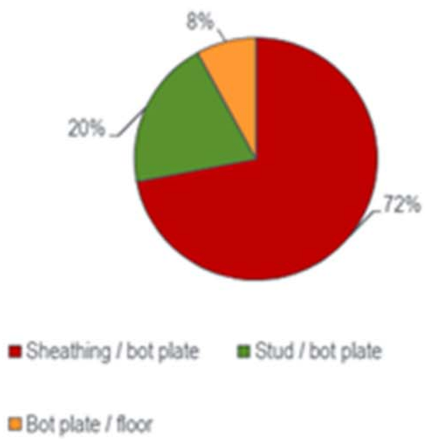
Zones	DOE Challenge Home		IECC 2012	
	Requirement	Contribution to requirement (%)	Requirement	Contribution to requirement (%)
1 – 2	3	17	5	10
3 – 4	2.5	20	3	17
5 – 7	2	25	3	17
8	1.5	33	3	17

Common Enclosure Opportunities

Air Leakage Distribution

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy





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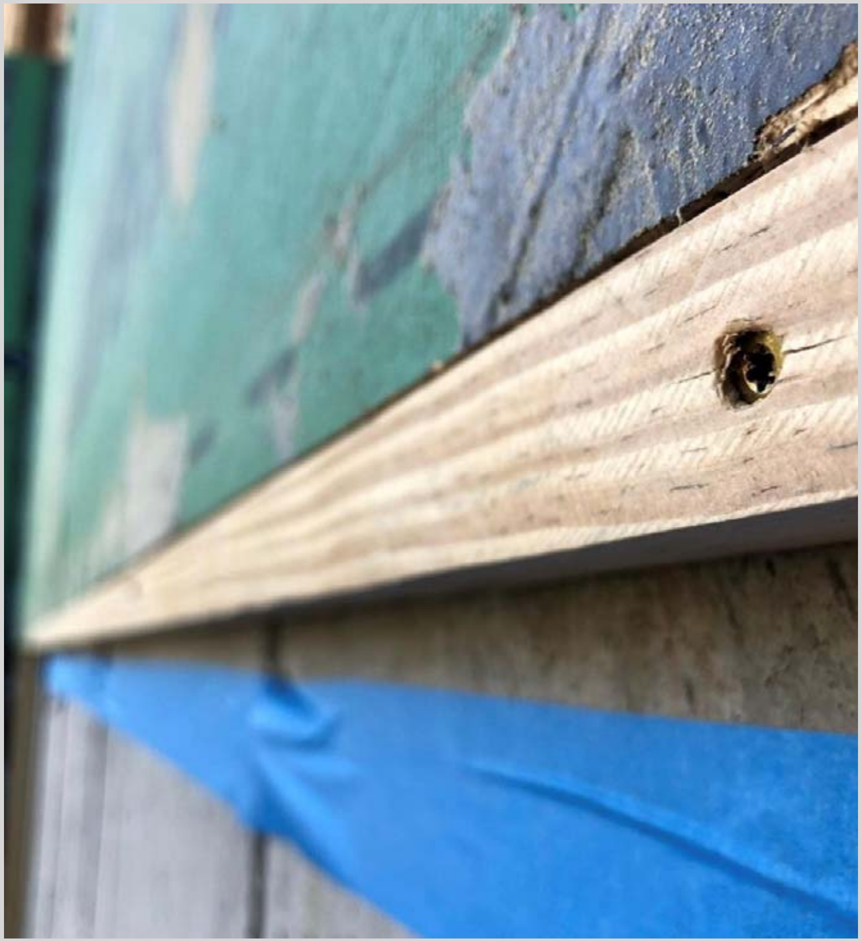

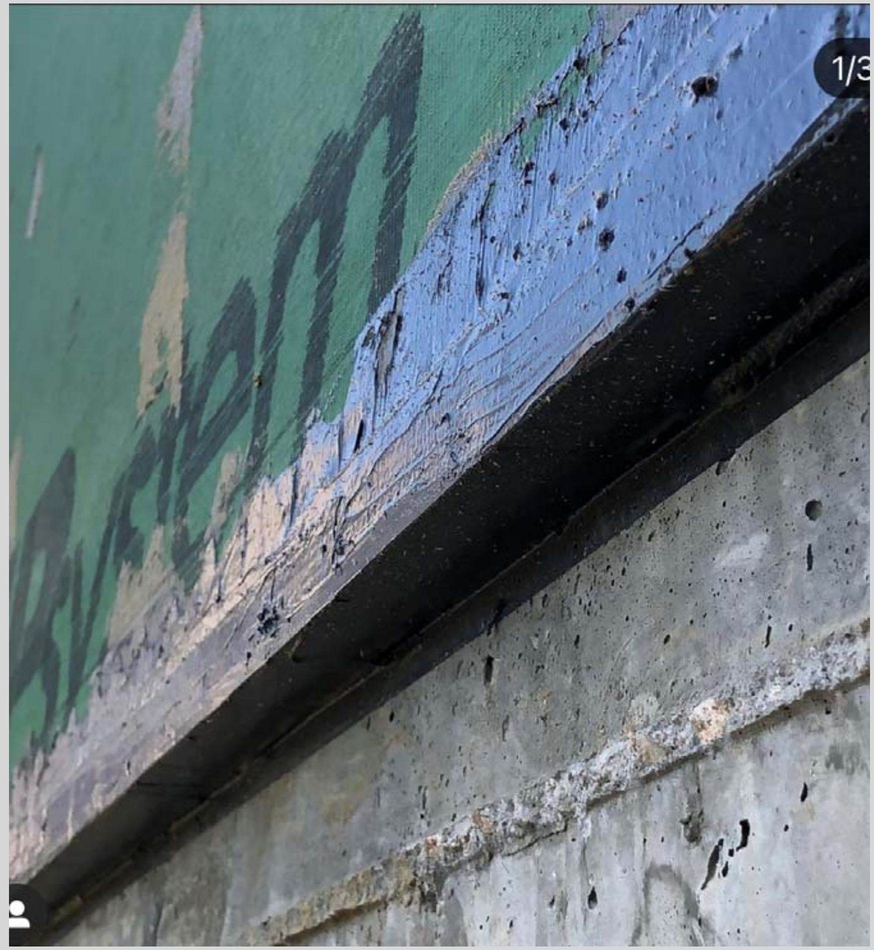

Good Air Sealing Details

Good Air Sealing Details

Source: Chris Conway, Conway Energy

Good Air Sealing Details

Good Air Sealing Details

Building Diagnostics – Testing the Envelope

- Blower Door: measures the amount of air that leaks through the building envelope

Research: Commercial Enclosure Testing

Impact of Envelope Airtightness on Sma… Perf…

Building		Test #	infiltration at -75 Pa (cfm)	ELR_{75} (cfm/ft^2)	ELR_{75} ($m^3/h \cdot m^2$)	Air Sealing Measures
Marshall	Dining	1	14,467	1.30	23.8	Initial test
		2	8,515	0.58	10.6	Spray foamed roofline
		3	6,192	0.42	7.7	Removed exterior fascia and sealed the eave from the outside on dining room side. Spray foamed wall on kitchen side and porch side.

ABSTRAC

Southface Energy Institute has leveraged its small commercial (<50,000 ft² (4,645 m²)) high performance building program, EarthCraft Light Commercial (ECLC), and its DOE-sponsored Advanced Commercial Building Initiative to assess uncontrolled envelope air leakage in 38 new and existing buildings. Building envelope leakage rates were measured using the US Army Corps of Engineers (USACE) multi-point test protocol for depressurization and pressurization of buildings to ±75 Pa (0.3 inH_2O) with masking of outdoor air, make-up air, and exhaust envelope penetrations. Average leakage rates were measured to be 0.25 cfm/ft^2 (4.6 $m^3/h \cdot m^2$) for ECLC buildings and 0.74 cfm/ft^2 (13.6 $m^3/h \cdot m^2$) for existing buildings in the Atlanta, Geogia metropolitan area. In addition to the USACE test, Southface performed envelope pressure tests with various configurations of outdoor air, make-up air, and exhaust penetrations masked and unmasked to determine damper presence and performance. Building pressures were measured while only air handling units (AHUs) were operating, AHUs + exhausts operating, and AHUs + exhausts + kitchen hoods all operating to determine most buildings do not operate under slightly positive pressure. Valuable lessons learned from conducting these multi-blower door envelope pressure tests are presented to assist streamlining testing procedures. Buildings that received retrofit air sealing measures were tested before and after completion of these upgrades and show significant reductions in infiltration can be achieved. The largest source of air leakage pathways was found to be in complex roof assemblies. Lastly, the impact of envelope tightness on heating and cooling energy consumption was analyzed with Open Studio energy models of three buildings using measured infiltration data. Results show savings varied from building to building, but the modeling methodology using BLAST infiltration coefficients resulted in the greatest savings while applying DOE-2 coefficients resulted in the least savings.

Table 2. Summary of 6-side ELR_{75} Before and After Air Sealing Retrofits

…rom the wall on … ngle and … re roof … vents). purpose.

Window a/c units were removed. Gymnasium windows and 1 large window in foyer were replaced.

Table 4. Summary of Heating and Cooling Energy Consumption from Energy Models

		6-side ELR_{75}	Infiltration @ -4 Pa (cfm)	Constant kWh	Constant % savings	DOE-2 kWh	DOE-2 % savings	BLAST kWh	BLAST % savings
school	baseline	0.89	12,357	126,466	17.8%	99,924	9.1%	136,760	20.1%
	post-sealing	0.58	6,832	103,908		90,838		109,248	
worship	baseline	0.62	4,019	64,814	7.0%	58,607	3.2%	72,284	10.3%
	post-sealing	0.46	2,856	60,271		56,707		64,812	
fire station	baseline	1.44	3,989	36,067	18.1%	31,143	8.4%	40,059	25.5%
	post-sealing	0.42	1,027	29,537		28,520		29,856	

Southface

Advanced Commercial Building Initiative

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Moisture Control Layers and Management

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Why is Moisture Important?

Moisture damage contributes to over **90%** of all building, and building material failures (ASHRAE)

Except for structural errors, moisture is the leading cause of building problems costing more than **9 billion** dollars annually in the US. (ASTM)

EPA Building Assessment Survey and Evaluation (BASE) study:

- indoor air quality of 100 randomly selected public and private office buildings in the 10 U.S. climatic regions.
- Study found that **85%** of the buildings had been damaged by water at some time and <u>45% had leaks at the time the data were collected</u>

Moisture Flow in Buildings

Moisture flows in two forms: liquid & vapor

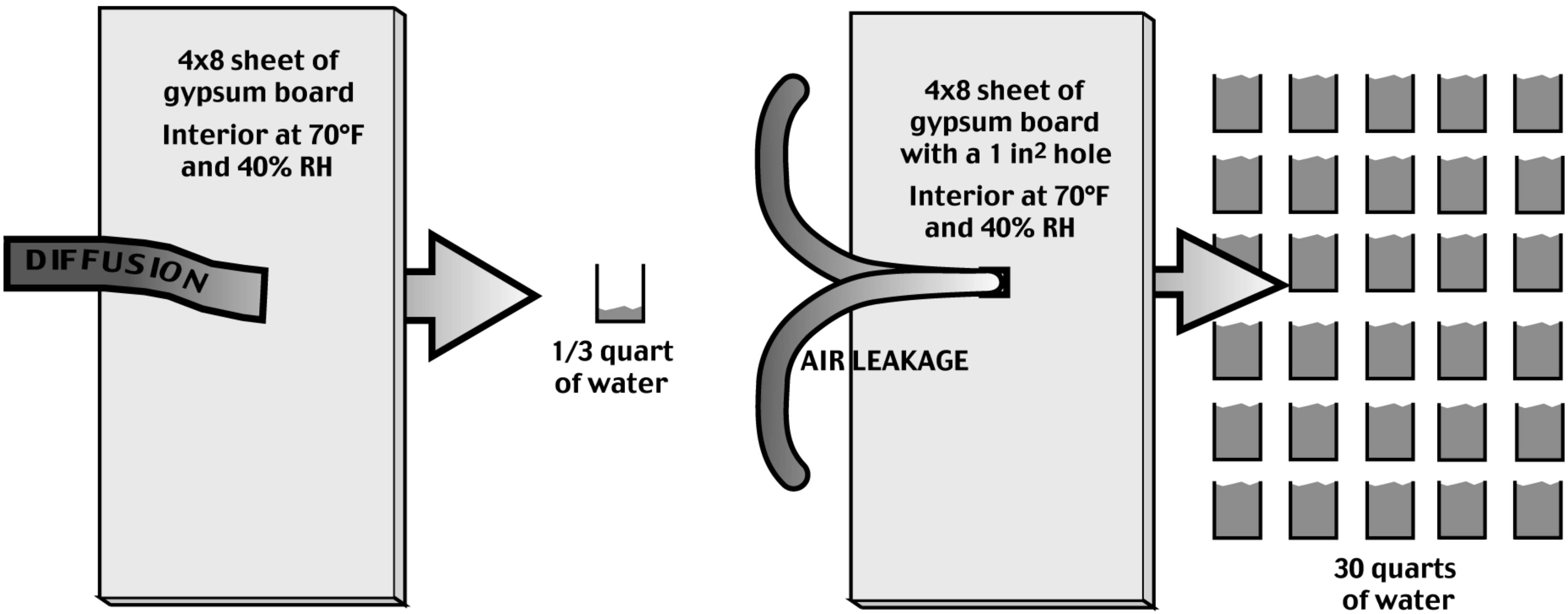
Moisture flows from wet to dry

- **Bulk**
  Liquid water (rain, drainage, plumbing leaks)
- **Capillary**
  Wicking through porous materials (concrete, fiberglass & cellulose insulation, wood)
- **Diffusion**
  Molecules of water moving through porous materials
- **Infiltration**
  Moisture laden air brought into or out of the house

