How does a home perform?

Understanding basic building science

Field Fusion

Energizing the discussion around building efficiency.

energyLogic

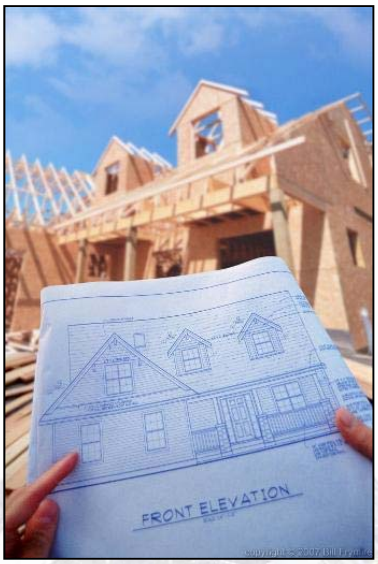
energyLogic

Presented By Robby Schwarz

Agenda

Intro to Building science

- The connection to the IECC
- Systems Thinking
- Applied Building Science
  - Heat Flow
  - Air Flow
  - Moisture Flow



Change is Hard … Change is Good… Change can be Made Easier

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Expectation

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Pathways through the 2015/18 IECC

- Prescriptive
  - Baseline but no code tool used for quantification
- UA Trade off
  - Area waited U-Value
- Simulated Performance
  - Annual Cost Compliance
- Energy Rating Index
  - HERS Index

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Fundamental Questions

Is It There?	*Does It Work?*

EnergyLogic

Fundamental Questions

Is It There?	Does It Work?

EnergyLogic

Fundamental Questions

Is It There?	Does It Work?

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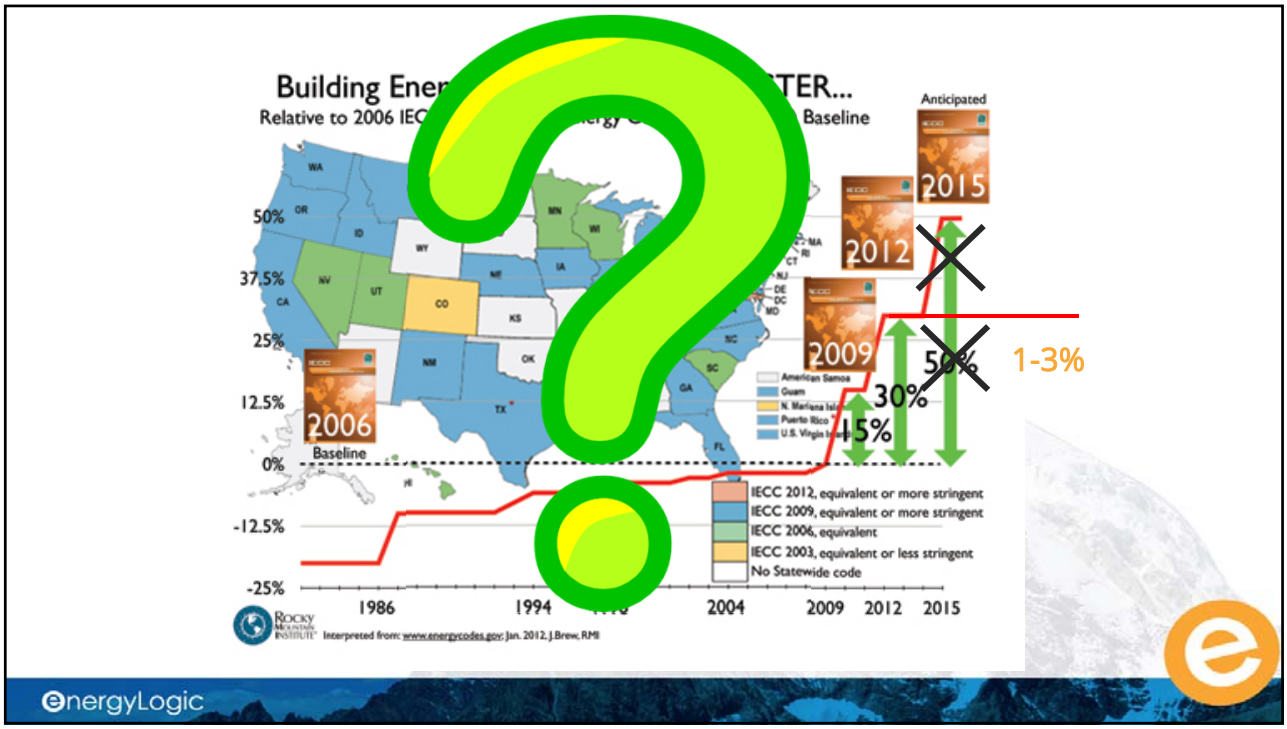

The Pathways and Mandatory sections of the IECC

- Lead us to sound applied building science and systems thinking

Look how houses have changed

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The House as a System

(Quote from the EEBA Builders Guide) www.eeba.org

"Residential Construction is a complex operation including thousands of processes by dozens of industries, bringing together hundreds of components and sub-systems into a house."

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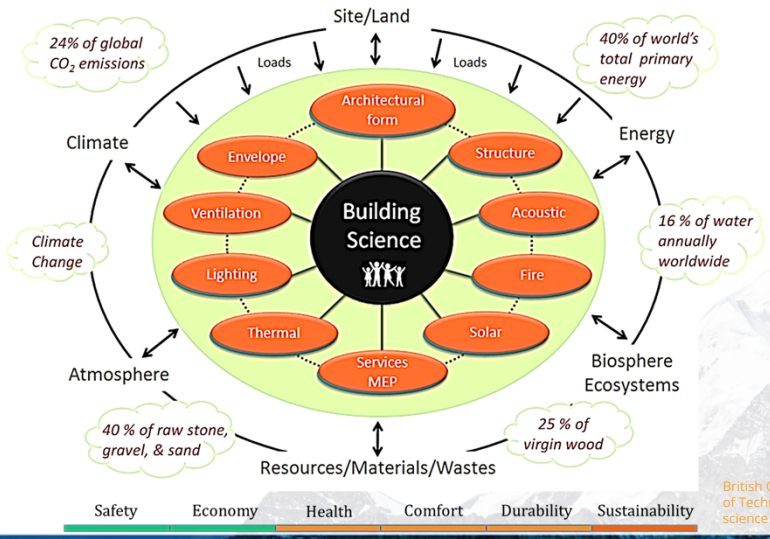
Applied Building Science



British Columbia Institute of Technology building science program

Systems Thinking

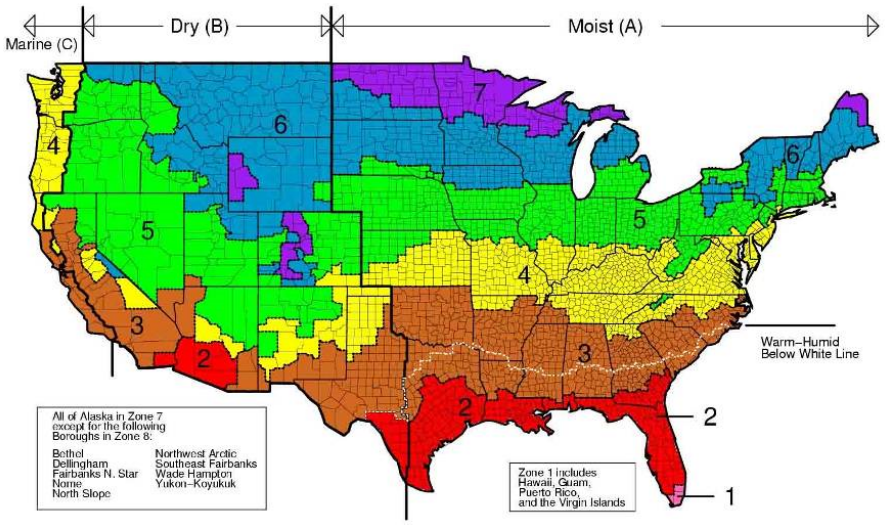
- Holistic approach rather than a component approach.
- Synergy
  - The various parts work together
  - Achieving what could not be achieved before!
- Meeting the Expectations
  - Safe
  - Comfort
  - Durable
  - Efficient
  - Environmental