Moisture Flow in Buildings – Exercise

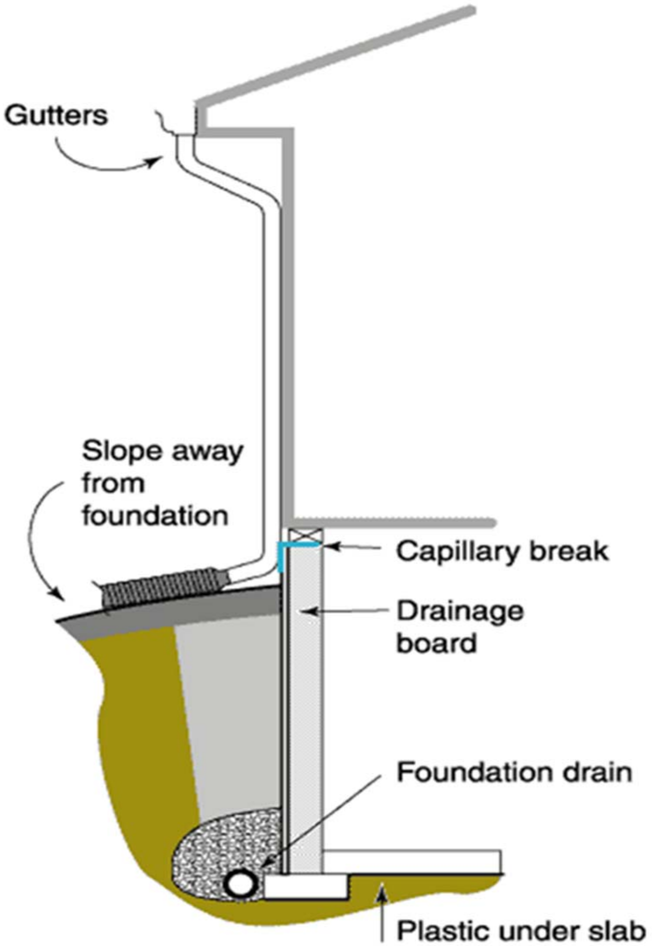
Source: www.greenbuildingadvisor.com

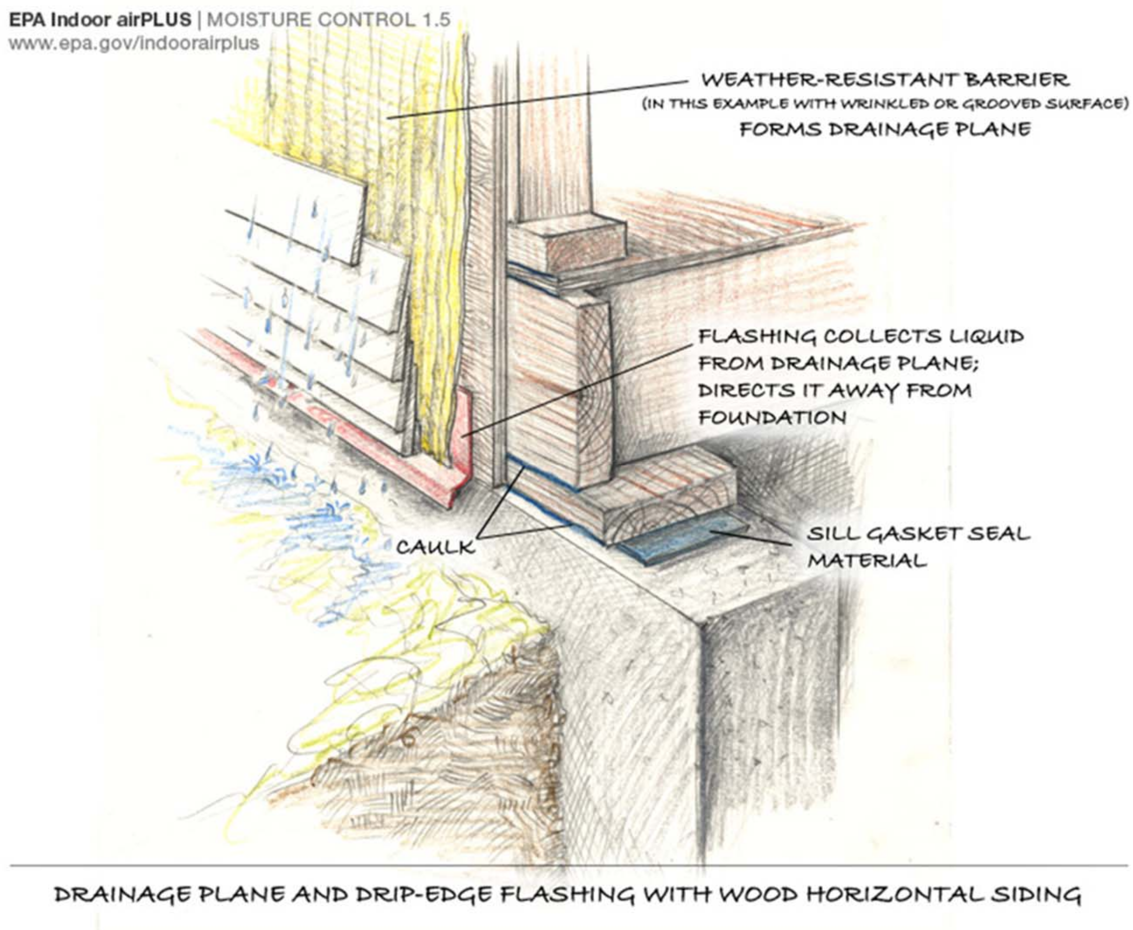
Vapor Diffusion vs. Air Leakage



Source: www.buildingscience.com

Foundations and Exterior Moisture Management





Source: www.epa.gov/indoorairplus

Behind Cladding - Exterior Moisture Management

Behind Cladding - Exterior Moisture Management

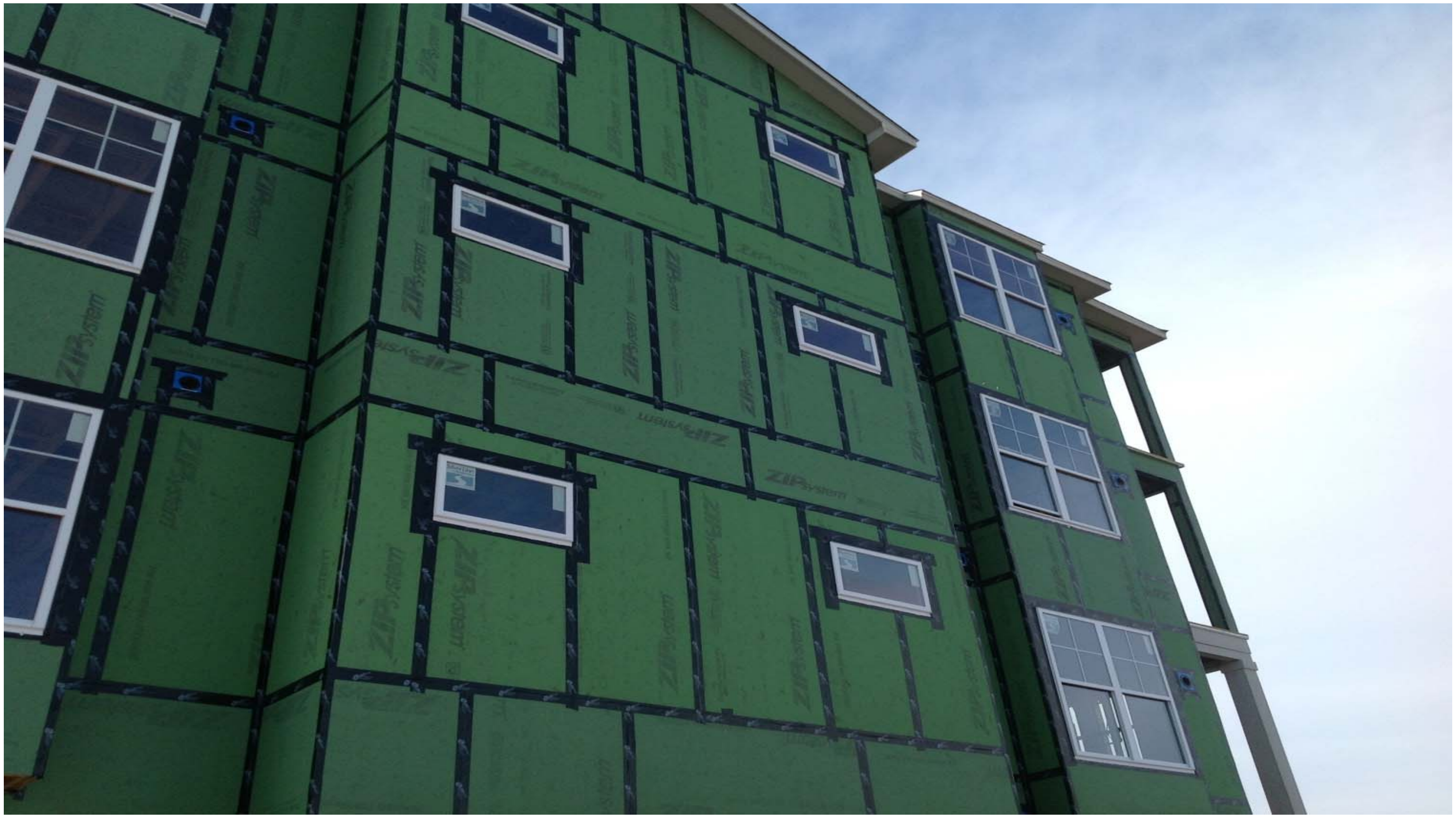
Control Layers – Water Management

- Wall Air Barrier and Water Control Layers
  - House Wrap (WRB)

Flashing Integrated with Drainage Plane

Control Layers – Water Management

- Wall Air Barrier and Water Control Layers
  - Continuous Insulation and Integrated Sheathing Products



Better Get Your Flashing Details Right

- Kick-out flashing on roofs sloped along adjoining walls missed OFTEN, required by code

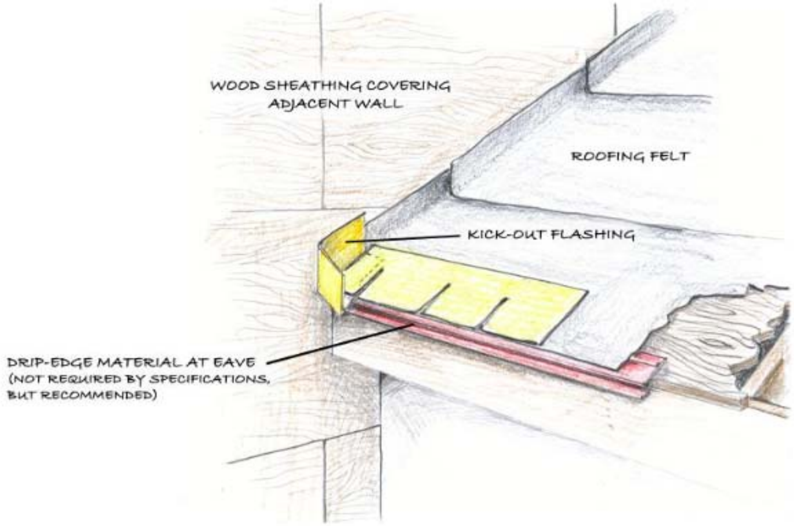
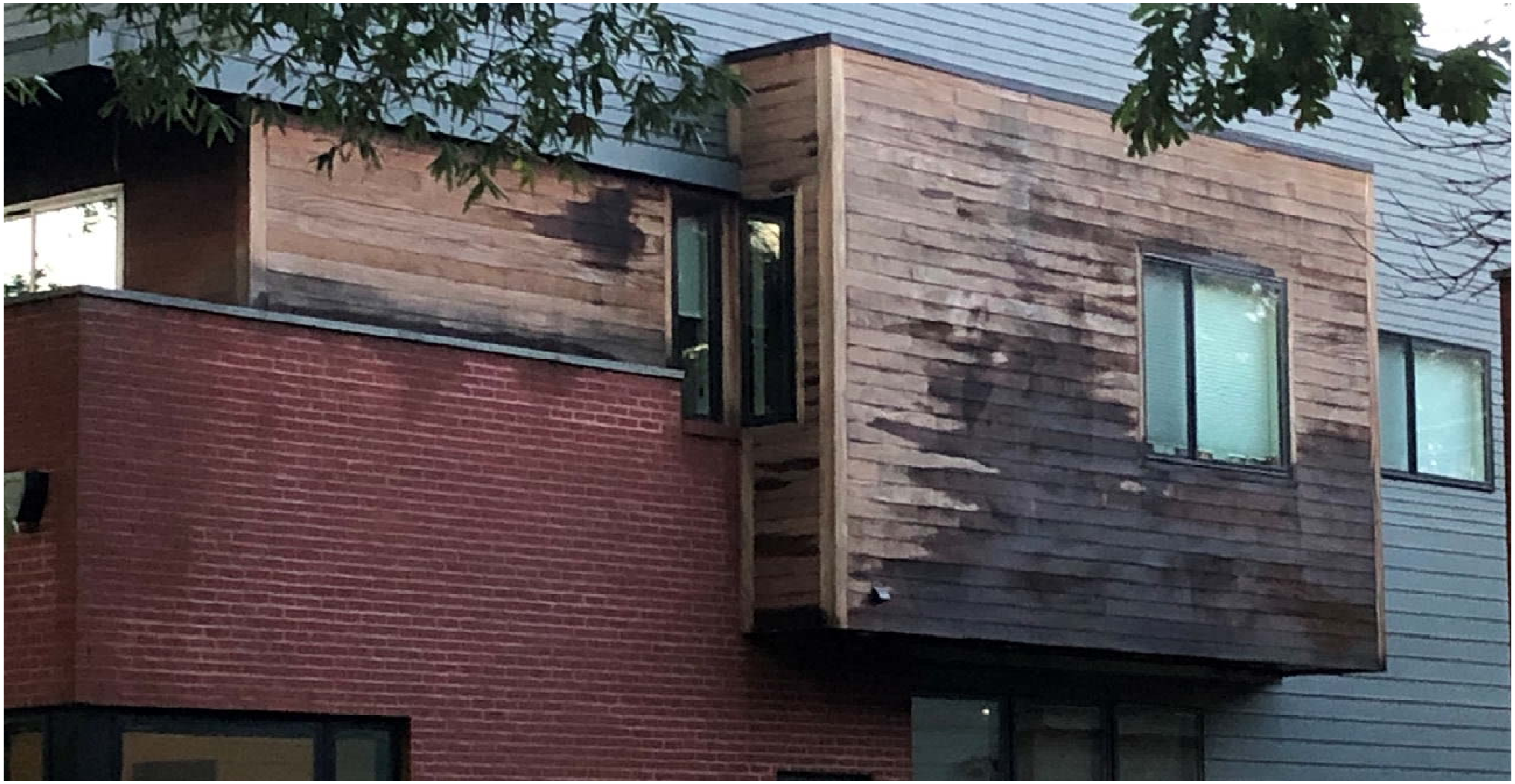


Figure 16: Step 1: Kick-out flashing beginning run of step flashing
(Graphic courtesy of US EPA Indoor airPLUS)

Large Overhangs

Complicated Geometry



Active Moisture Control During Construction

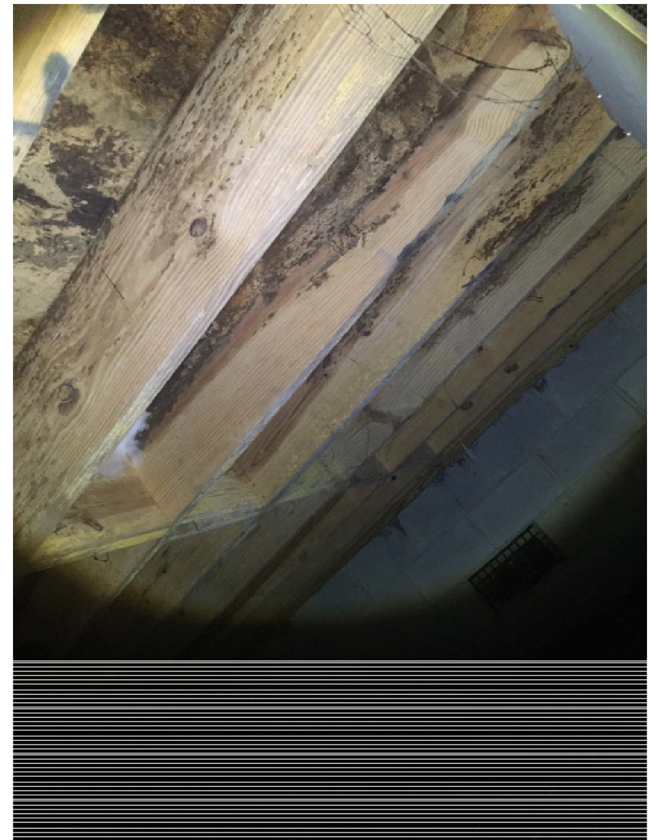
Source: https://www.jlconline.com/how-to/framing/drying-wet-framing_o

During Construction

- Controlling Construction Schedule and Practices
  - Allow Proper Time for Drying of Construction Materials; Prevent Water Intrusion to Extent Possible

http://www.gypsumsubfloors.com/

Existing Homes

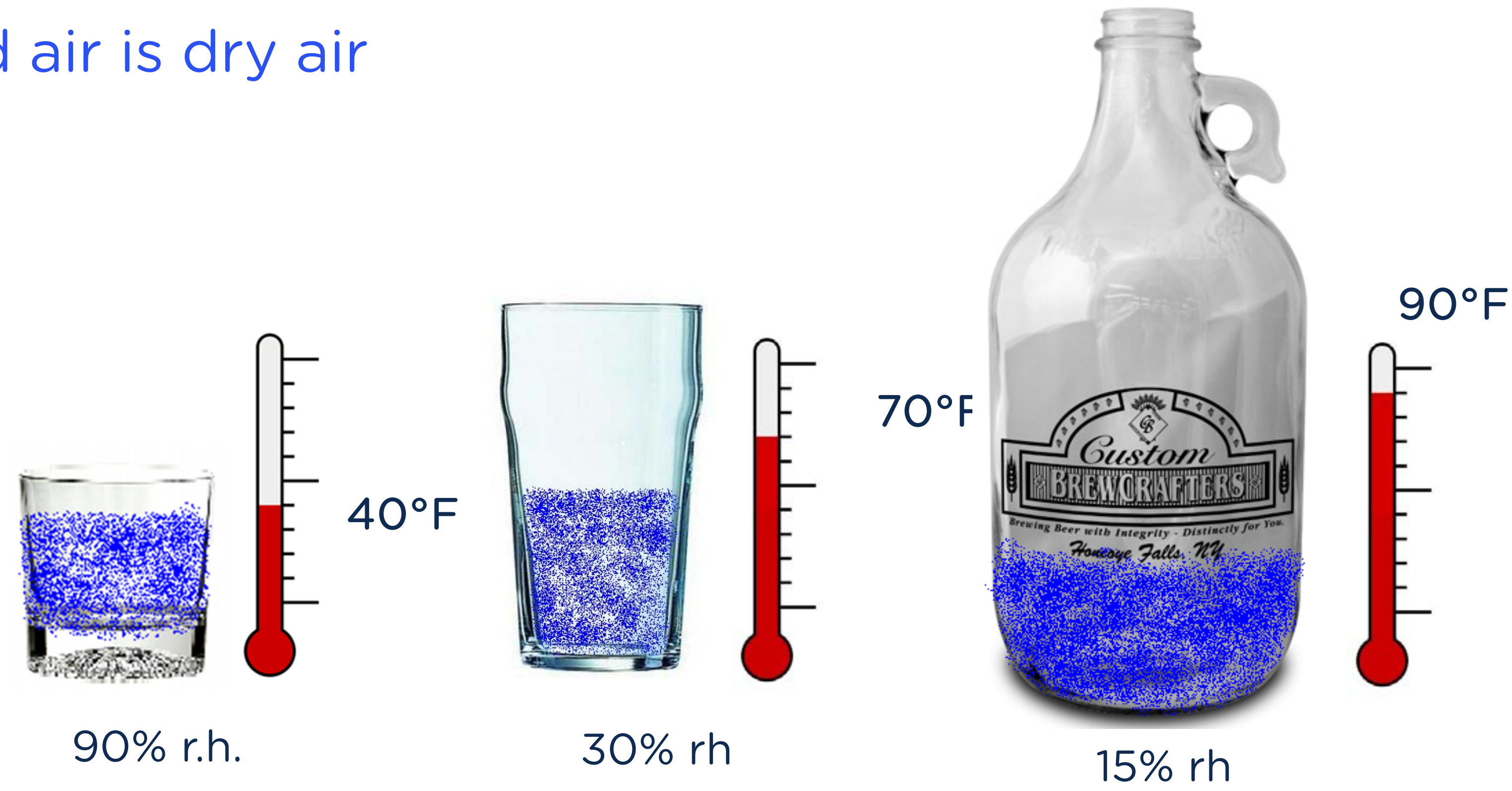


Existing Homes

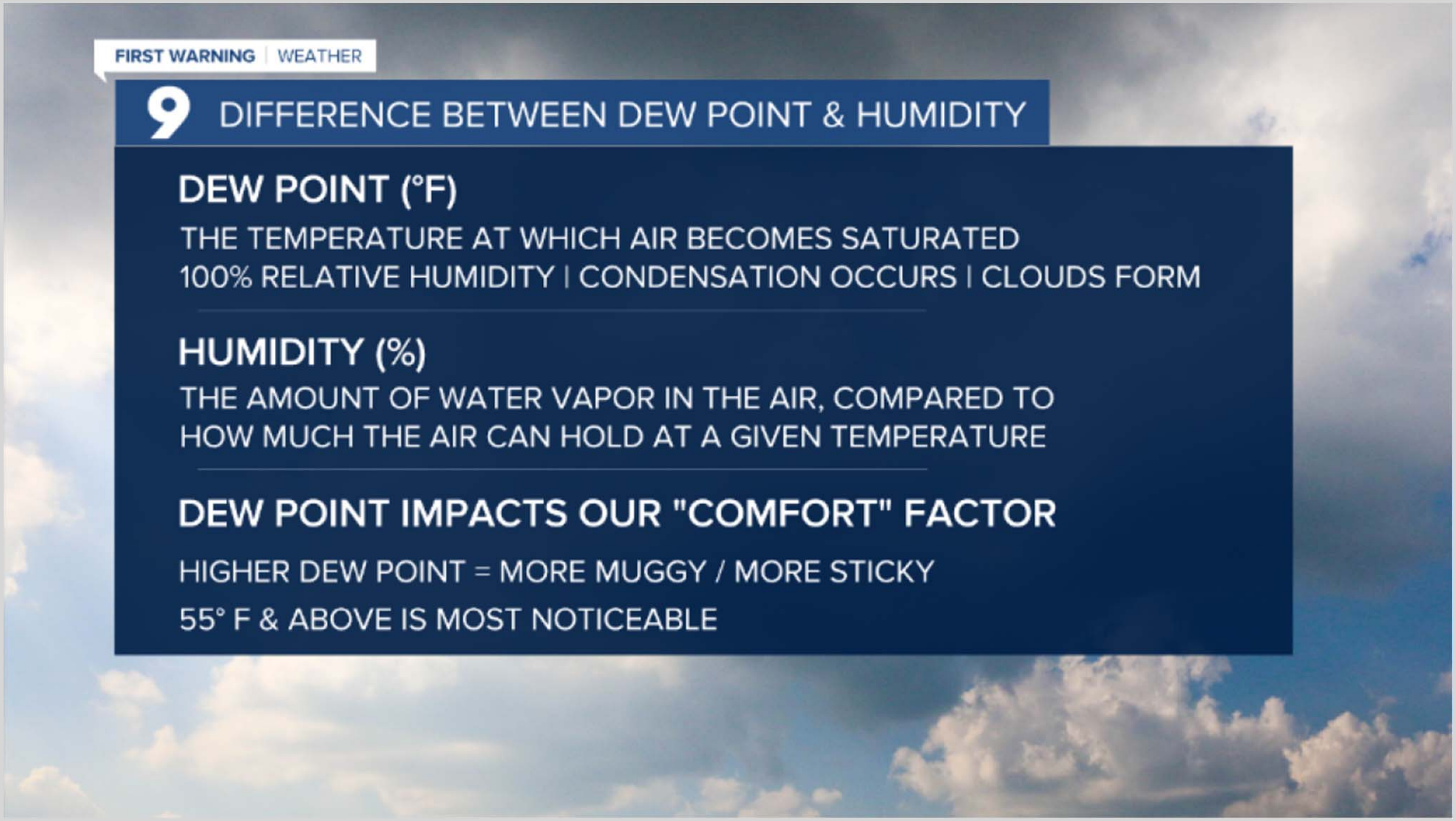
Temperature & Relative Humidity

Each glass contains 30 “grains” of water vapor

Cold air is dry air



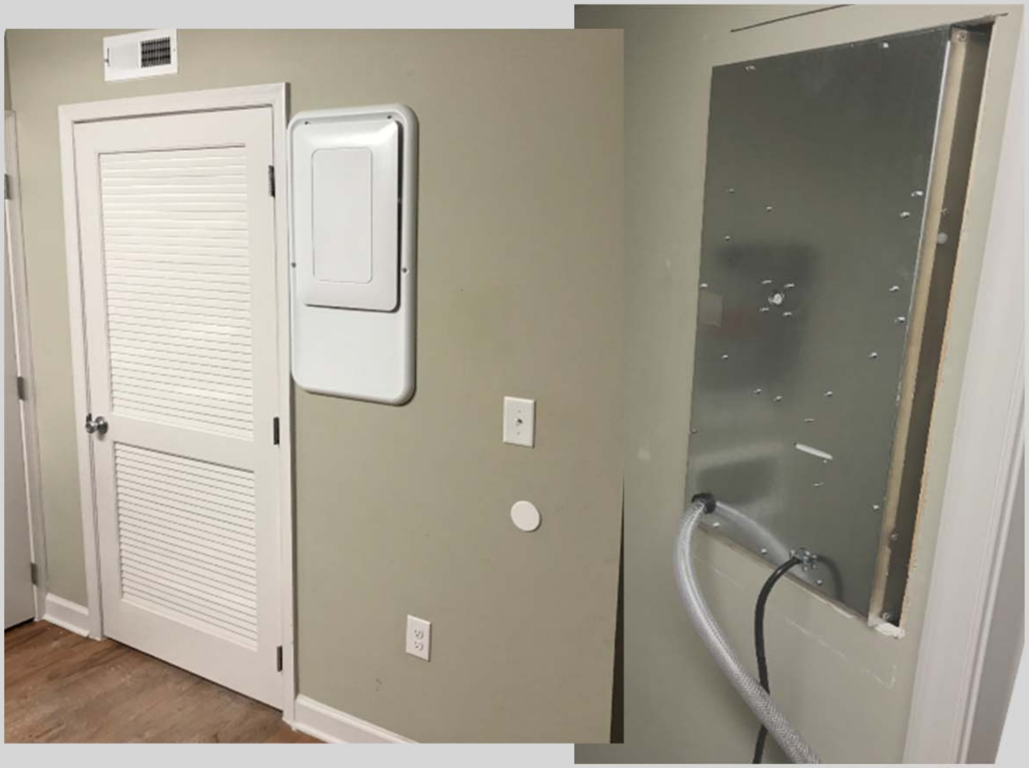
Interior Moisture



Source: https://www.kgun9.com/weather/the-difference-between-dew-point-and-humidity

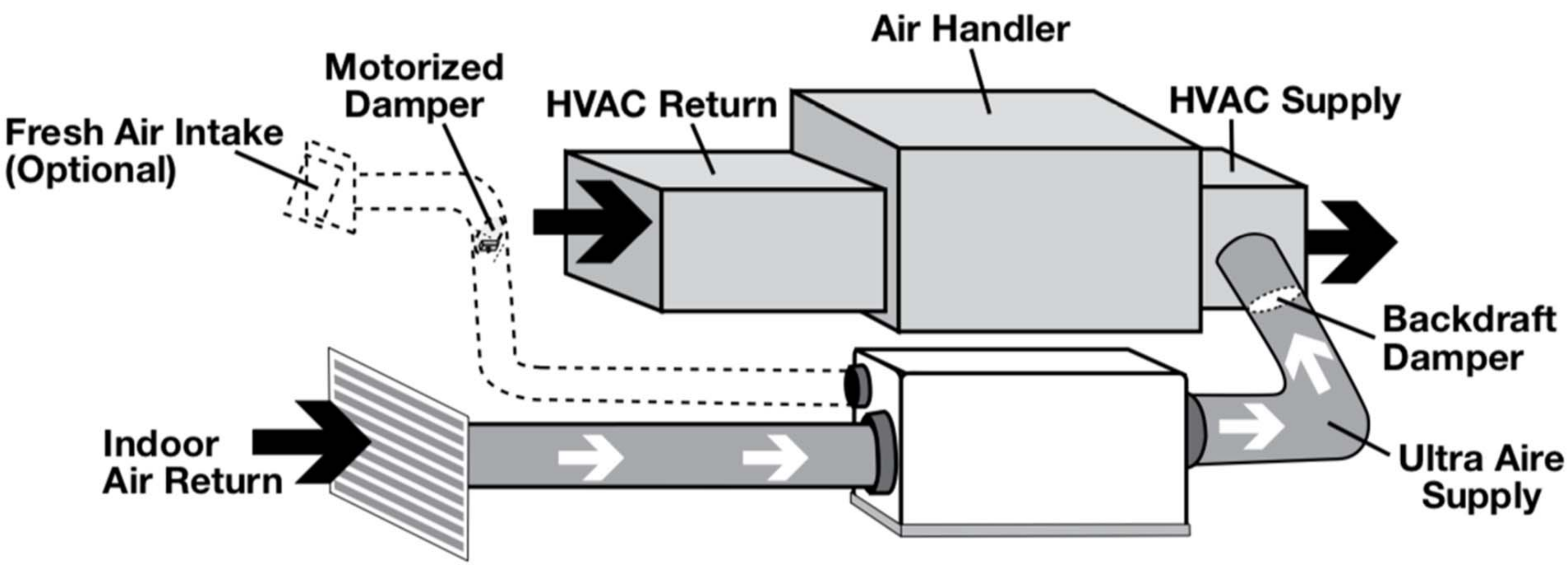
Interior Moisture

- Change from Humidification → Dehumidification



Integrated Dehumidification

Dedicated Ultra Aire Return to HVAC Supply



Building Science & Health

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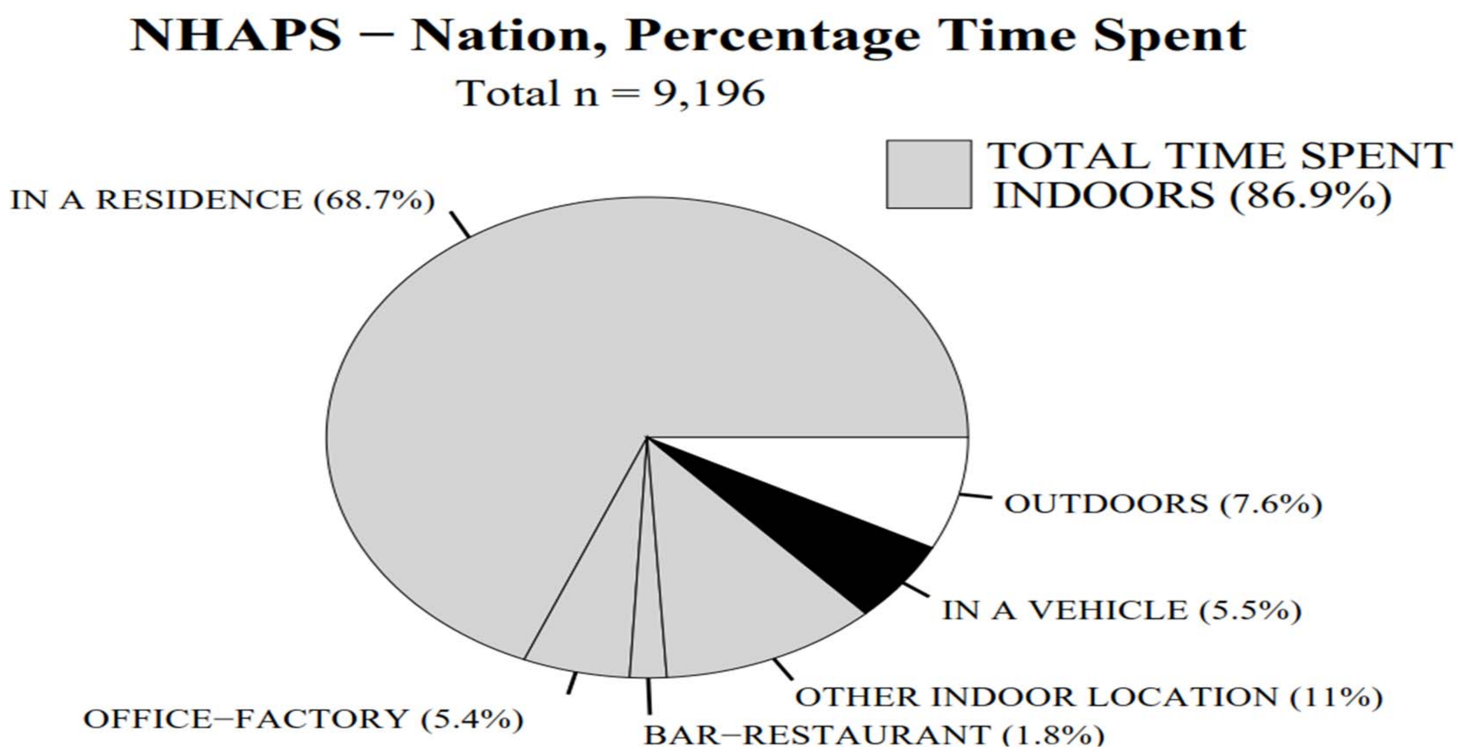
The Importance of IEQ

Air within buildings can be more seriously polluted than outdoor air, even in industrialized cities

The Importance of IEQ

On average, Americans spend more than 68% of their time in residences, 87% of their time indoors



Source: The National Human Activity Pattern Survey (NHAPS); Kleipsis Et. Al., LBNL

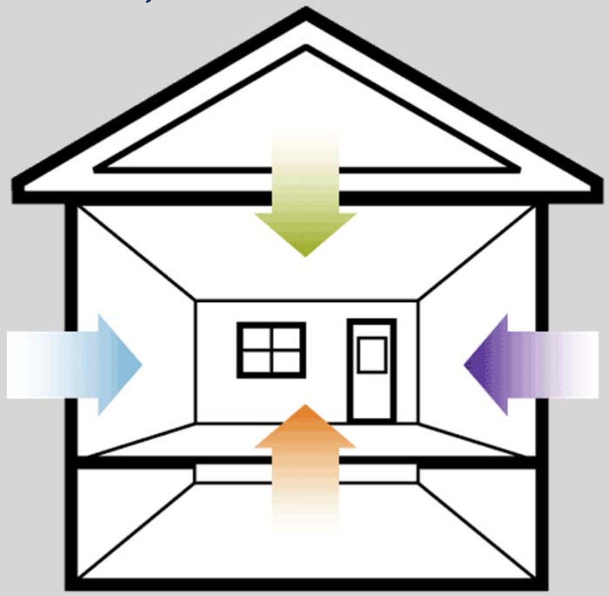
The Importance of Indoor Environmental Quality

The old and the young are the most susceptible to the effects of poor IAQ, spend more time indoors

Sources of Air

ATTIC

Insulation fibers, dust, coal soot, rodent scat



OUTSIDE

Pollen, auto fumes, dust

GARAGE

Carbon monoxide, pesticides, gasoline, fertilizers

CRAWLSPACE

Mold, dust, lead, radon, moisture, termiticide

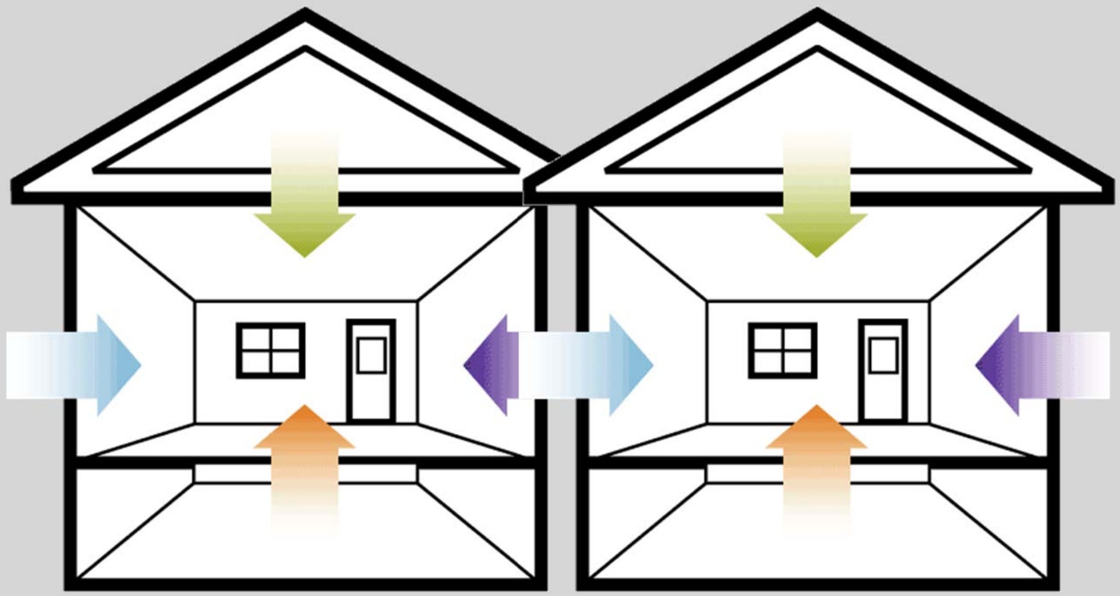
Sources of Air

ATTIC

Insulation fibers, dust, coal soot, rodent scat

OUTSIDE

Pollen, auto fumes, dust



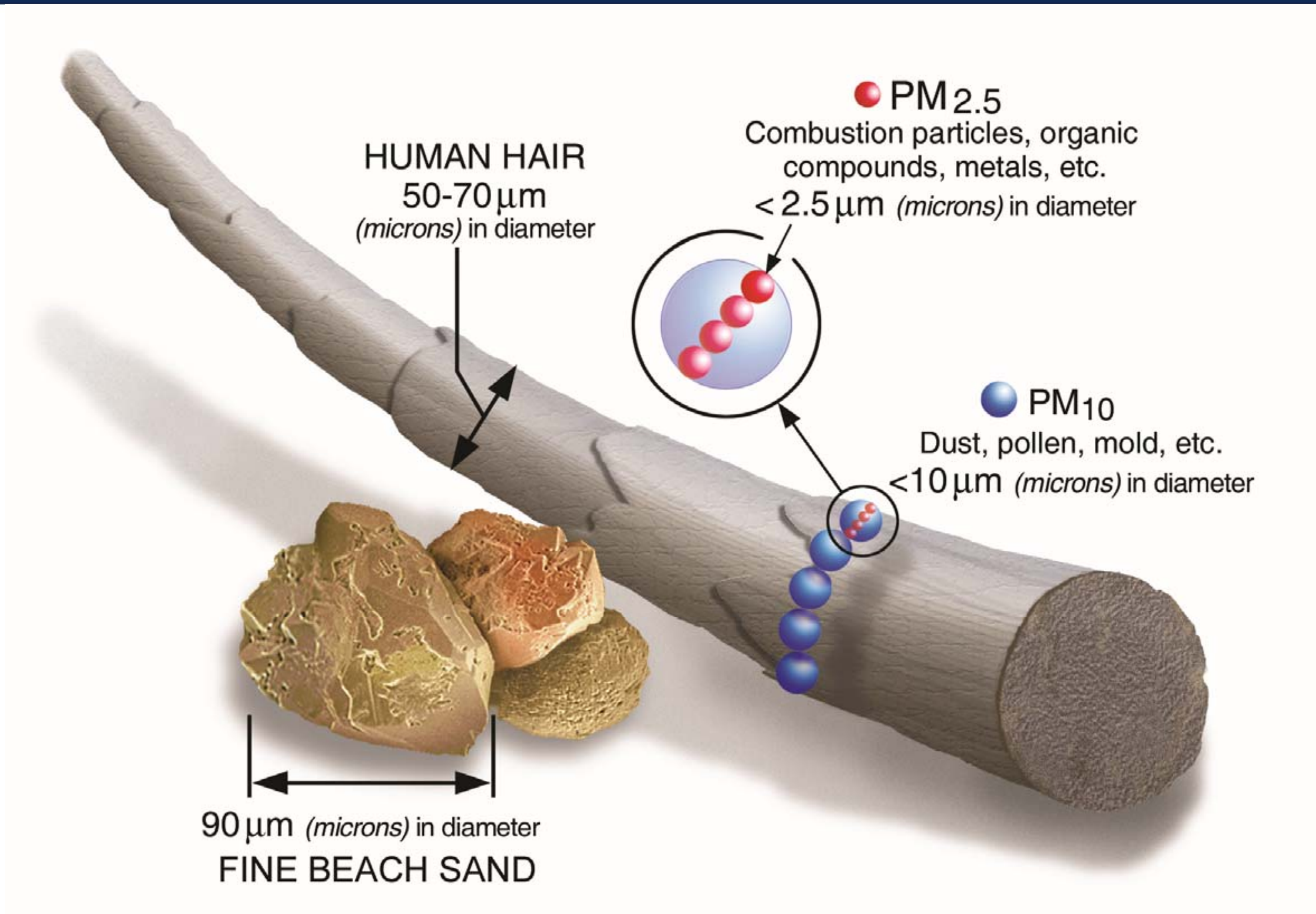
ALSO

Adjacent Units in MF

CRAWLSPACE

Mold, dust, lead, radon, moisture, termiticide

PM 10 and PM 2.5



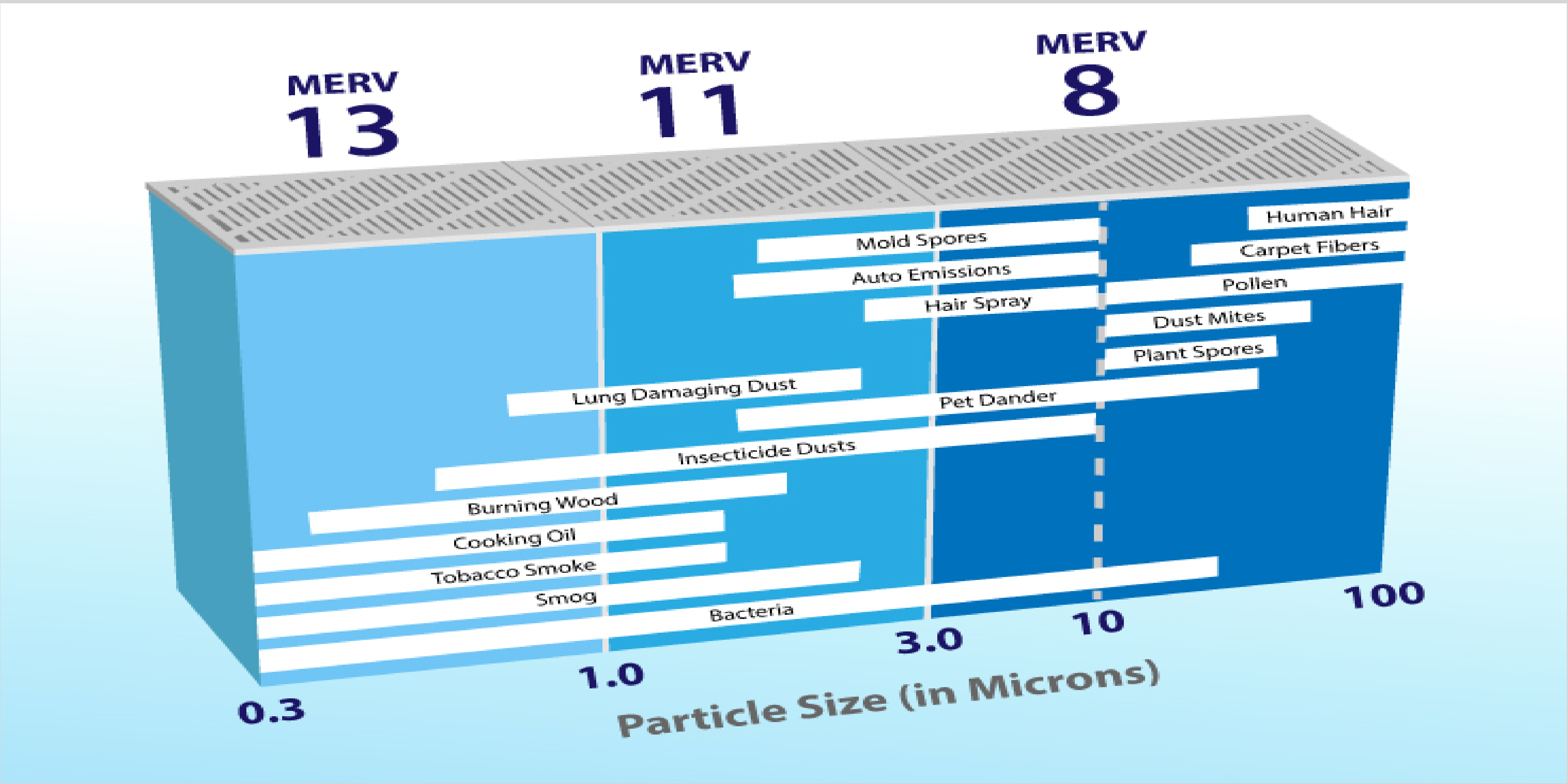
https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#effects

Fine Particle Sources

- Tobacco, cannabis, & fireplace smoke
- Candle soot and soot from standing pilot lights on gas fireplaces/appliances not burning cleanly
- Blown insulation and Carpet fiber pyrolysis on hot heat exchange surfaces such as electric resistance baseboard heaters and resistance heating elements in heat pumps;
- Aerosolized clay, concrete cutting particulates and gypsum sanding from construction are all sources of PM in homes

Lstiburek, J. 2019 'Up In Smoke' *ASHRAE Journal Vol. 61 No. 11* pg. 72-75

Filtration



Source: filterfast.com

Residential Filtration

- In general, lower airflow will lead to higher efficiency for very small particles (more time to diffuse through filter fibers) and lower efficiency for larger particles

- Fan motors in residential systems:
  - permanent split capacitor (PSC) motor fans are the conventional choice and they are usually sensitive to filter pressure drop
  - electrically commutated motor (ECM) fans often have speed control and increase the fan speed if there is increased pressure drop (i.e., from a filter).