Synergy = Systems Thinking

- 1+1 = 1
  - Fan + Duct = Air flow
- 1+1 = 2
  - Fan + Duct = Air flow + Ventilation
- 1+1 = 3
  - Fan + Duct = Air flow + Ventilation + Durability
- 1+1 = 4
  - Fan + Duct = Air flow + Ventilation + Durability + IAQ

House as a System and Applied Building Science

Codes Climate Map



IECC

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Micro Climates

- Controlled environment
  - Consistent Comfort
  - Temperature
  - Humidity
  - Air Quality
- Predictability / Control
  - Tighter
  - Insulation
  - Mechanical Systems
  - Ventilation

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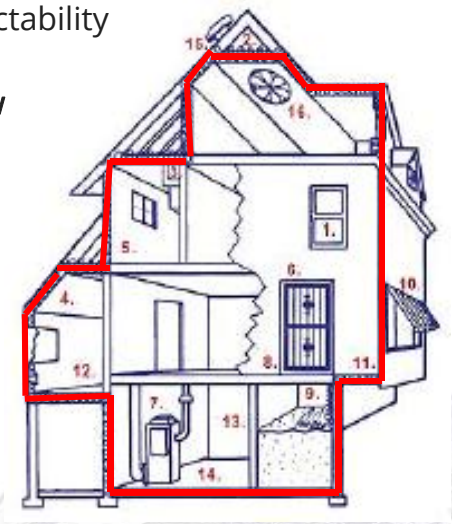
What / Where is the Thermal Envelope?

- Control & Predictability
  - Air Flow
  - Moisture Flow
  - Thermal Flow



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R402.4 Air Leakage and Air Barriers (Mandatory)

- The building thermal envelope shall be constructed to limit air leakage in accordance with the requirements of Sections R402.4.1 through R402.4.4.
- The components of the building thermal envelope as listed in **Table R402.4.1.1** shall be installed in **accordance with the manufacturer's instructions** and the criteria listed in Table R402.4.1.1

2012 IECC Table

TABLE R402.4.1.1
AIR BARRIER AND INSULATION INSTALLATION

COMPONENT	CRITERIA[a]
Air barrier and thermal barrier	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed. Air-permeable insulation shall not be used as a sealing material.
Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.
Walls	Corners and headers shall be insulated and the junction of the foundation and sill plate shall be sealed. The junction of the top plate and top of exterior walls shall be sealed. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier. Knee walls shall be sealed.

2015/18 IECC Table

TABLE 402.4.1.1 (N1102.4.1.1)
AIR BARRIER AND INSULATION INSTALLATION

COMPONENT	AIR BARRIER CRITERIA	INSULATION INSTALLATION CRITERIA
General Requirements	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed.	Air-permeable insulation shall not be used as a sealing material.
Ceiling / attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.	The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.

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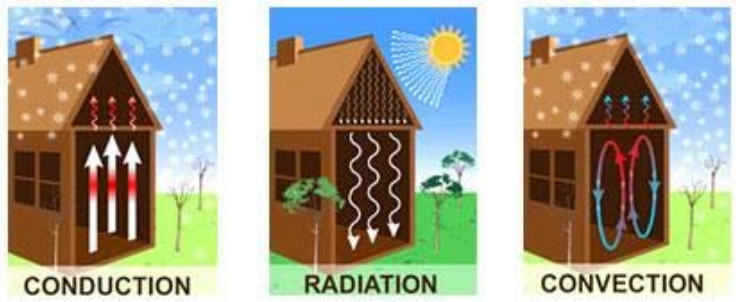
Thermal Flow

The Building Science Broken down



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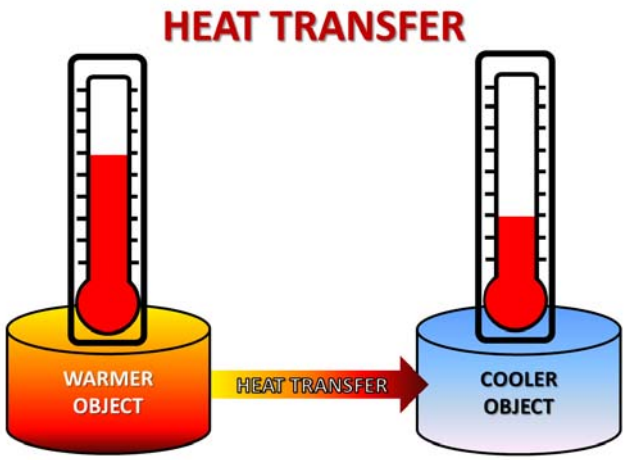
http://www.bpihomeowner.org/blog/technically-speaking-principles-heat-transfer

Heat Flow



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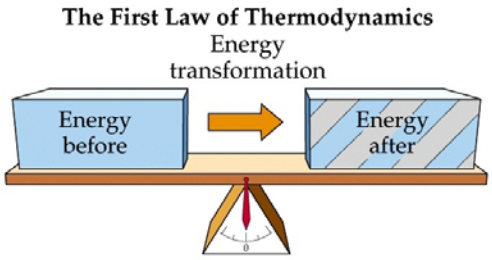
1st Law of Thermodynamics

- Energy cannot be created or destroyed
- Energy moves and changes form
- Flow of heat is an energy transfer mechanism



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2nd law of Thermodynamics

- Heat moves from high temperature regions to low temperature regions
  - Hot to Cold
- It never flows from low to high without adding additional energy
- No reaction is 100% Complete, there is always energy loss

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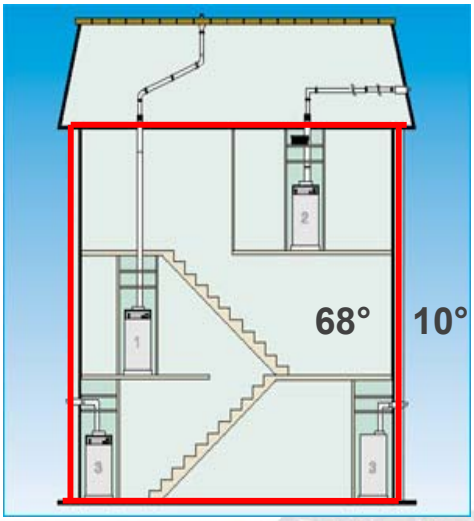
Temperature difference is the force that drives heat movement



- Delta = Difference = Δ
- Delta T = Temperature Difference

ΔT = 58°

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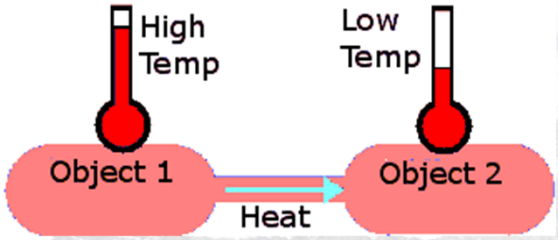
Temperature vs. Heat