To really understand how a filter is going to perform you need to know a lot about the system and the fan, not just about the filter.

Siegel, J. 2019 'Residential Filtration' *ASHRAE Journal Vol. 61 No. 11* pg. 76-78

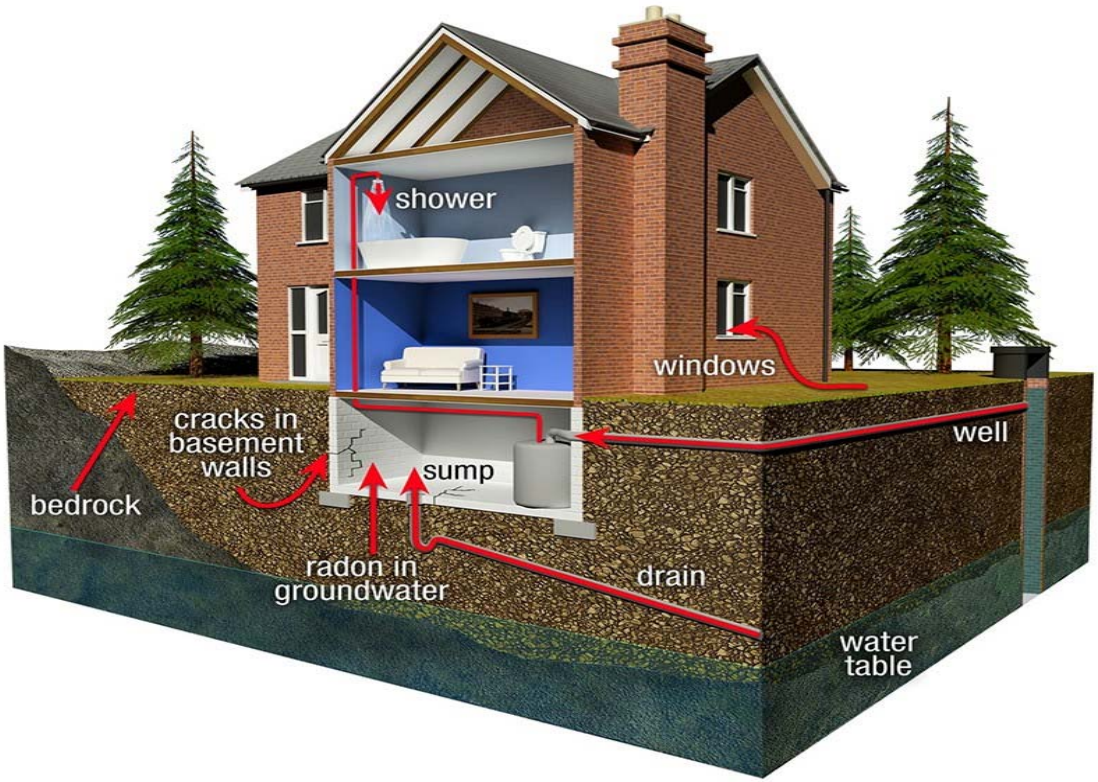
Actual Filter Condition

Actual Filter Condition

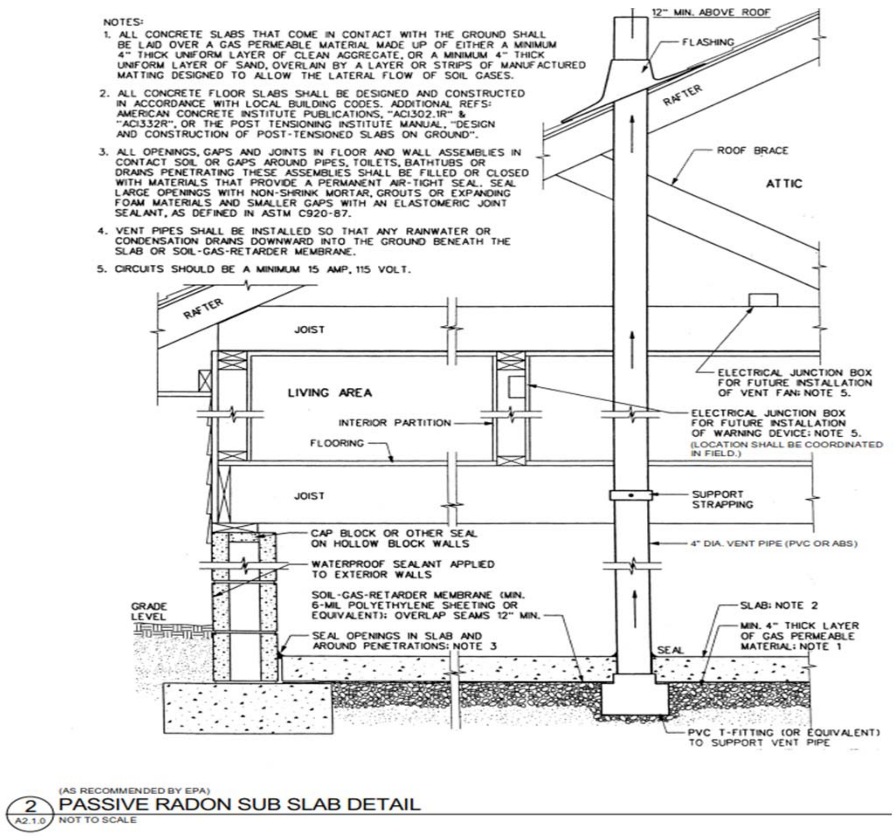
Actual Filter Condition

Addressing Indoor Pollutants

- Good IEQ Begins at the Design Phase
  - Source Control



Steven Hall Art & Illustration



Wienceck & Associates

Combustion Appliances

- Good IEQ Begins at the Design Phase
  - Equipment Selection and Sizing

How Do We Address IAQ

- Good IAQ Begins at the Design Phase
  - Source Control

How Do We Address IAQ

- Good IAQ Begins at the Design Phase
  - Source Control

IEQ During Construction

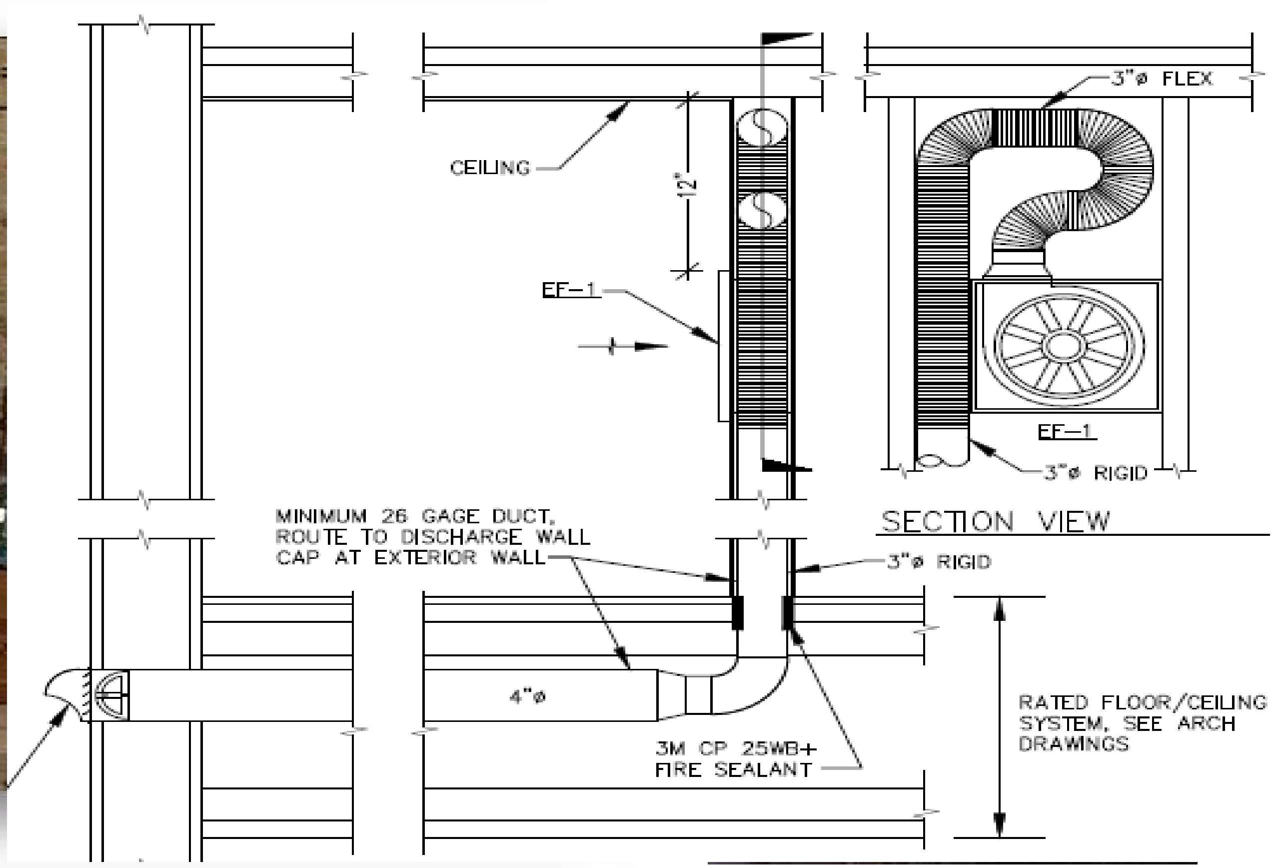
- Controlling Construction Schedule and Practices
  - Prevent Water Intrusion to Extent Possible

IEQ During Construction

- Controlling Construction Schedule and Practices
  - Allow Proper Time for Drying of Construction Materials; Prevent Water Intrusion to Extent Possible

How Do We Address IEQ

- Good IEQ begins at design



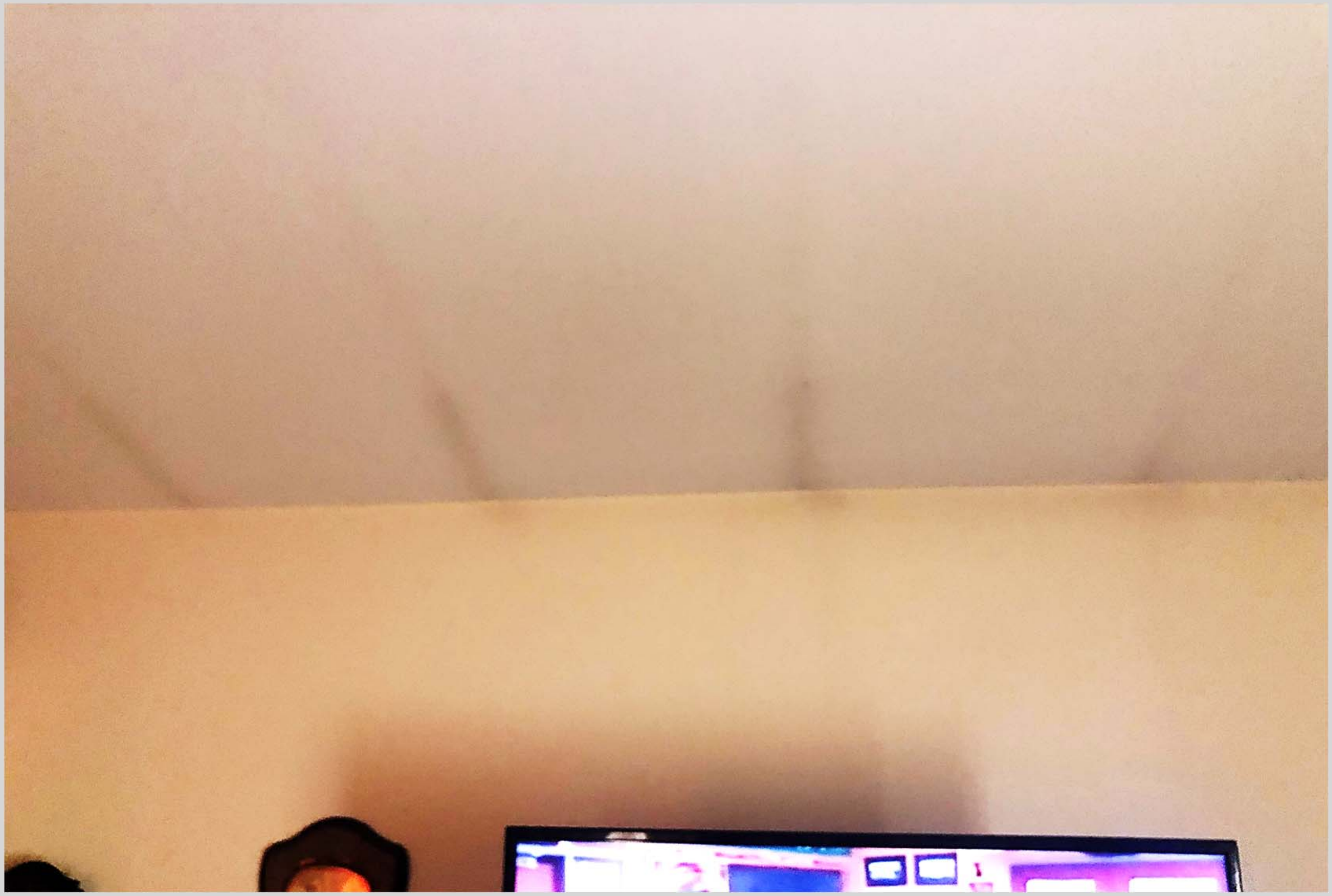
IEQ During Construction

- Controlling Construction Schedule & Practices
  - Protect HVAC During Construction

Combustion Appliances

Source: Southface Energy Institute

IEQ Complaints



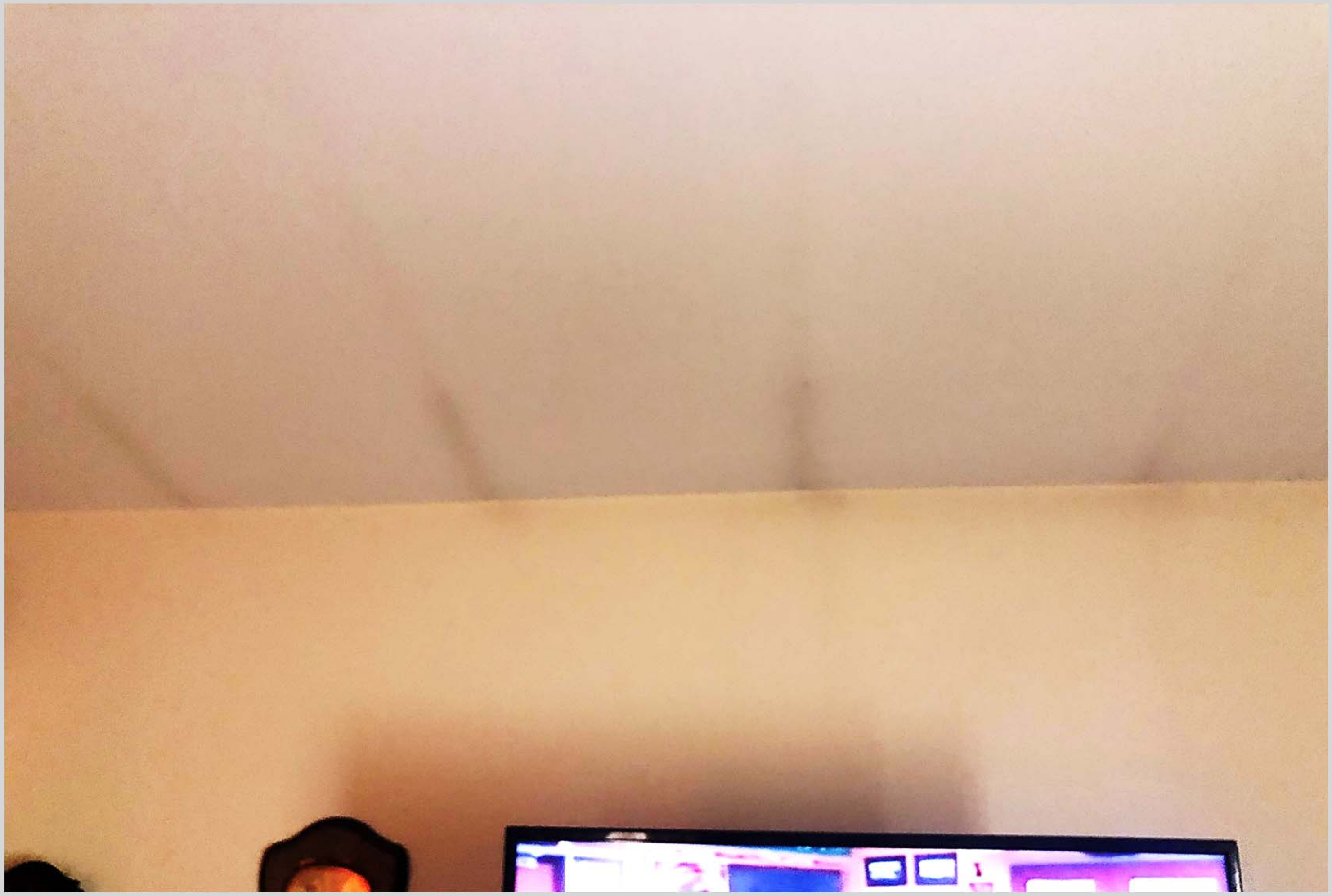
IEQ Complaints

IEQ Complaints

Standing Pilot Lights and Candles

Lstiburek, J. 2019 'Up In Smoke' *ASHRAE Journal Vol. 61 No. 11* pg. 72-75

IEQ Complaints



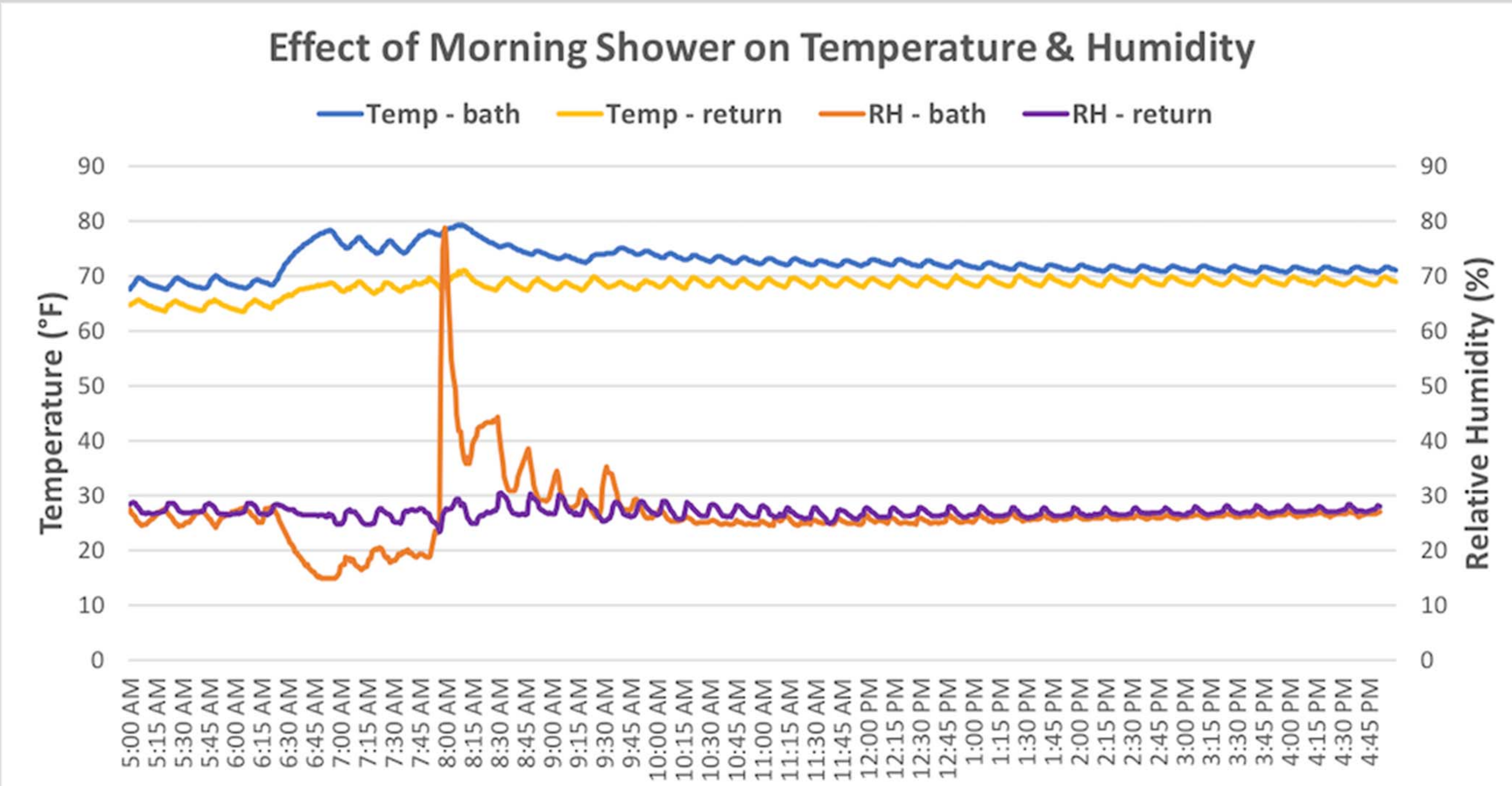
IEQ Complaints

Pollutant Superhighway

- Prevent Things Like These

Point Source Ventilation

Bath Fan Usage



https://www.energyvanguard.com/blog/do-you-really-need-run-bath-fan-winter

Flow Testing

Flow Testing

Maintenance

Kurt Vonnegut
@Kurt_Vonnegut

Another flaw in the human character is that everybody wants to build and nobody wants to do maintenance.

Capture Efficiency Study - LBL

- This study demonstrated that airflows of installed devices are often below advertised values and that **less than half of the pollutants emitted by gas cooking burners are removed under many operational conditions**
- Achieving capture efficiencies that approach or exceed **75% requires operation at settings that produce prohibitive noise levels.**
- Using **back burners improves performance**
- Results suggest the need for improvements in hood designs to achieve high pollutant capture efficiencies at acceptable noise levels.

Singer, et. al. ‘Performance of Installed Cooking Exhaust Devices’ 2011 Lawrence Berkeley National Laboratory

Capture Efficiency Study - LBL

- 200 cubic feet per minute (CFM) was necessary, but often not sufficient, to attain capture efficiency in excess of 75% for the front burners.

Singer, et. al. 'Performance of Installed Cooking Exhaust Devices' 2011 Lawrence Berkeley National Laboratory

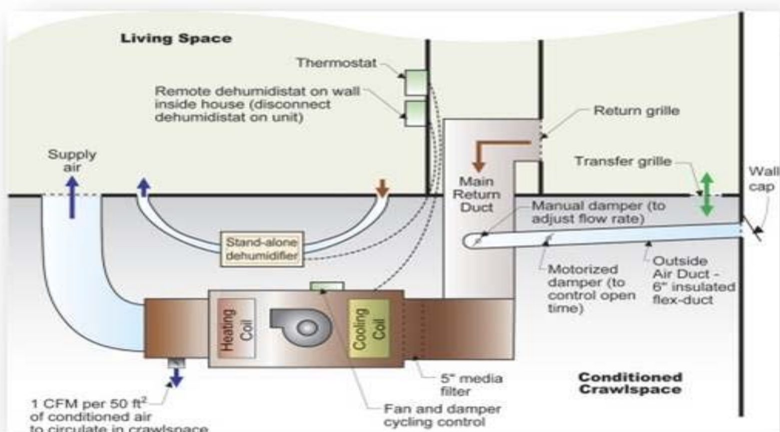
Fresh Air Ventilation Requirement

EarthCraft Requires Fresh Air Ventilation on All Projects

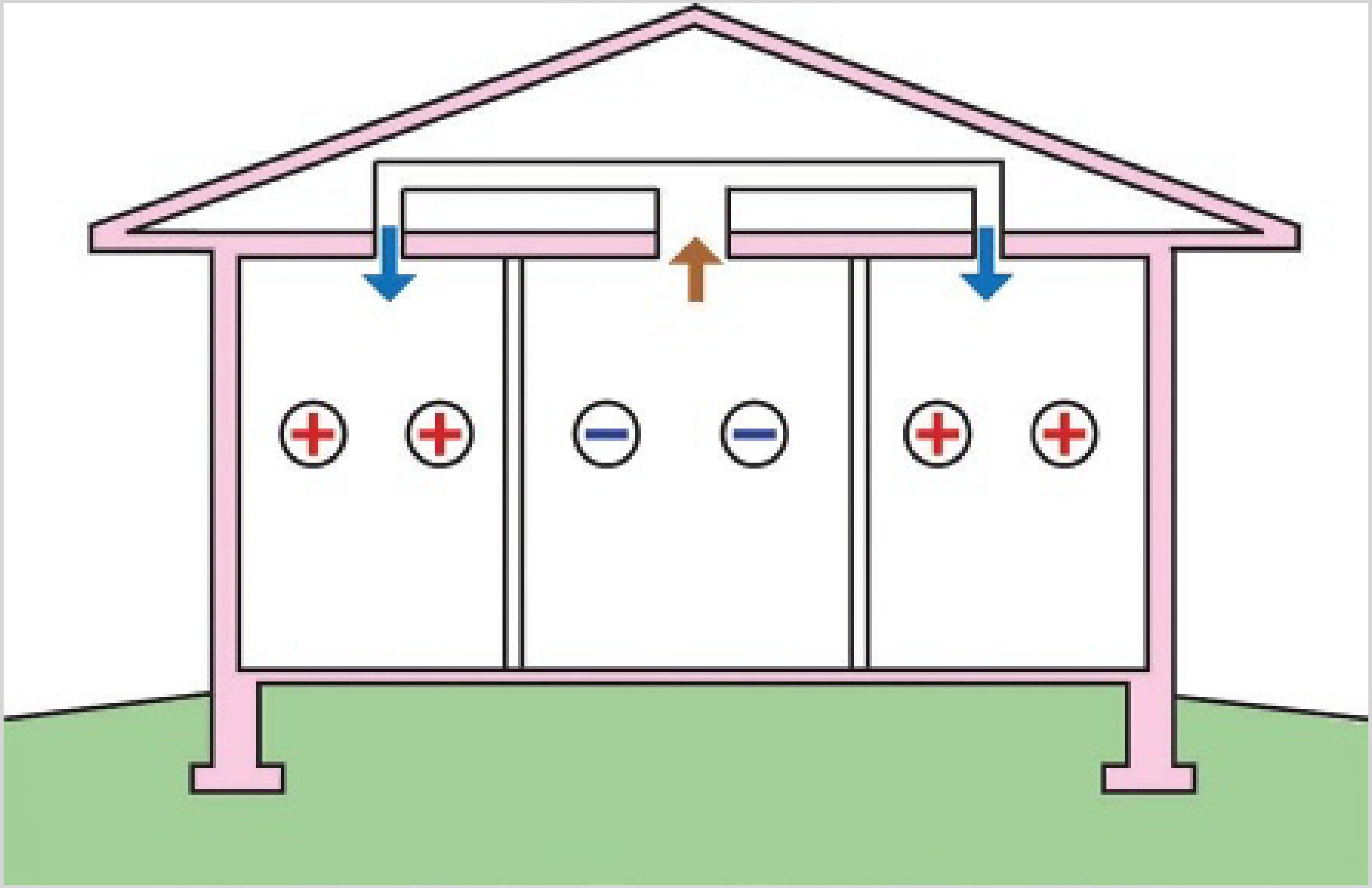
- ASHRAE 62.2 – 2010, 2013 for Flow Rate
- Intakes Must Be Ducted to Exterior of Building
- Intakes Must Be At Least 10’ Away from Exhaust Outlets, Vehicle Idling Zones, and May Not be Pulled From Roof
- Intakes Must Be 2’ Above Grade
- All Ventilation Ductwork Must be Insulated and Sealed with Mastic or Mastic Tape

Fresh Air Ventilation

- Design for positive pressure or balanced
- Don’t suck on buildings in our climate zone (negative pressure/exhaust systems)
- Tenant vs. owner paid in Multifamily



Return Pathways



Lstiburek, J. 2019 'Up In Smoke' *ASHRAE Journal Vol. 61 No. 11* pg. 72-75

Return Pathway

Lstiburek, J. 2019 ‘Up In Smoke’ *ASHRAE Journal Vol. 61 No. 11* pg. 72-75

Diagnostic Testing + 2018 Energy Code

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Main Changes

- Energy Certificate
- R-49 attics
- Buried ducts
- Lighting
- Blower door testing
- Manual J design criteria

2018 New Item – Energy Certificate

- insulation values
- window values
- equipment efficiencies and types
- duct testing results
- blower door results

Building Envelope Specs

Ceiling: R-24
Above Grade Walls: R-16
Foundation Walls: N/A
Exposed Floor: R-19
Slab: null
Infiltration: 850 CFM50 (4.69 ACH50)
Duct Insulation: R-6
Duct Lkg to Outdoors: 51.24 CFM25 (5 / 100 s.f.)

Window & Door Specs

U-Value: 0.29, SHGC: 0.24
Door: R-5

Mechanical Equipment Specs

Heating: Air Source Heat Pump • Electric • 9 HSPF
Cooling: Air Source Heat Pump • Electric • 16 SEER
Hot Water: Water Heater • Electric • 0.95 Energy Factor

2018 Thermal Envelope - Attic

R402.1.2 Insulation and Fenestration Criteria

The *building thermal envelope* shall meet the requirements of Table R402.1.2, based on the *climate zone* specified in Chapter 3.

TABLE R402.1.2

INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION U-FACTOR[b]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[i]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c] WALL R VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.32	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	15 or 13+1[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20+5[h] or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20+5[h] or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

NR = Not Required.

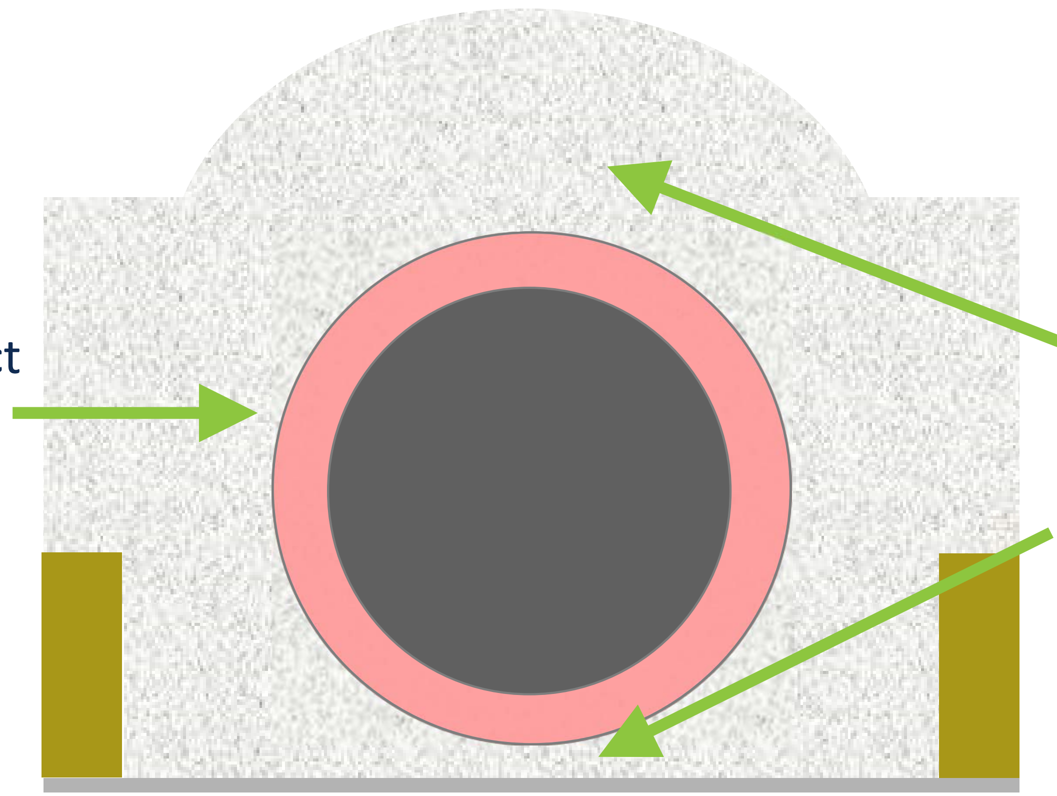
Complete Coverage is Essential

Estimated R-values for Insulation Compressed into Framing Cavities

Nominal Lumber Size	Cavity Depth											
I Joist	14"	49										
I Joist	11 7/8"	44	38									
2x12	11 1/4"	42	37	30								
I Joist	9 1/2"		33	29								
2x10	9 1/4"		32	29	30	25						
2x8	7 1/4"			25	25	24						
2x6 *(metal)*	6"					21			19			
2x6	5 1/2"						21	20	18			
2x4 *(metal)*	4"						16	16	14			
2x4 *(metal)*	3 5/8"						15	15				
2x4	3 1/2"						15	14		15	13	11
2x3	2 1/2"									11	10	8.9
2x2 *(metal)*	1 5/8"											6.5
2x2	1 1/2"											6.1
Label R-Value		R-49	R-38	R-30		R-25	R-21	R-20	R-19	R-15	R-13	R-11
Label Thickness		14"	12"	10"	9 1/2"	8"	5 1/2"		6 1/4"	3 1/2"		

https://insulationinstitute.org/wp-content/uploads/2016/08/Compressed_R_values.pdf

2018 New Item – Buried Ducts



2018 New Item – Lighting %

50% 2012 VECC →

75% 2015 →

<u>2018 VECC</u>

- 90% high efficacy lighting

When to test ducts

R403.3.4 Duct leakage (Prescriptive).

The total leakage of the ducts, where measured in accordance with Section R403.3.3, shall be as follows:

1. Rough-in test: The total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m^2) of conditioned floor area where the air handler is installed at the time of the test. Where the air handler is not installed at the time of the test, the total leakage shall be less than or equal to 3 cubic feet per minute (85 L/min) per 100 square feet (9.29 m^2) of conditioned floor area.
2. Postconstruction test: Total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m^2) of conditioned floor area.

Envelope Testing

R402.4.1.2 Testing

The building or *dwelling unit* shall be tested and verified as having an air leakage rate not exceeding five air changes per hour in *Climate Zone* 4. Testing shall be conducted in accordance with RESNET/ICC 380, ASTM E779, or ASTM E1827 and reported at a pressure of 0.2 inch w.g. (50 Pascals). A written report of the results of the test shall be signed by the party conducting the test and provided to the building official. Testing shall be conducted by a Virginia licensed general contractor, a Virginia licensed HVAC contractor, a Virginia licensed home inspector, a Virginia registered design professional, a certified BPI Envelope Professional, a certified HERS rater, or a certified duct and envelope tightness rater. The party conducting the test shall have been trained on the equipment used to perform the test. Testing shall be performed at any time after creation of all penetrations of the building thermal envelope.

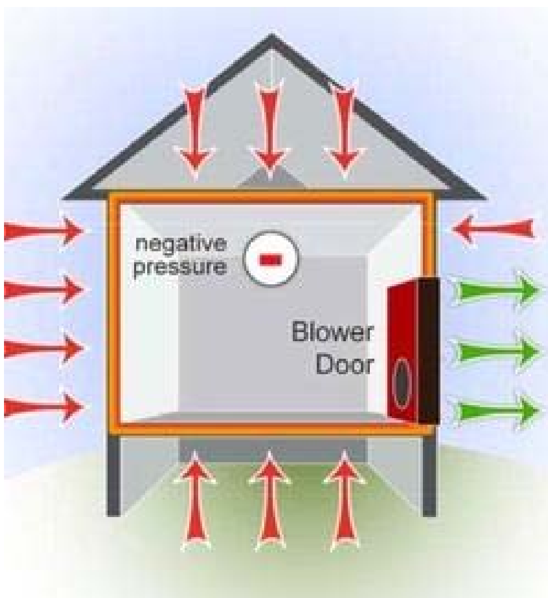
Note: Should additional sealing be required as a result of the test, consideration may be given to the issuance of a temporary certificate of occupancy in accordance with Section 116.1.1.