- Temperature is a measure of the internal energy of a system
  - A measure of how fast molecules are moving in a system
- Heat is a measure of how energy is transferred from one system (or body) to another

EnergyLogic

Heat

- Energy Transferred from one body to another
- Things do not have to be hot to have heat
  - They only have to be hotter/have more heat than another body to transfer heat



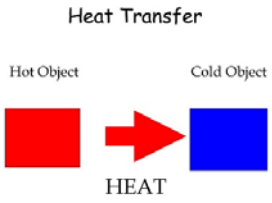
EnergyLogic

Two Types of Heat

- Sensible heat
  - Heat able to be sensed by a thermometer
  - Heat absorbed (added) or released (taken away) by a substance during a change in temperature
  - This is the energy described by heat load calculations
- Latent heat
  - Heat released or absorbed by a substance during a change in phase
  - Phase changes
    - Solid to liquid / liquid to vapor
    - This is the energy that drives a heat pump or air conditioner
    - Condensation

EnergyLogic

Two Kinds of Energy



- Potential
  - Stored energy
    - Cord of wood, ice cub, Battery, hot water heater

  Energy that can flow between Objects

- Kinetic Energy
  - This is the energy of motion
  - Atoms of molecules in motion are Kinetic energy
  - The temperature of energy is a description of faster moving atoms or molecules
  - Energy that is measured by a thermometer

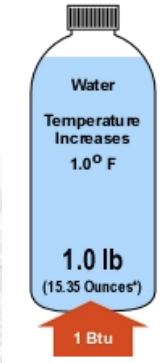
BTU Measurement of energy

British Thermal Unit

The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit
  - Approximately the energy produced by burning one wooden match

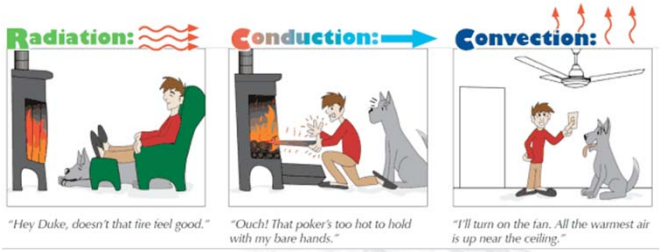
- The term "BTU" is used to
  - Describe the heat value (energy content) of fuels,
  - To describe the power of heating and cooling systems, such as furnaces
  - BTU *per hour* (BTU/h) is understood, though this is often confusingly abbreviated to just "BTU".

- The unit **MBTU** was defined as one thousand BTU presumably from the Roman numeral system where "M" stands for one thousand (1,000).
  - Many companies and engineers use **MMBTU** to represent one million BTU.
  - Alternatively a *therm* is used representing 100,000 or 10^5 BTU



How Heat Moves

- Heat Moves/transfers by:
  - Conduction
  - Convection
  - Radiant energy movement
- All heat transfer mechanisms occur simultaneously



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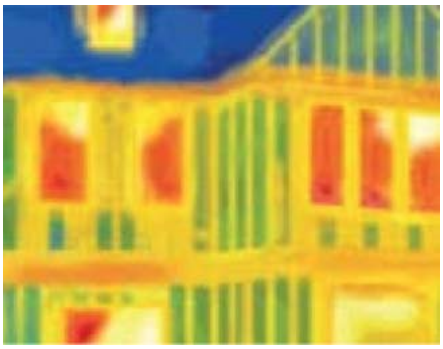
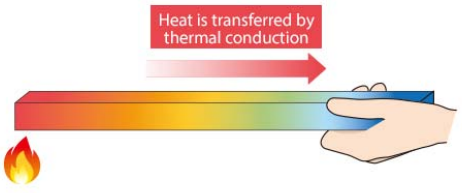
https://www.drenergysaver.com/insulation/how-insulation-works.html

Conduction

- Energy conducts through solid objects
- Always from warm to cold until a balance is reached





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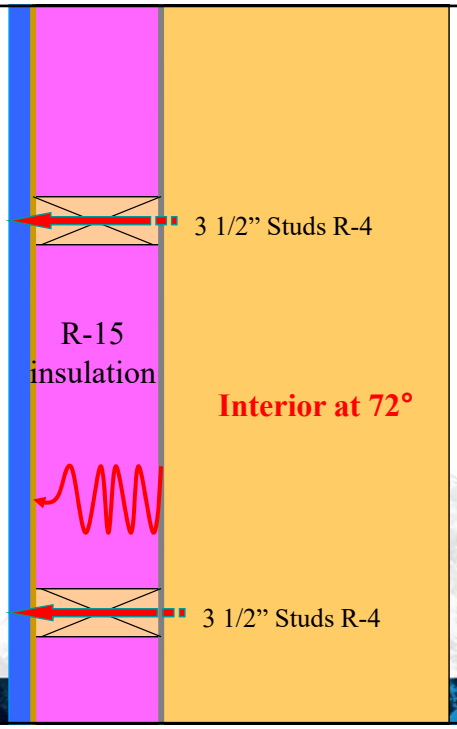
Conductive Heat Loss

Exterior at 20°

The more lumber in a wall system, the greater amount of thermal bridging is taking place. A 16" o.c. wall typically is 25% wood.

Rigid insulation adds a continuous thermal break →

Heat flow through solid objects →



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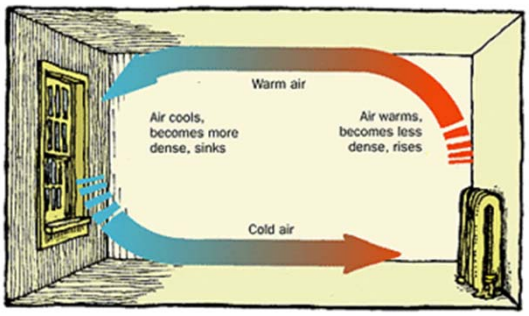
Convection

- Energy transferred by a moving fluid such as:
  - Air
  - Water



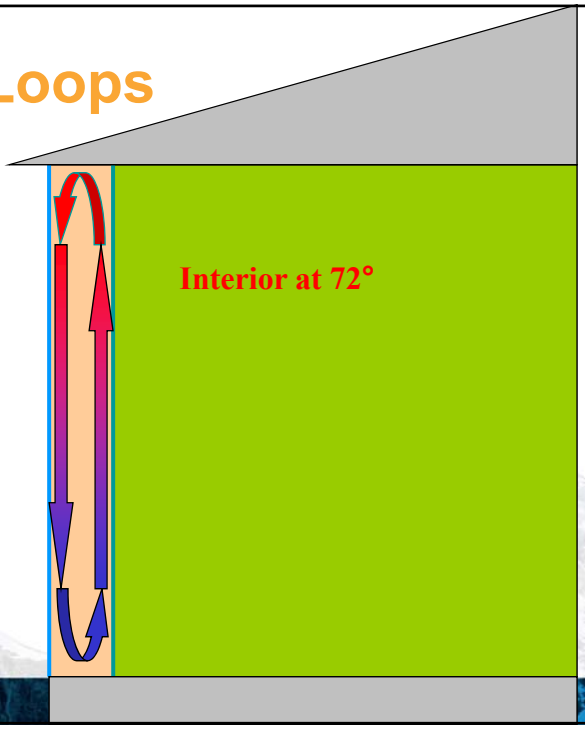
EnergyLogic

Convective Heat Loops

Exterior at 20°

Interior at 72°

Hollow wall cavities must be completely filled with insulation to discourage convective heat loops.