Blower Door Testing

Air Leakage: quantifying air moving through the building envelope

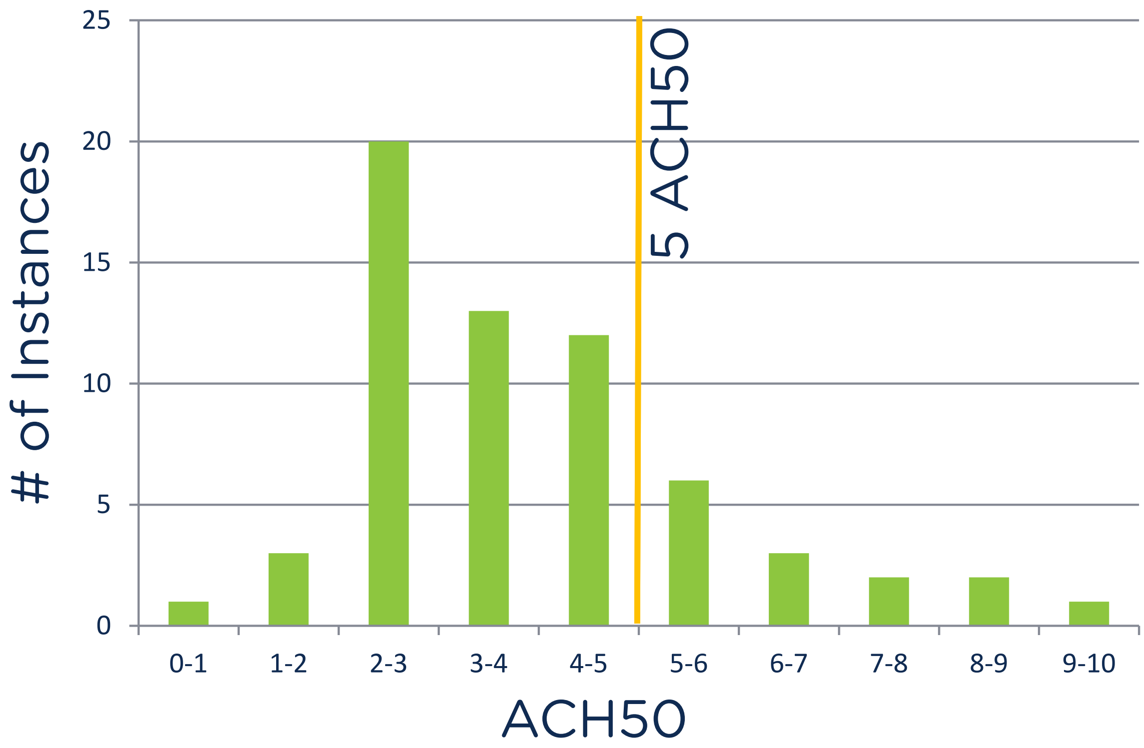
Adopted in VA 2018

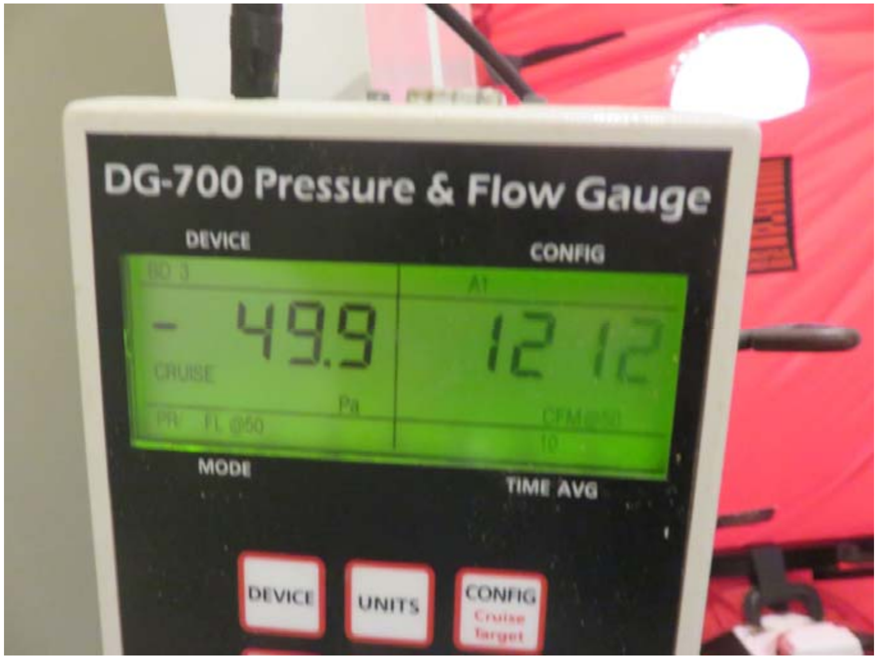
- Verification via Testing
- ≤ 5 ACH50



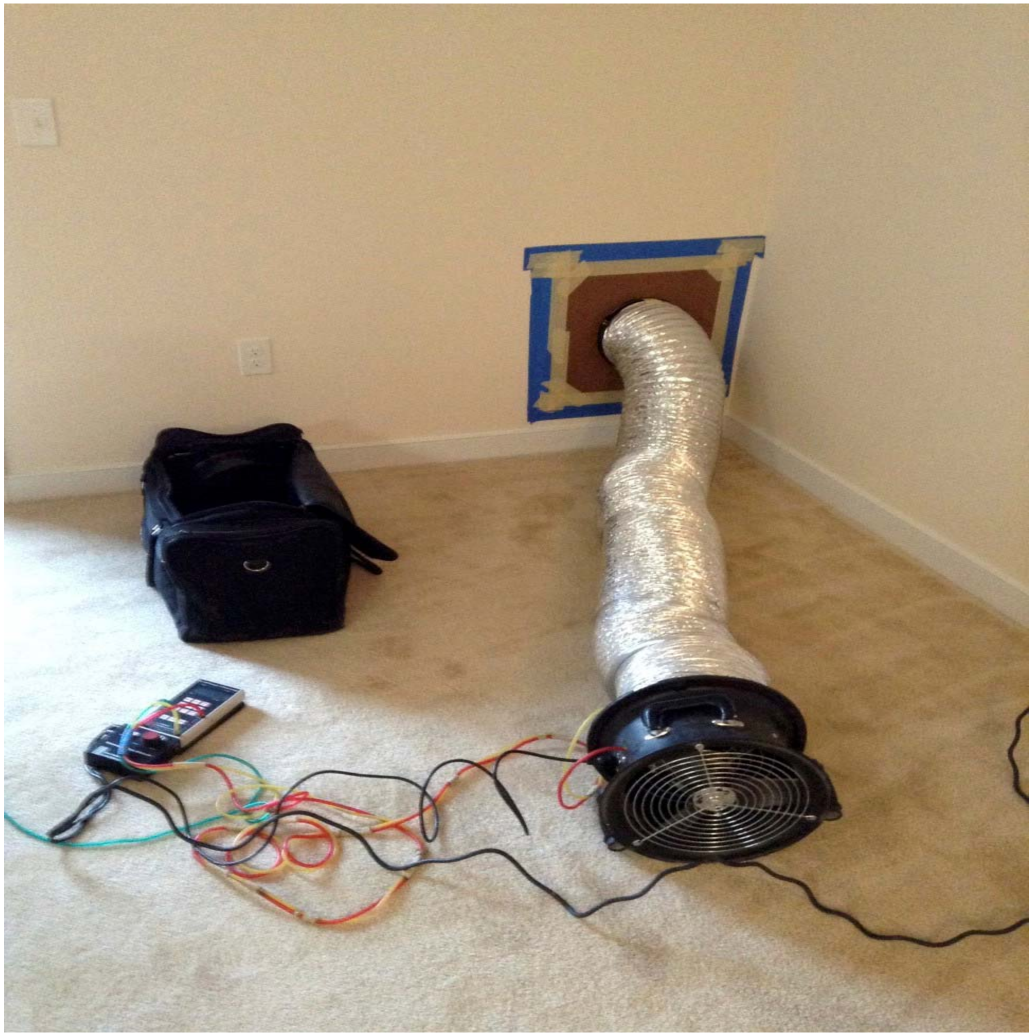
Results

Envelope tightness (ACH50)



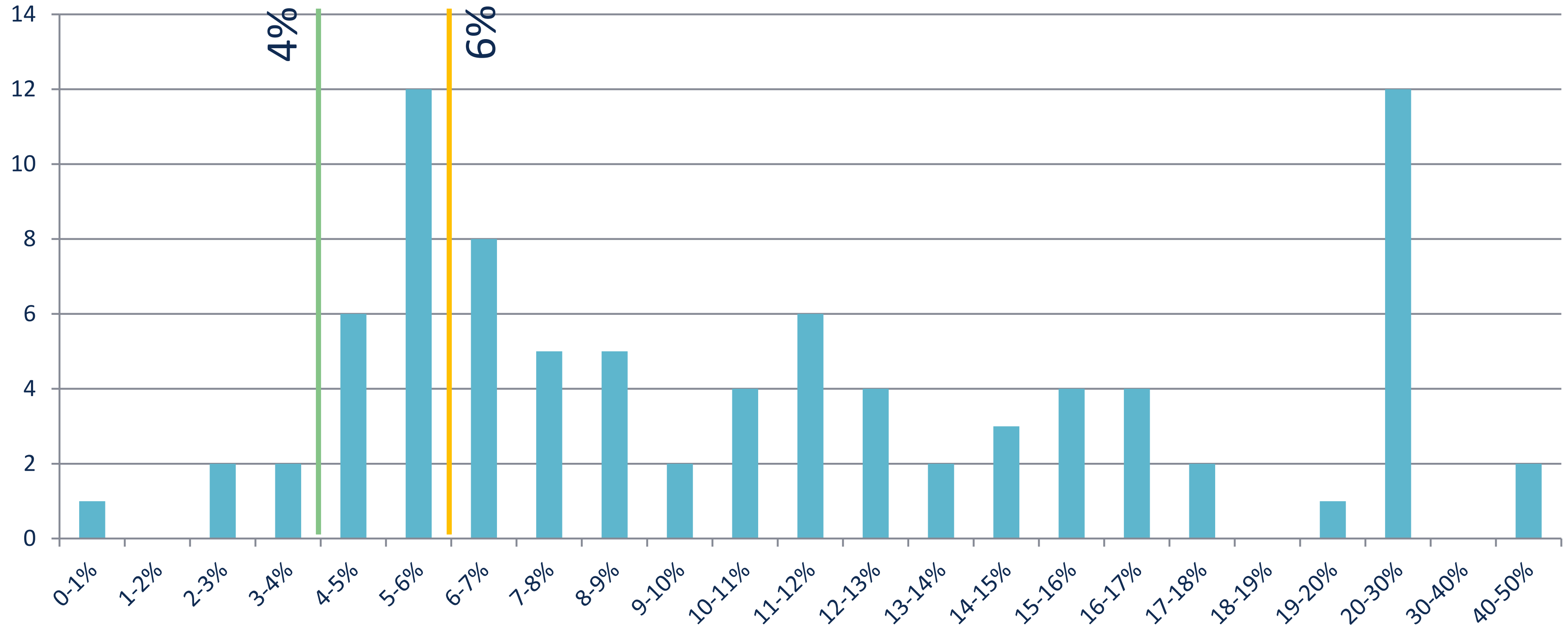


Who can test ducts



Duct Leakage – State of the Market

Total duct leakage



Efficient, Healthy HVAC Systems

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HVAC Definitions

1 Ton:	12,000 btuh of conditioning capacity, +/- 400 CFM air flow
CFM:	Cubic Foot Per Minute, Unit of measurement for airflow
Static Pressure	resistance to airflow in a heating and cooling system's components and duct work. The push of the air must be greater than the resistance to the flow or no air will circulate through the ducts. Stated in Inches of Water Column iwc/or in. w.c.
The 'V' in HVAC	Ventilation!!

Principles of Good Design & Execution

HVAC Systems Shouldn't Leak:	Air is a fluid and should not leak from the HVAC system. Think about your plumber.
House as a System:	Every individual system in the home is working together to create acceptable indoor environmental quality – THAT'S THE POINT!!!
Upsize:	Ducts not Equipment.
Elegance:	Simplicity should be the rule not the exception

HVAC Equipment Sizing

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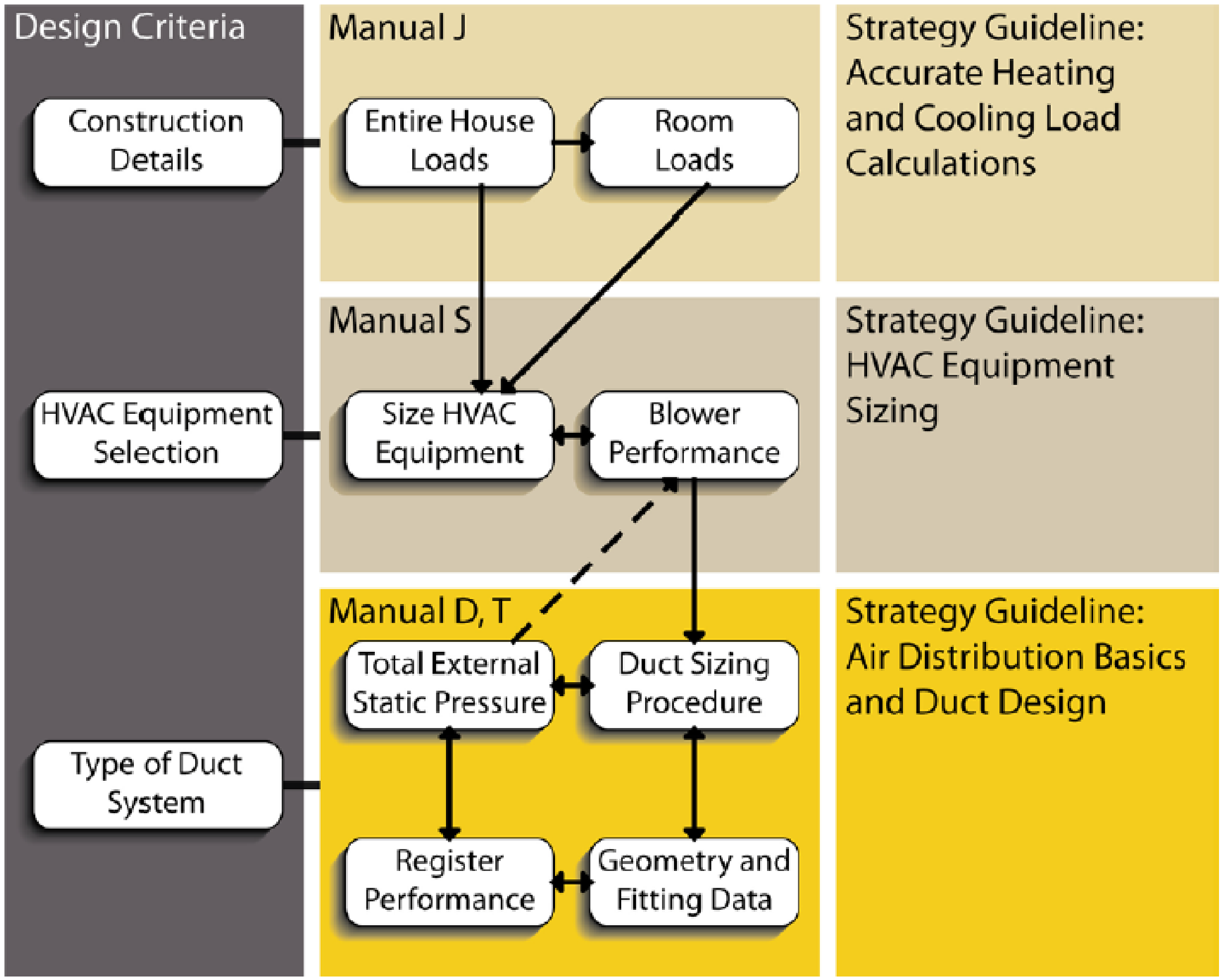
HVAC Load Calculations



Source: Advanced Strategy Guideline: Air Distribution Basics and Duct Design

HVAC Design Guidelines

- Manual J based on actual orientation and location
- Outdoor design temperature 99% design temperatures
- ACHnat selected at 0.35 or "tight" for New Construction, "semi-tight" for renovation
- Indoor: 75^0 cooling; 70^0 heating
- Must use actual window, insulation, and door spec.
- Number of occupants (number of bedrooms plus one)
- Mechanical ventilation
- Room x Room loads
- Realistic internal loads *(1200-2400 Btu sensible)*

HVAC Design Guidelines

Rhvac - Residential & Light Commercial HVAC Loads
EarthCraft Virginia
Richmond, VA 23220-4629

Elite Software Development, Inc.
Page 2

Project Report

General Project Information

Project Title:	
Project Date:	Wednesday, October 02, 2019
Client Name:	
Company Name:	Viridiant

Design Data

Reference City:	Richmond AP, Virginia
Building Orientation:	Front door faces West
Daily Temperature Range:	Medium
Latitude:	37 Degrees
Elevation:	164 ft.
Altitude Factor:	0.994

	Outdoor Dry Bulb	Outdoor Wet Bulb	Outdoor Rel.Hum	Indoor Rel.Hum	Indoor Dry Bulb	Grains Difference
Winter:	18	16.64	n/a	n/a	70	n/a
Summer:	92	75	46%	50%	75	39

Check Figures

Total Building Supply CFM:	330	CFM Per Square ft.:	0.338
Square ft. of Room Area:	977	Square ft. Per Ton:	1,104
Volume (ft³):	7,816		

Building Loads

Total Heating Required Including Ventilation Air:	12,616	Btuh	12.616	MBH
Total Sensible Gain:	7,962	Btuh	81	%
Total Latent Gain:	1,859	Btuh	19	%
Total Cooling Required Including Ventilation Air:	9,821	Btuh	0.82	Tons (Based On Sensible + Latent)
			0.88	Tons (Based On 75% Sensible Capacity)

Notes

Rhvac is an ACCA approved Manual J, D and S computer program.
Calculations are performed per ACCA Manual J 8th Edition, Version 2, and ACCA Manual D.
All computed results are estimates as building use and weather may vary.
Be sure to select a unit that meets both sensible and latent loads according to the manufacturer's performance data at your design conditions.