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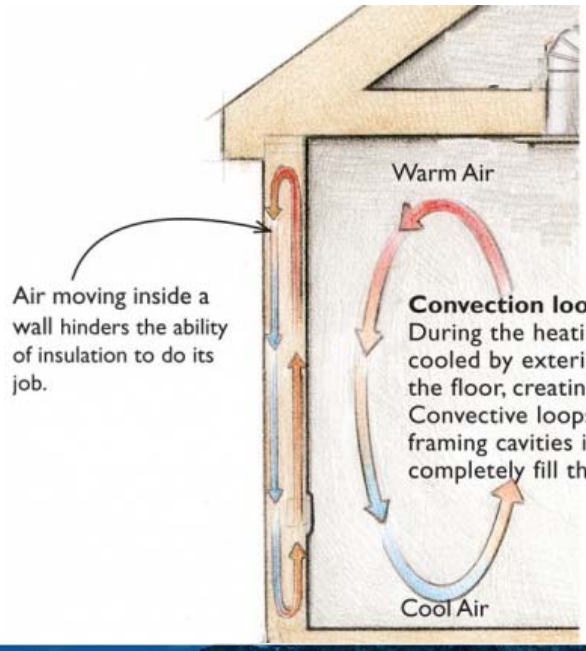

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Radiation

- Radiant heat energy flies through open space
  - From an object of high temperature
  - To an object of lower temperature.

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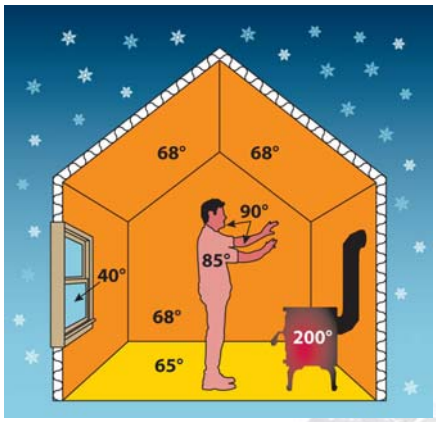
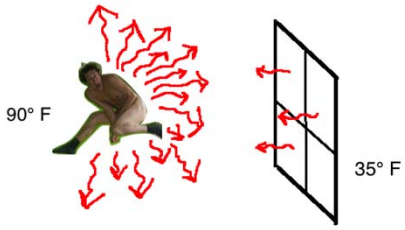
Human Comfort

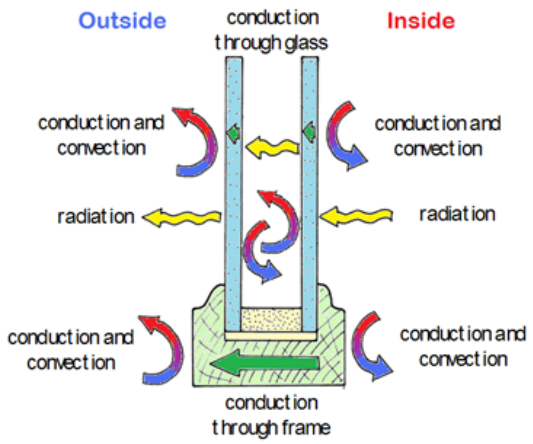
Mean Radiant temperature





EnergyLogic

Thermal Transmittance



- Heat flow through building assemblies, simultaneously, by conduction, convection, and radiant heat flow

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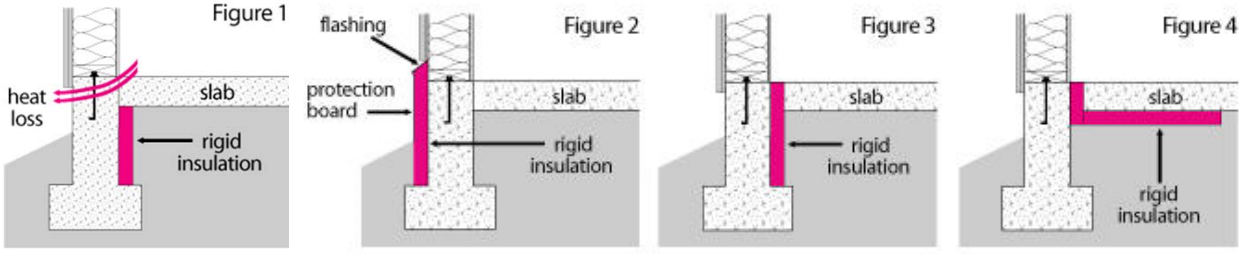
Controlling Thermal/Heat Flow



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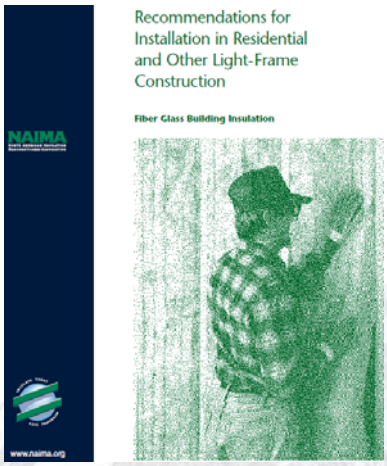
Air sealing and insulation

2015 IECC R402.4

- The components of the thermal envelope as listed in Table R402.4.1.1 **shall** be installed in accordance with the **manufacture's instructions** and the criteria listed in table R402.4.1.1 as applicable to the method of construction



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Insulation

Insulation traps pockets of air

Stagnate Air Pockets create the R-value

Air Barrier

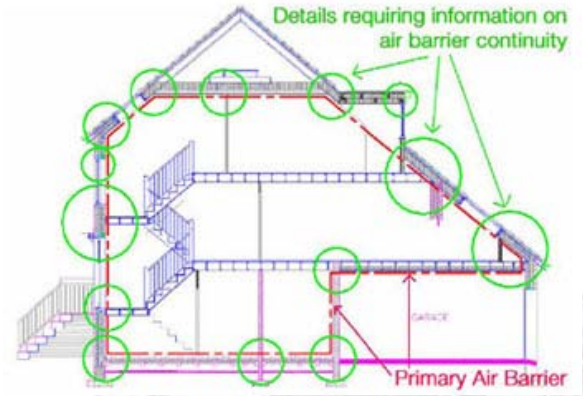
Stopping the movement of air from scrubbing away the stagnate air pocket

Now it works

EnergyLogic

Two Functions of an Air Barrier

- Interior vs. Exterior air barrier
- At its simplest form
  - Interior drywall
  - Exterior sheathing
    - House Wrap?
    - Drainage Plan
- Function
  - Enclosing Insulation
    - 6 sided encapsulation
  - Air control



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CONTROLLING THERMAL FLOW

Most insulation is NOT an air barrier

Resists Conduction

Does not resist Air Flow:
That is the job of the air barrier

* An Air Barrier is any solid material that blocks air flow including sealing at edges and seams

What is the biggest insulation Myth:
Insulation Stops the movement of air!

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Air Flow

The Building Science
Broken down

EnergyLogic

How does air move in a house?

EnergyLogic

Freight Train

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Can a House Be Too Tight?

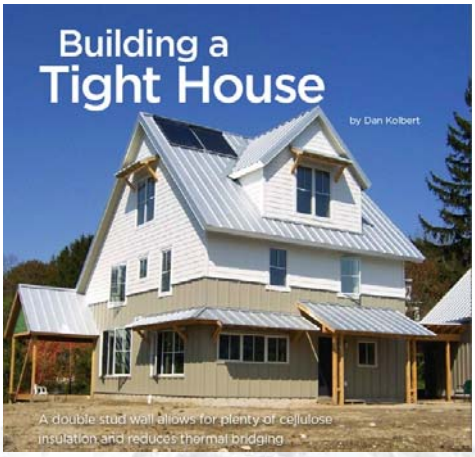
NO!

- Wrong question
- Control **air flow**
- In order to control the air

Real question …….

- Can houses be under-ventilated?

YES!



Build Tight and Ventilate Right

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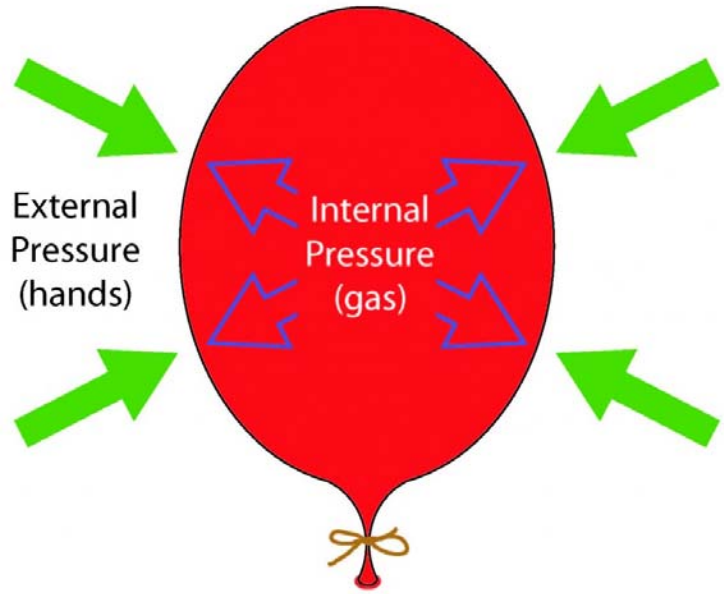
EnergyLogic

EnergyLogic



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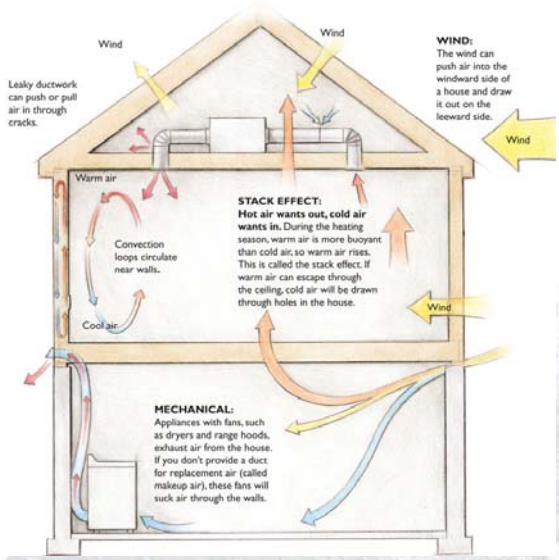
The important forces affecting air leakage in homes

- Stack
- Wind
- Mechanical



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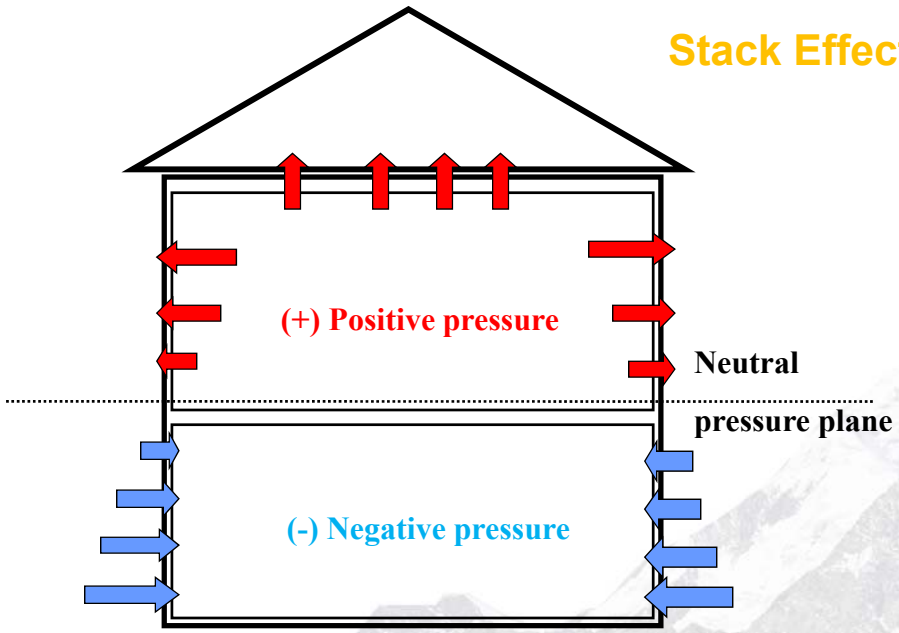
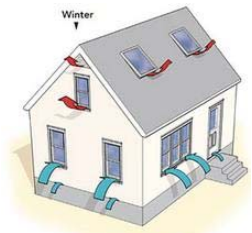
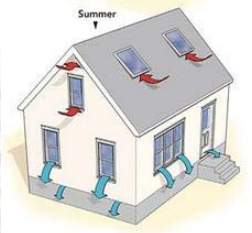
http://www.greenbuildingadvisor.com/air-leaks-waste-energy-and-rot-houses