HVAC Design Guidelines

Total Building Summary Loads

Component Description	Area Quan	Sen Loss	Lat Gain	Sen Gain	Total Gain
.28/.26: Glazing-, outdoor insect screen with 50% coverage, U-value 0.28, SHGC 0.26	114.2	1,664	0	2,046	2,046
11P: Door-Metal - Polyurethane Core, U-value 0.29	21	317	0	171	171
12D-0bw: Wall-Frame, R-15 insulation in 2 x 4 stud cavity, no board insulation, brick finish, wood studs, U-value 0.086	988.8	4,423	0	1,192	1,192
18A1-21o: Roof/Ceiling-Roof Joists Between Roof Deck and Ceiling or Foam Encapsulated Roof Joists, Spray Foam Insulation, Dark or Bold-Color Asphalt Shingle, Dark Metal, Dark Membrane, Dark Tar and Gravel, R-21 open cell 1/2 lb. spray foam, 5.5 inches in 2 x 6 joist cavity, 1 inch on joist, U-value 0.047	977	2,389	0	1,286	1,286
19C-0sp-v: Floor-Over enclosed crawl space, R-11 insulation on exposed walls, sealed crawl space, passive, no floor insulation, carpet or hardwood, vinyl covering, U-value 0.368	977	1,234	0	403	403
Subtotals for structure:		10,027	0	5,098	5,098
People:	4		800	920	1,720
Equipment:			0	1,200	1,200
Lighting:	0			0	0
Ductwork:		0	0	0	0
Infiltration: Winter CFM: 6, Summer CFM: 0		315	0	0	0
Ventilation: Winter CFM: 40, Summer CFM: 40		2,274	1,059	744	1,803
Total Building Load Totals:		12,616	1,859	7,962	9,821

Minisplits

Source: https://commons.wikimedia.org/wiki/File:Wall-mount_AC.jpg

Minisplits

Source: https://www.mitsubishicomfort.com/

Minisplits

Source: https://www.mitsubishicomfort.com/, https://www.greecomfort.com/

Cold Weather/Inverter Heat Pumps

- No inefficient electric strip heat
- No accidental miswiring of system leading to expensive bills
- Quiet
- Full capacity down to below 0

HEATING PERFORMANCE

Outdoor Ambient Temperature (DB)		Return Air Temperature 70°F (DB)		
		TC (Btu/h)	COP	Power Input (W)
MAX OUTPUT	-22°F	18700	1.40	3920
	-20°F	19500	1.45	3950
	-15°F	22000	1.61	4000
	-10°F	23000	1.65	4100
	-5°F	24000	1.68	4200
	0°F	24000	1.85	3800
	5°F	24000	2.10	3350
	10°F	24000	2.23	3150
	15°F	24000	2.35	3000
	17°F	24000	2.43	2900
	20°F	24000	2.61	2700
	25°F	24000	2.82	2500
	30°F	24000	2.99	2350
	35°F	24000	3.09	2280
	40°F	25000	3.46	2120
	45°F	25000	3.58	2050
	47°F	26000	3.85	1980

	Outdoor Ambient Temperature																
	65	60	55	50	47	45	40	35	30	25	20	17	15	10	5	0	-5
MBh	29.87	28.00	26.17	24.36	**23.20**	22.36	20.21	18.21	16.57	15.36	14.48	14.00	13.39	11.85	10.32	8.79	7.25

Cold Weather/Inverter Heat Pumps

ASHP.neep.org

Brand	AHRI, Model, Unit	Ducting Configuration	Heating Capacity (Rated Btu/hr @47°F)	Heating Capacity (Max Btu/hr @5°F)
CARRIER			0 24000 - 30000 80000	0 24000 - 34000 80000

CARRIER
Performance Series
AHRI #: **204344191**
Singlezone Ducted, Centrally Ducted
23,890 Max Btu/hr @**5°F**
23,600 Rated Btu/hr @**47°F**
23,000 Rated Btu/hr @**95°F**
COP @5°F: **2.59**
HSPF: **10.5**
Outdoor Unit #: **38MAQB24R--3**
Indoor Unit #: **FV4CNF002**

VIEW DETAIL

CARRIER
Performance Series
AHRI #: **203380995**
Singlezone Ducted, Centrally Ducted
28,430 Max Btu/hr @**5°F**
23,200 Rated Btu/hr @**47°F**
23,000 Rated Btu/hr @**95°F**
COP @5°F: **2.14**
HSPF: **11.2**
Outdoor Unit #: **38MAQB24R--3**
Indoor Unit #: **FM(C,U)4Z24**AL***

VIEW DETAIL

HVAC Load Calculations

HVAC Load Calculations

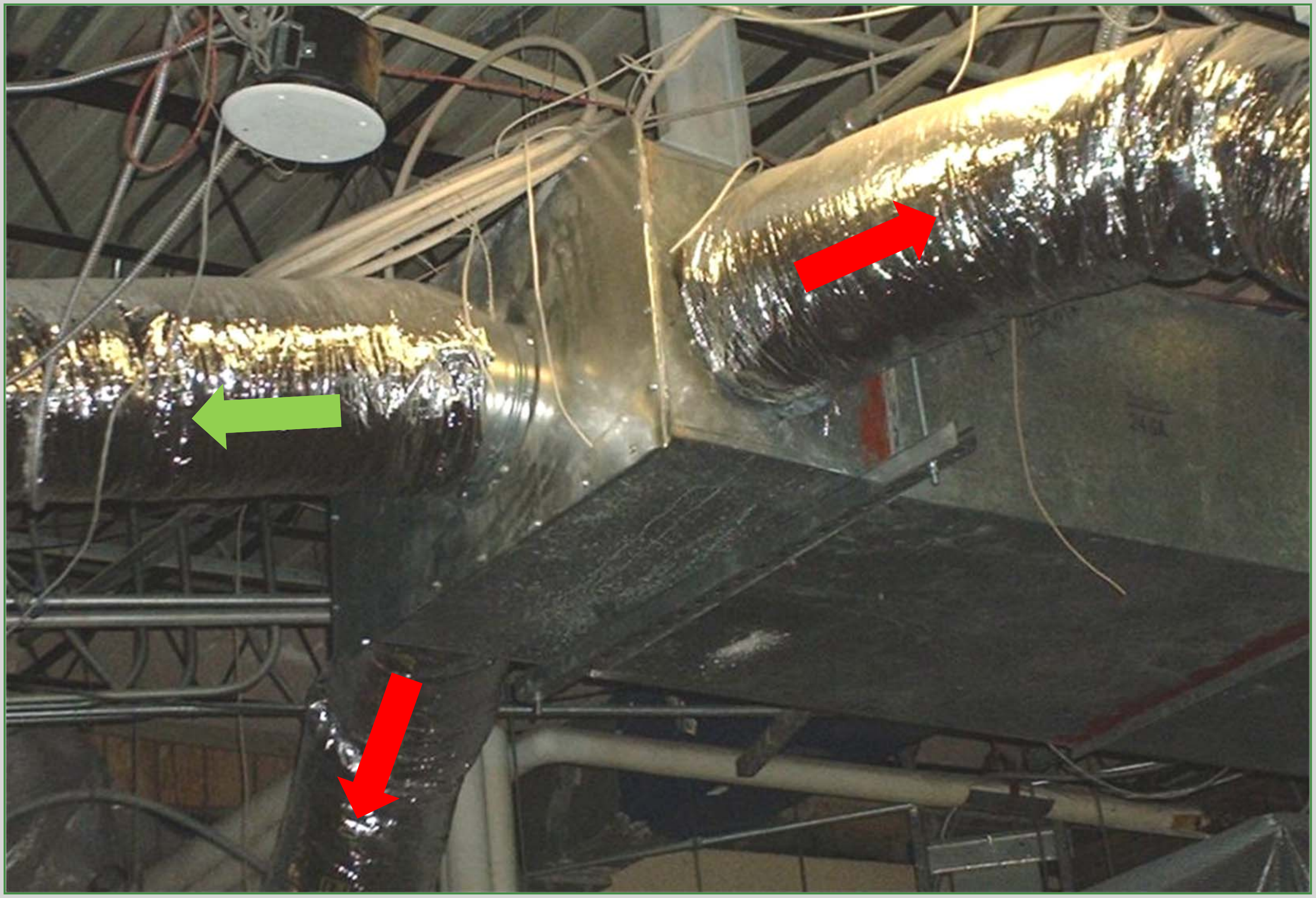
- Bigger is Not Better

Duct Layout – What we look for in the field

- No ducts within 6” of supply plenum cap
- All supply duct take-offs spaced at least 6” apart
- Rigid supply trunk

https://www.energyvanguard.com/blog/duct-design-3-total-effective-length

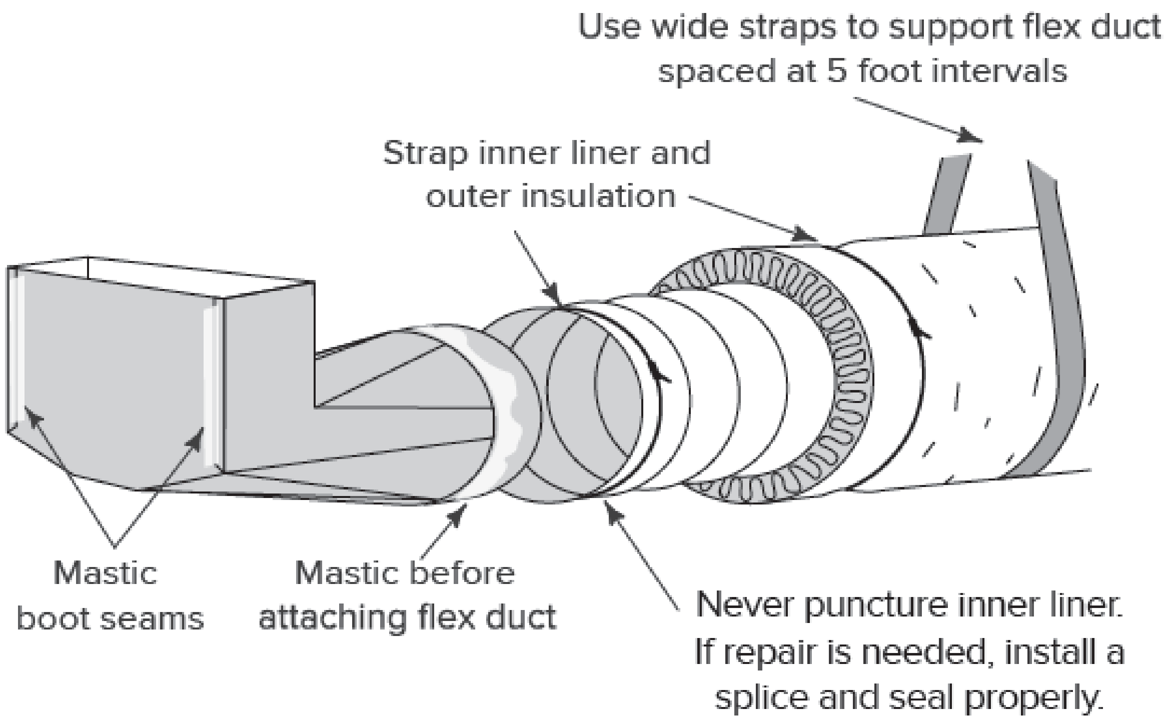
Duct Layout

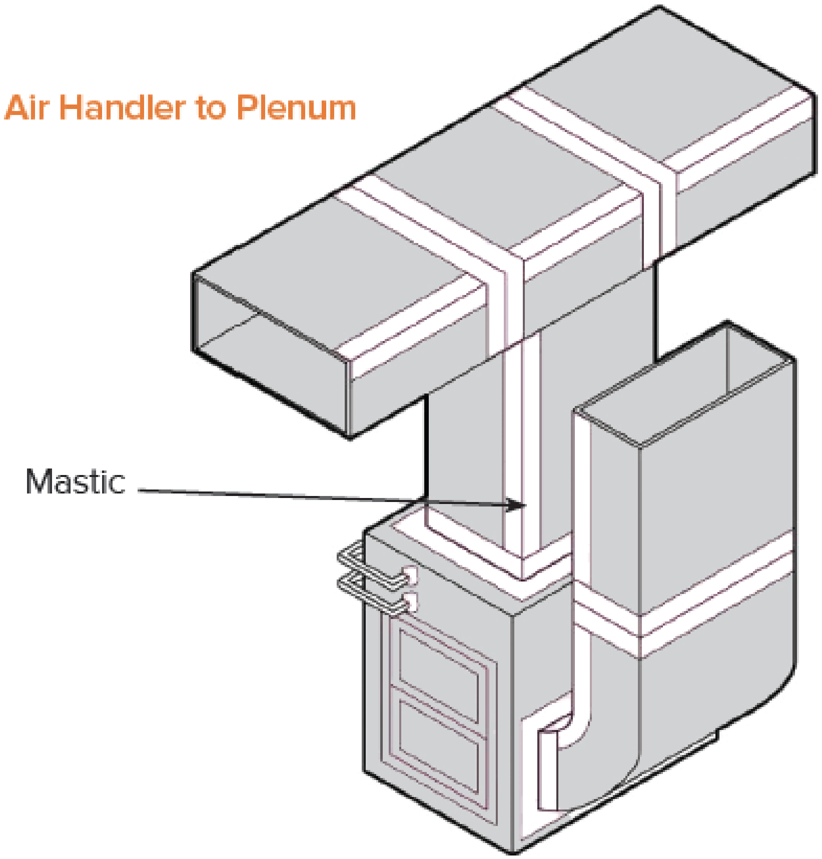


Quality Duct Installation

Duct Boots

Common Duct Leakage Sites



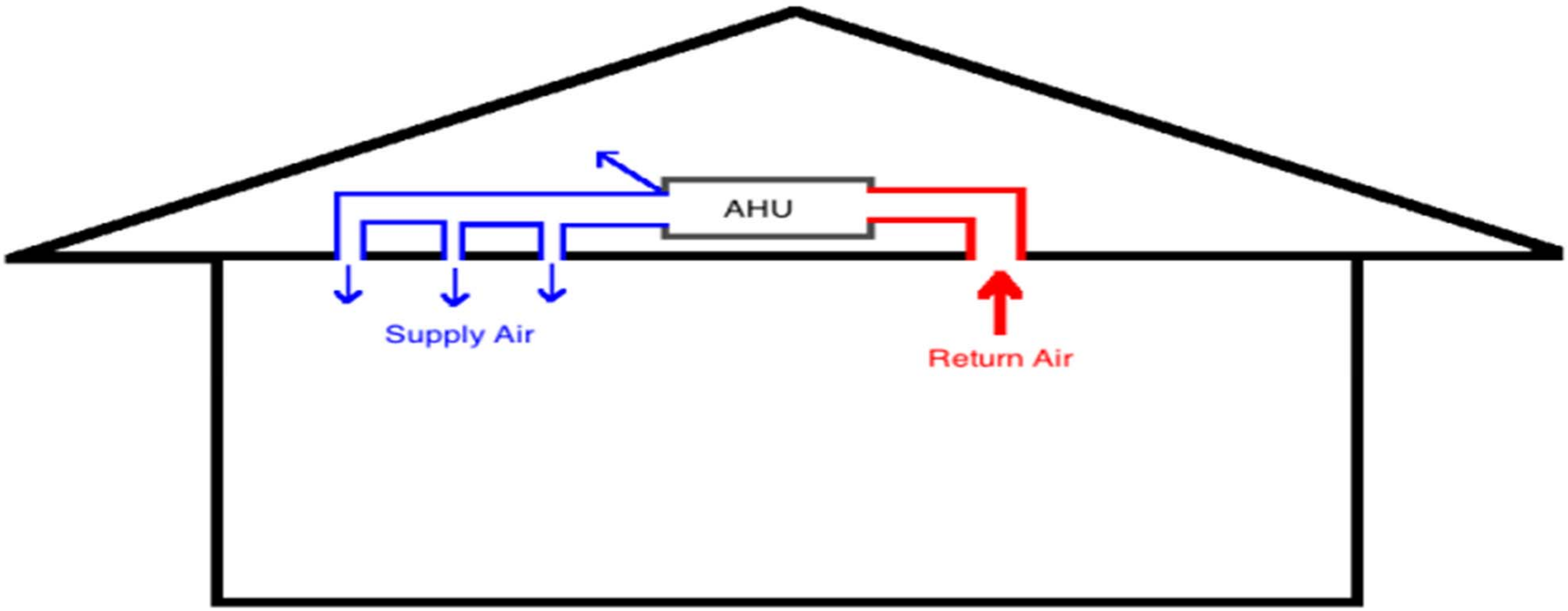


Duct Sealing: Tips for meeting the duct tightness number, Southface Energy Institute, Southeast Energy Efficiency Alliance, Advanced Energy

Ductwork Outside the Envelope?

The House is a System

Duct Leakage induces envelope leakage



Supply Duct Leakage

http://www.greenbuildingadvisor.com/blogs/dept/building-science/how-duct-leakage-steals-twice

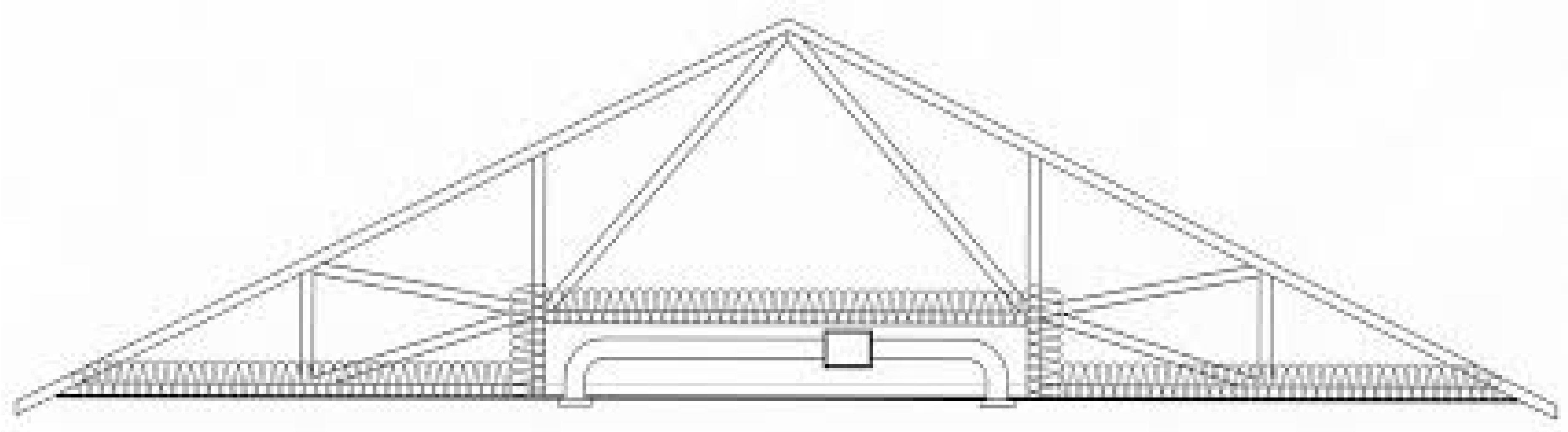
Attics

Conditioned attic: insulate roof deck, provide conditioned air

https://www.energy.gov/sites/prod/files/1-1c_Unvented_Conditioned_Attics_SR%2010-11-12.jpg