Stack Effect: warm air rising







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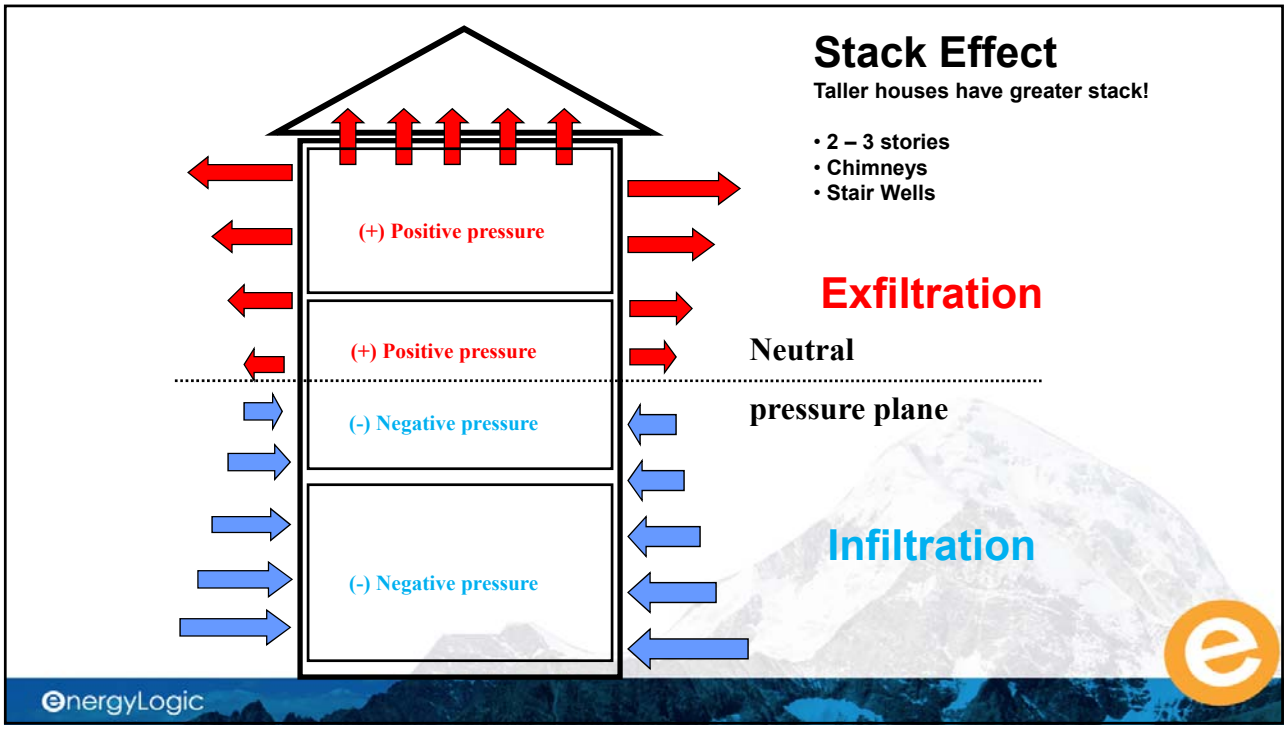
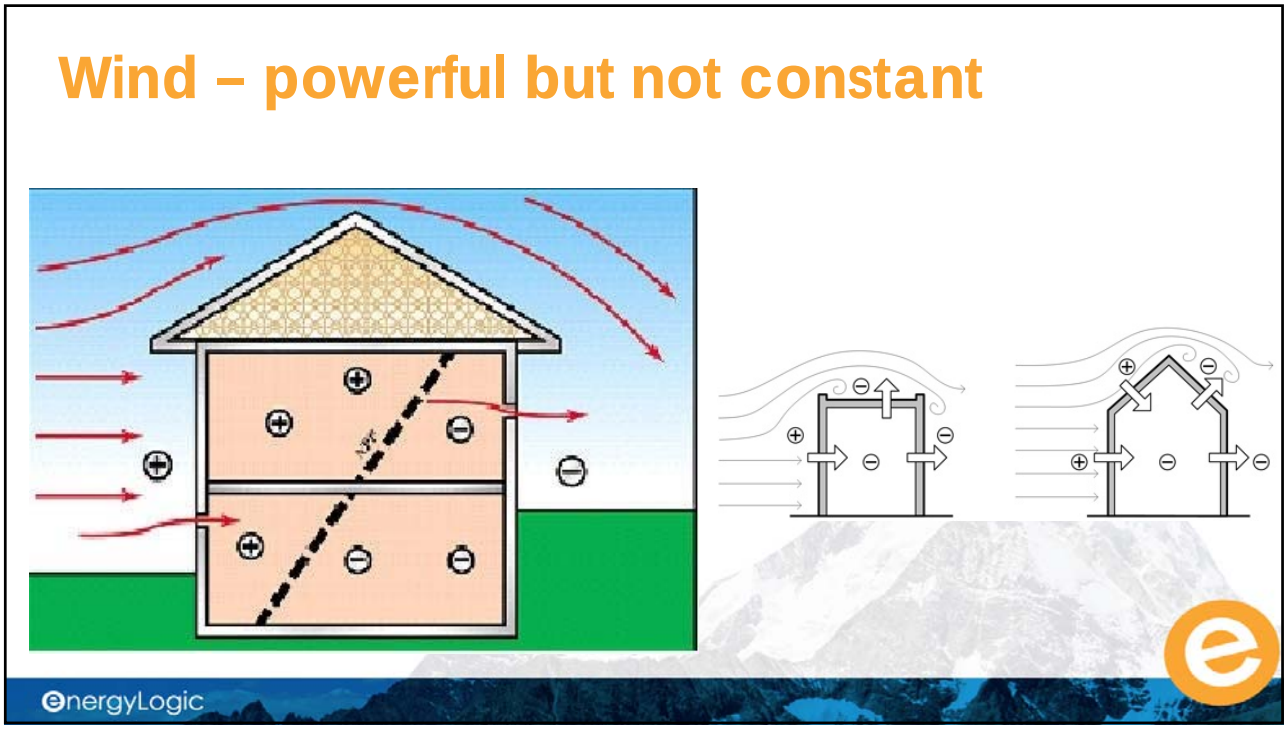
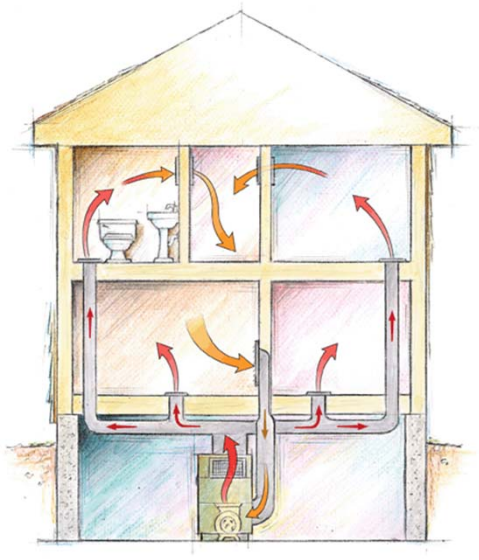

Stack Effect
Taller houses have greater stack!
• 2 – 3 stories
• Chimneys
• Stair Wells
(+) Positive pressure
(+) Positive pressure
(-) Negative pressure
(-) Negative pressure
Exfiltration
Neutral
pressure plane
Infiltration
EnergyLogic


Wind – powerful but not constant
EnergyLogic



Mechanical

- HVAC Systems
- Fans
  - Room Pressures
  - House pressure

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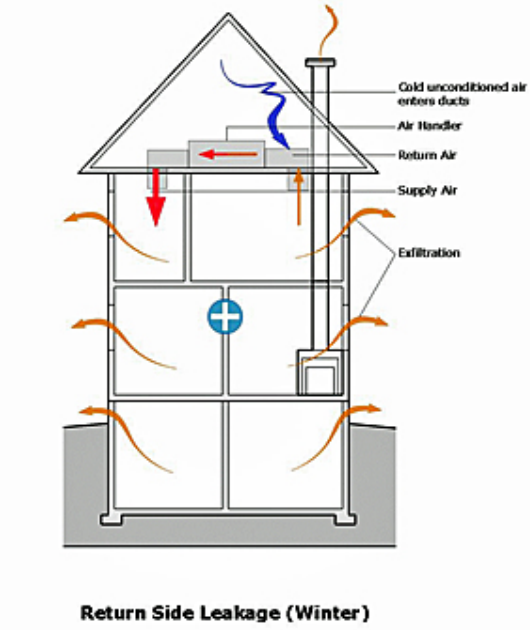

Return Side Leakage (Winter)

Supply Side Leakage (Summer)

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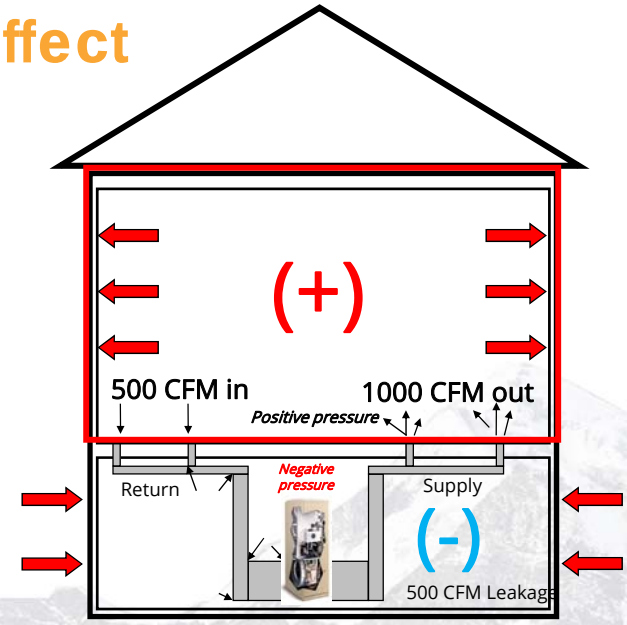
Mechanical effect

Return Leaks

Dominant leakage on the return ducts sends the basement zone negative



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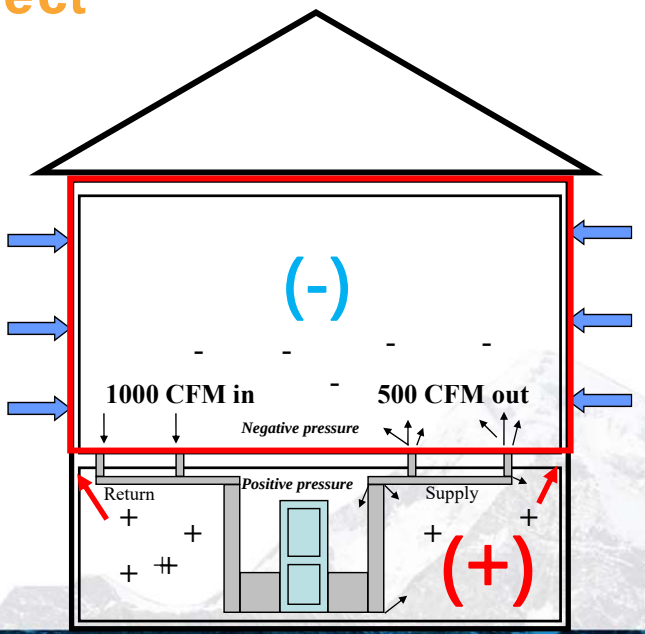
Mechanical Effect

Supply Leaks

If you have dominant leakage on the supply ducts



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Air Flow Summary

- Air is a fluid and will move if there is a path and a pressure present
  - Hole and driving force

If either is missing air will not move

Air in = Air out

CFM = Cubic foot of air

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Moisture Flow

The Building Science Broken down

EnergyLogic

http://www.greenbuildingadvisor.com/blogs/dept/energy-solutions/four-ways-water-gets-buildings

Vapor + Air

- Air = transport mechanism
- Vapor travels with air
- Move air, move moisture
- Summary
  - Hole / driving forces
  - If one or the other is missing, no flow
  - Equilibrium: No air in, No air out

Control the air by building tight!

EnergyLogic

Table 402.4.1.1 Air Barriers and Insulation Installation

(Mandatory)

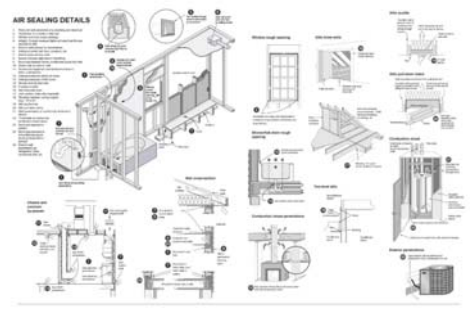
IECC

- R103.2 Information on Construction documents
- Details shall include but are not limited to:
  - Insulation location and R-values
  - Window U-value & SHGC
  - Mechanical System design criteria
  - Mechanical and water heater Type, size and efficiency
  - Duct sealing, insulation and location
  - Air sealing details

2015/18 IECC Table

TABLE 402.4.1.1 (N1102.4.1.1)
AIR BARRIER AND INSULATION INSTALLATION

COMPONENT	AIR BARRIER CRITERIA	INSULATION/INSTALLATION CRITERIA
General Requirements	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed.	Air permeable insulation shall not be used as a sealing material.
Ceiling / attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.	The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.



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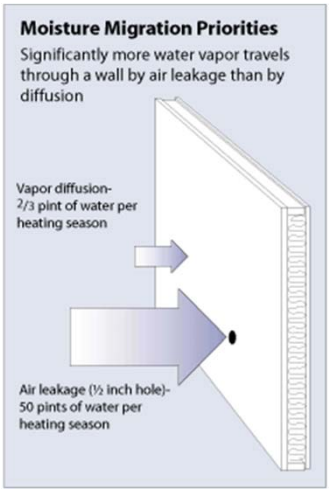
Moisture Flow



https://portlandenergysavers.com/energy_efficiency/moisturemovement.php

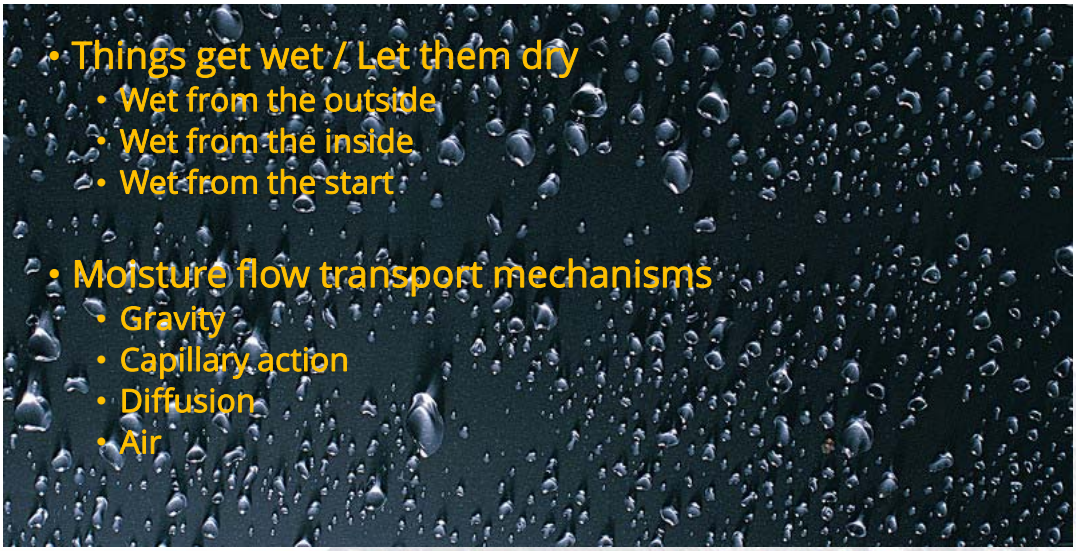
Why is this a 100 year old house?

Drafty, uncomfortable, yet very durable houses
- –Why?

Expectation?

We have changed the way we build so we need to understand moisture flow

Building Perspective



- Things get wet / Let them dry
  - Wet from the outside
  - Wet from the inside
  - Wet from the start
- Moisture flow transport mechanisms
  - Gravity
  - Capillary action
  - Diffusion
  - Air

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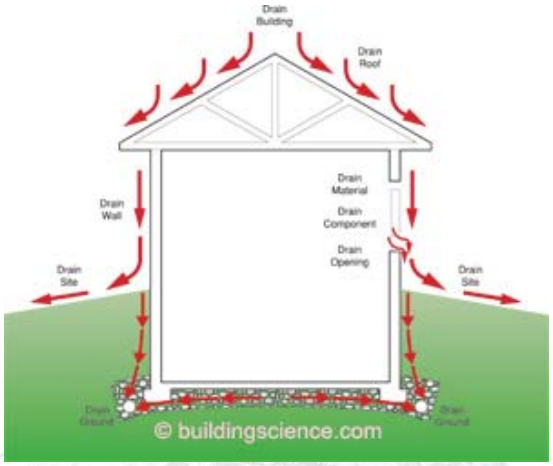
Gravity – Bulk Water

Wind Driven Rain, Snow, Ice…..