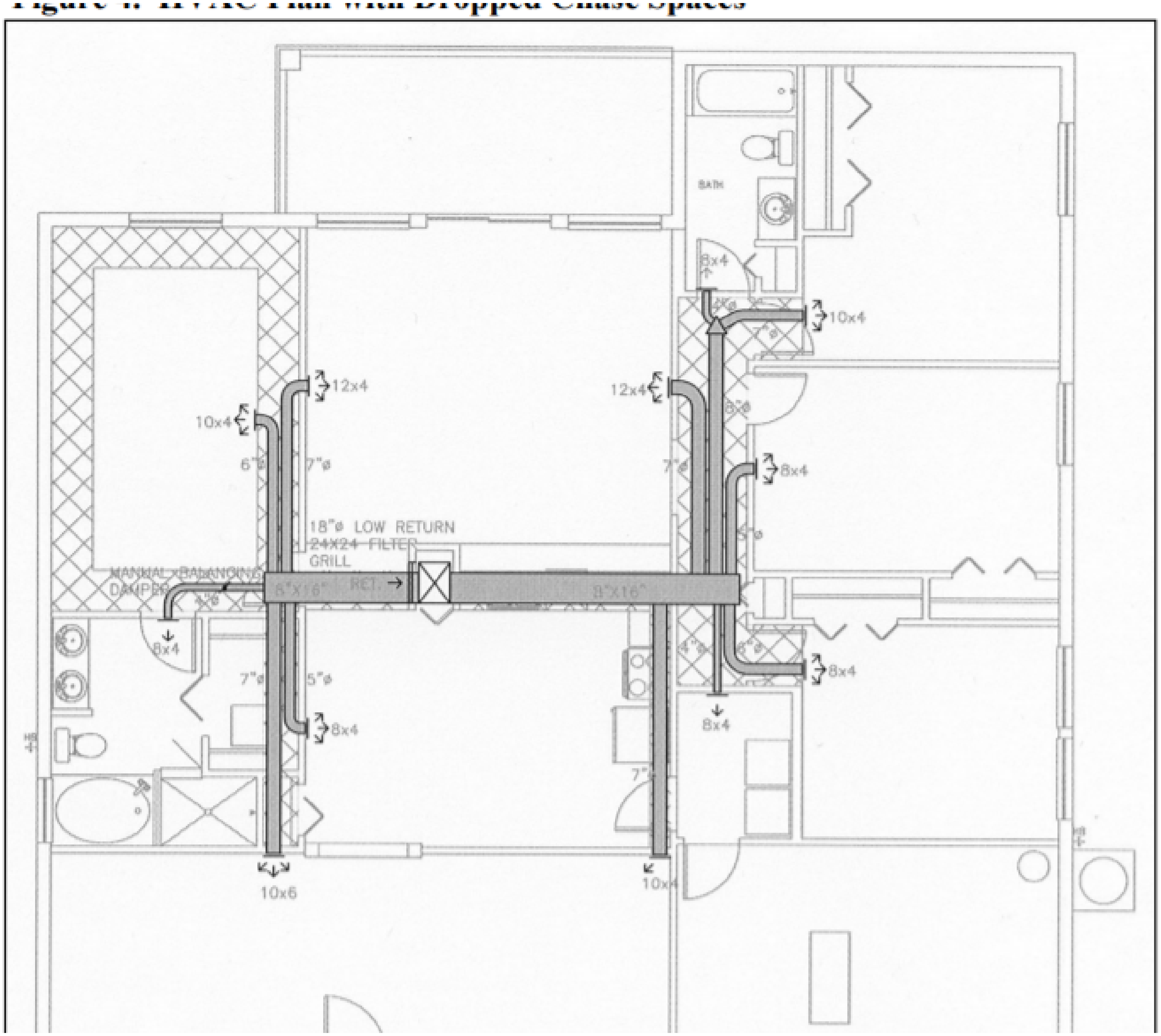
Attics

Plenum truss:
forms a reverse bulkhead for ductwork



https://aceee.org/files/proceedings/2002/data/papers/SS02_Panel1_Paper07.pdf

Attics

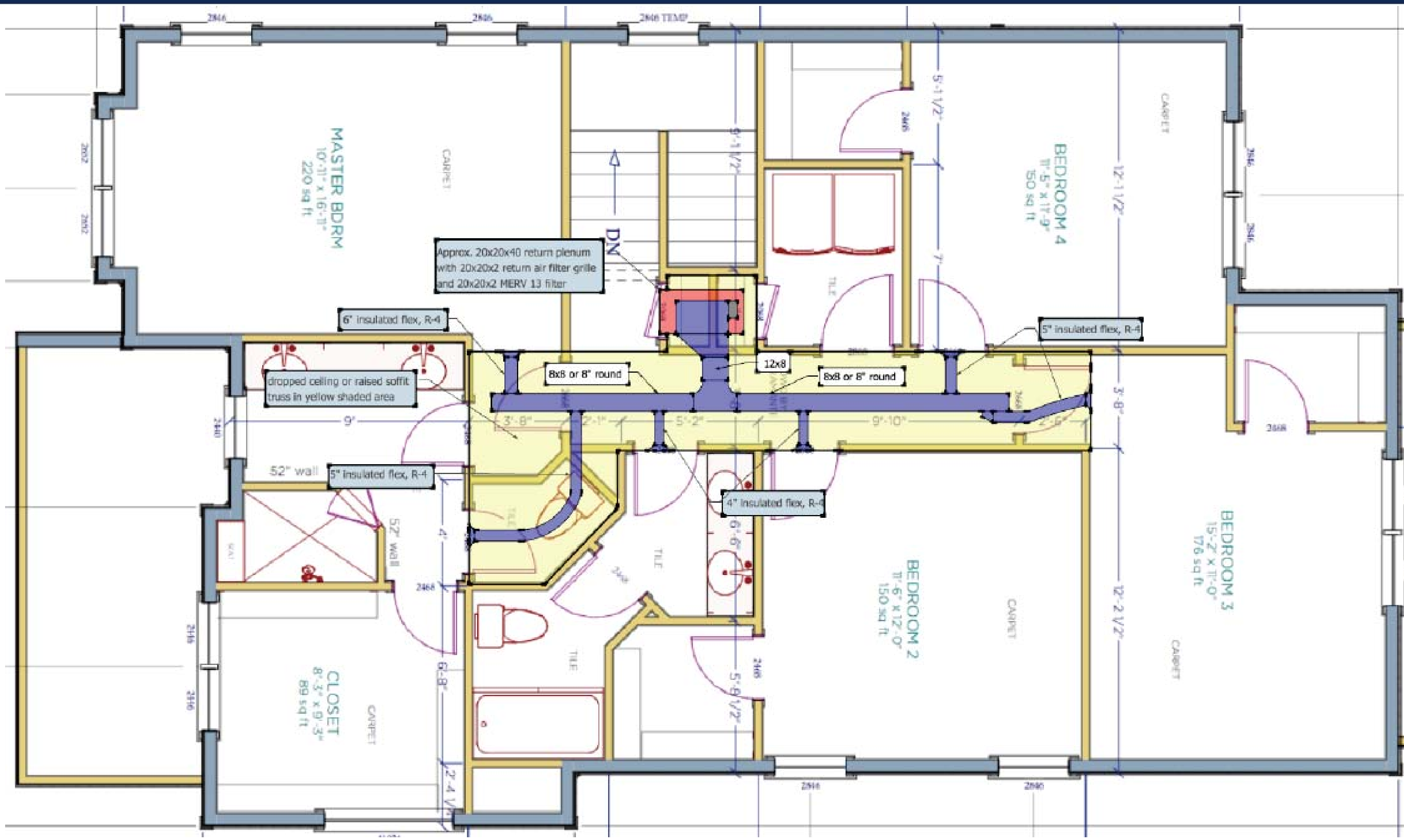


https://aceee.org/files/proceedin

Attics

https://aceee.org/files/proceedings/2002/data/papers/SS02_Panel1_Paper07.pdf

Attics



Think Little

Attics

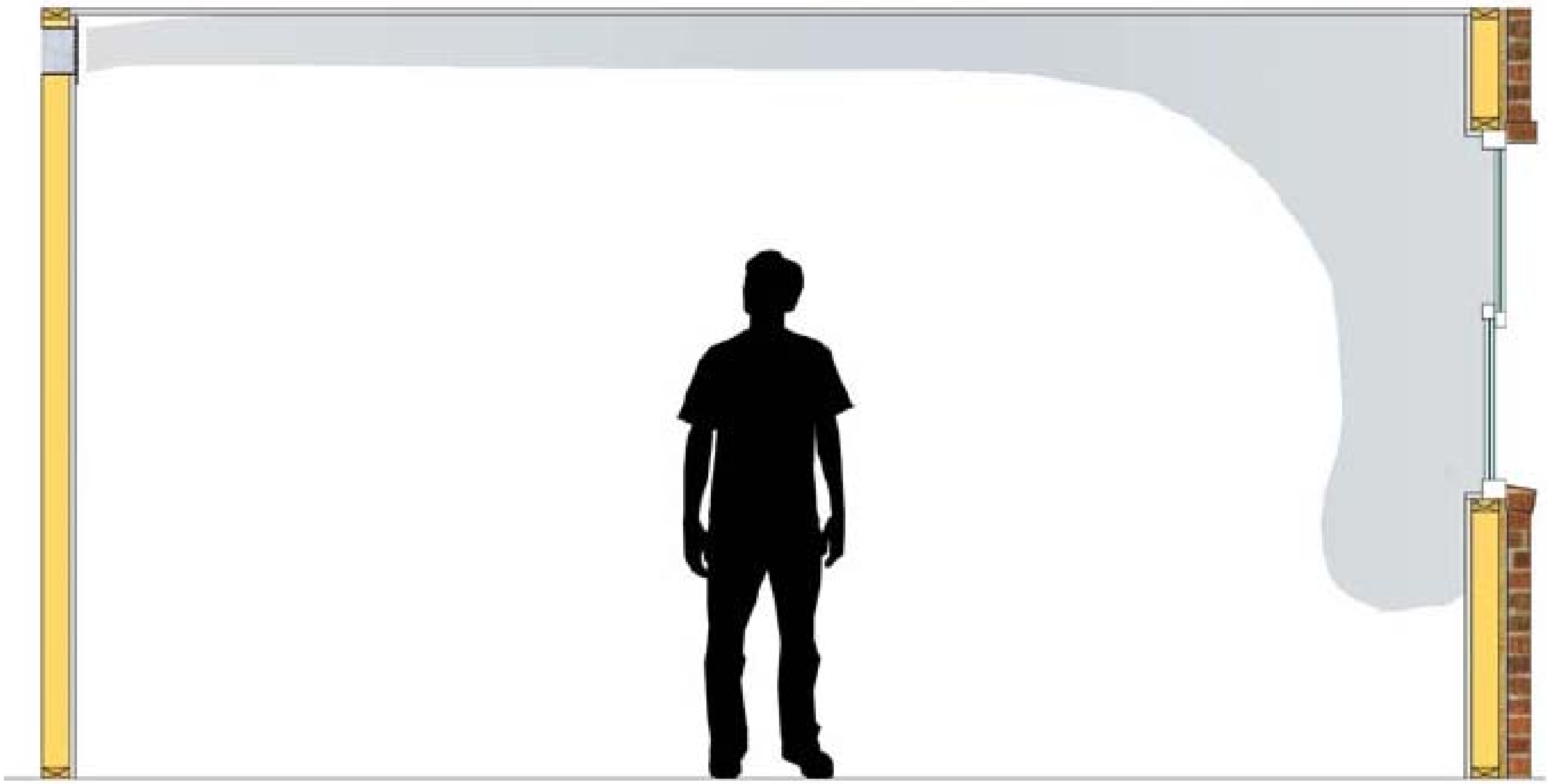


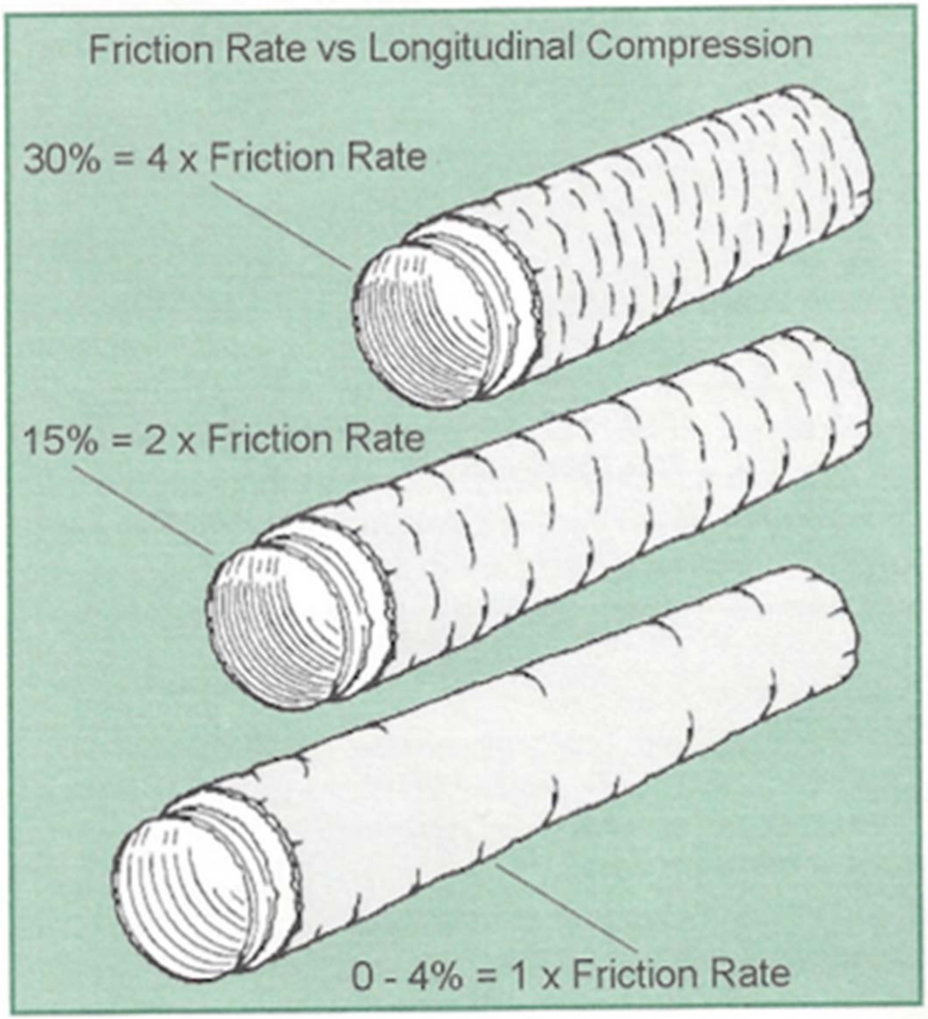
Figure 4. High sidewall supply outlet example

Source: Advanced Strategy Guideline: Air Distribution Basics and Duct Design

Duct Layout

Source: Think Little

Let's Talk Flex Duct



Source: https://www.energyvanguard.com/blog/57709/How-to-Install-Flex-Duct-Properly

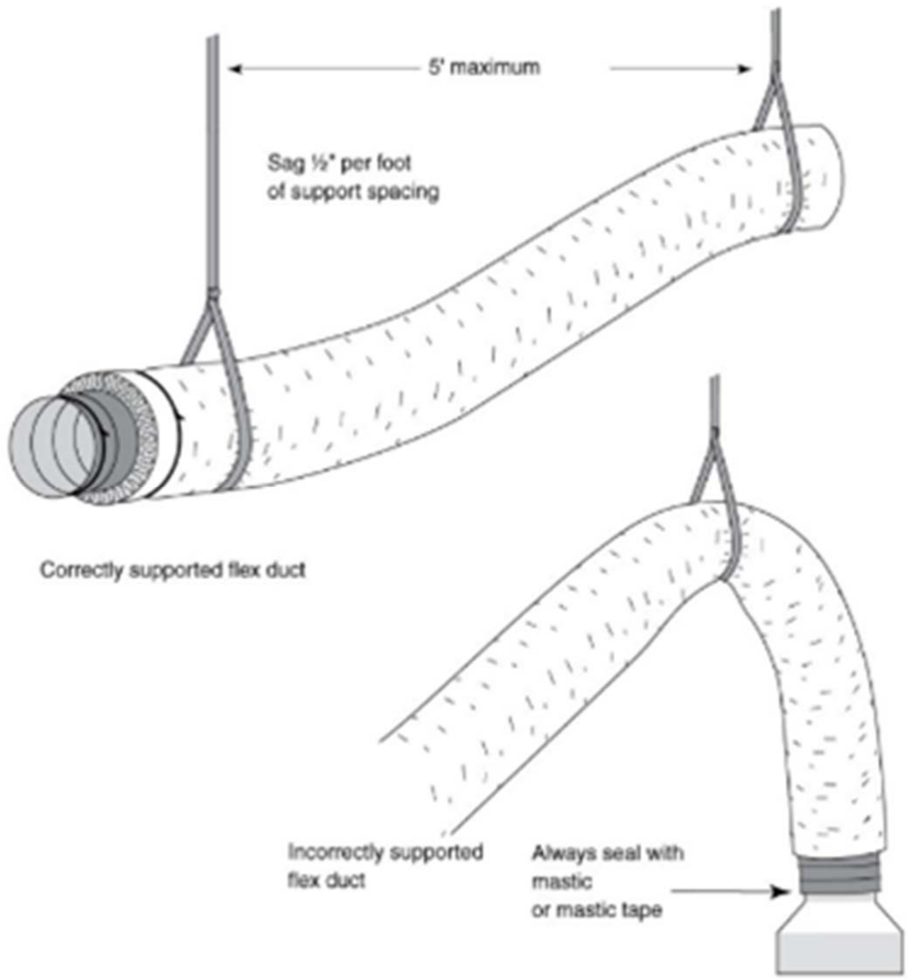
TRACKING DUCT LEAKAGE: Where to begin?

Let’s Talk Flex Duct

Let’s Talk Flex Duct

Let’s Talk Flex Duct

Quality Duct Installation



Let’s Talk Flex Duct


9

Let’s Talk Flex Duct

Relative Humidity

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Relative Humidity & Moisture

Ideal health & comfort is 30%-50% RH at room temperature (~72° F)

Moisture Problems	
Building decay	100% RH
Interior mold	RH > 70%
Dust mites	RH > 50%
Static electricity, dry sinus	RH < 25%

Conditions for Mold Growth

- Food: organic materials
  - Wood, paper, sheetrock
- Temperature: 40 º F to 100 º F (mold goes dormant in winter)
- Excess moisture is the primary cause
  - Water: flooding, roof & plumbing leaks
  - Water vapor: Mold grows above 70% RH

Lew Harriman – 'Wet N Wild – 40 Yrs. of Humidity Control'

"Secret Guide to Humidity Control and Mold Avoidance"

1. **Build air-tight** insulated enclosures with great windows.
2. **Dry the ventilation air,** using ASHRAE peak dew point design data to size the ventilation dehumidifier.
3. **STOP ventilation + exhausts** when nobody's in the building.
4. **Keep unoccupied buildings DRY (not cool)** by recirculating and operating the ventilation dehumidifier.

Resilience

- Construction Types
- Renewables and Battery Systems
- Flood Preparedness

By FEMA/Joselyne Augustino) - https://share.sandia.gov/news/resources/news_releases/images/2013/fema.jpg, Public Domain, https://commons.wikimedia.org/w/index.php?curid=27401730

Passive Survivability – Thermal Resilience

Homeothermy: form of temperature regulation used by humans, where the body maintains the same internal core temperature (98.6F), regardless of external influences.

Passive Survivability – Thermal Resilience

- ASHRAE’s Thermal Environmental Conditions for Human Occupancy Standard 55-2004
  - Indoor Summer Comfort Range: 74F – 83F
  - Indoor Winter Comfort Range: 67F – 79F
  - Acceptable for naturally ventilated spaces: 50F – 93F
- Concrete construction (thermal mass/ICF) has a higher passive survivability rating than wood or steel framed
- Lower window-to-wall ratio and natural ventilation strategies are critical for maintaining favorable conditions during summer outages
- Insulation and air-tightness substantially increase interior temperature during winter outages
- Small backup power for thermal maintenance

Lisa White, ‘Assessing Passive Survivability in Multifamily Buildings’

Programs and Research into Resilience

FORTIFIED HOME™

https://www.buildingscience.com/project/new-orleans-la-green-dream-2-case-study

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resiliency and sustainable building

As weather becomes more extreme, with hotter temperatures, heavier rainfalls, and higher winds, making buildings more resilient to weather related events is a practical and smart choice. It is possible to make both new and existing construction better
harsh weather and protect occupants
after a storm. This bulletin will primar
buildings, but is equally applicable to

The US Climate Resilience Toolkit (toolkit.climate.gov) provides an intuitive five step process to follow start to finish.

1

The first step is to determine potential threats specific to the building's geographic location. This includes common, known risks like hurricanes, emerging risks like flooding, as well as risks that scientists have determined as likely to arise in the future such as more frequent, severe storms and ocean level rise. Which risks are ultimately addressed is up to the building owner, but during the planning phase, it's valuable to understand the full range of possible adverse events that could impact the structure. For example, in Virginia, flooding, extreme temperatures, a range of storm types, and wildfires are issues that often affect homes and other buildings. These events are often coupled with risks that

Brock Environmental

Viridiant Lecture Series

planning for resilient and sustainable buildings

A resilient building is also a sustainable building. Buildings that do not need replacement or significant repairs after a disaster are more sustainable by nature. More critically, resilient buildings provide a safe shelter to their occupants during adverse weather events and following days. In this bulletin, we provide resources to help building owners perform a hazard assessment and begin to take action.

Follow-up Email

- Training certificate
- Feedback Survey
- Program Resources
- EarthCraft & ENERGY STAR Program Resources

Questions or comments?

viridiant

Some Helpful Links from Presentation

- Programmatic Links
  - ENERGY STAR Residential Programs
  - Zero Energy Ready Home Program
  - EarthCraft Programs – Viridiant
  - Enterprise Green Communities
  - Passive House Institute US

- Other Useful Links
  - Oak Ridge National Laboratory Foundation Handbook
  - Viridiant Code Update Resources

Some Helpful Links from Presentation

- Assemblies
  - The Perfect Wall – Building Science Corp.
- Durability
  - EPA Moisture Control Guide Book
- HVAC
  - HVAC Design and Load Sizing Code Official Guides
- Resilience:
  - Post Katrina Resilient/Efficient Home Design