- Layer the materials so that water is:
  - Directed down
  - Directed out
  - Directed way
- Utilize gravity



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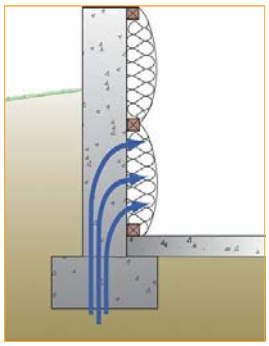
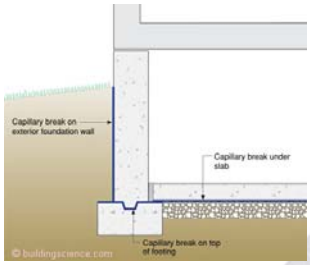
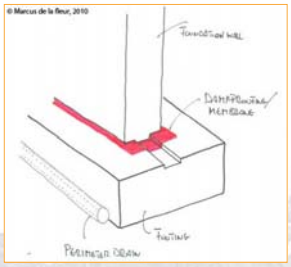
Capillary Action

- Water drawn upward or sideways
- Capillary Beak
- What is sill seal?







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Air leakage vs. Capillary break

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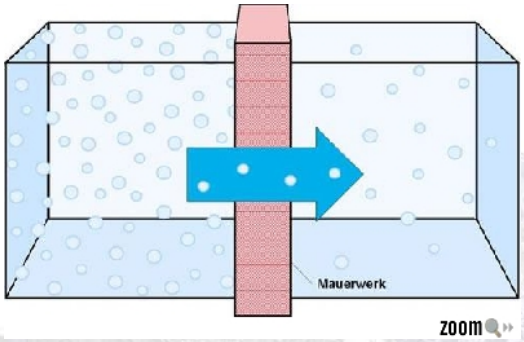
What is Vapor Diffusion?

- Moisture moving directly through a material
- What is Vapor Pressure?
  - It is the pressure exerted by water in air.

- It is a function of:
  - TEMPERATURE and
  - RELATIVE HUMIDITY



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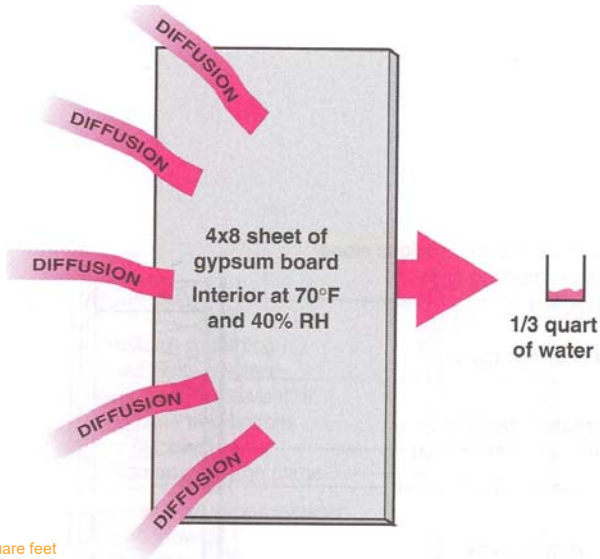
Vapor Diffusion a slow process



32 Square feet

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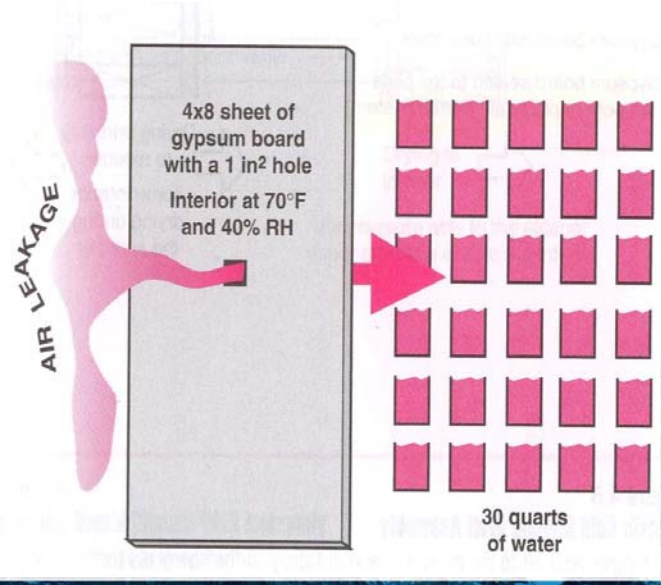
From EEBA Builder's Guide to Cold Climates by Joseph Lstiburek

The Problem is Air and the 4 M's

- Much
- More
- Moisture
- Movement

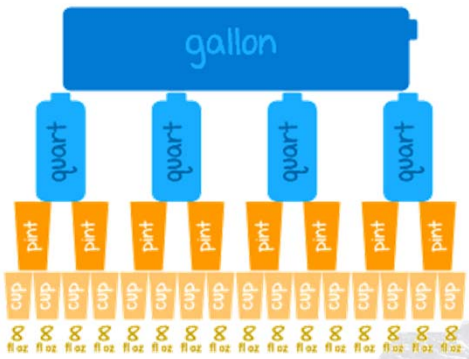


32 Square feet

From EEBA Builder's Guide to Cold Climates by Joseph Lstiburek

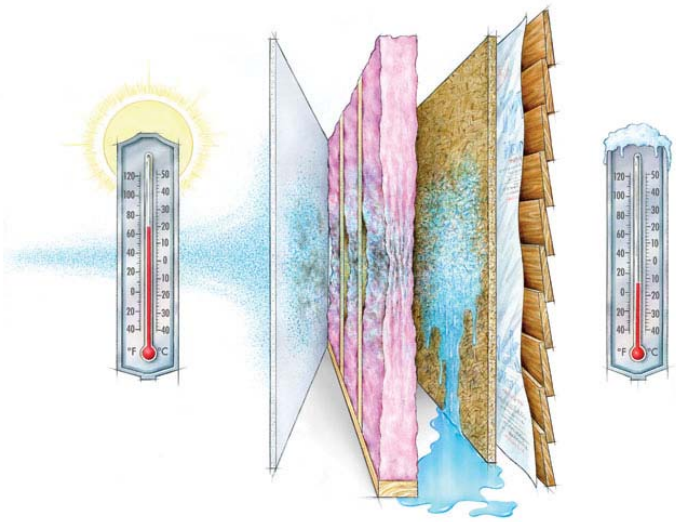
Diffusion vs. air leakage

- 1 Quart = 4 Cups
- 4 Quarts = 1 Gallon
- 30 Quarts = 7.5 Gallons



- Diffusion
  - 1/3 Quarts
- Air leakage
  - 30 Quarts

First Condensing Surface



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Dew-Point Condensation

% Relative Humidity

Temperature °F	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10
110	110	108	106	104	102	100	98	95	93	90	87	84	80	76	72	65	60	51	41
105	105	103	101	99	97	95	93	91	88	85	83	80	76	72	67	62	55	47	37
100	100	99	97	95	93	91	89	86	84	81	78	75	71	67	63	58	52	44	32
95	95	93	92	90	88	86	84	81	79	76	73	70	67	63	59	54	48	40	32
90	90	88	87	85	83	81	79	76	74	71	68	65	62	59	54	49	43	36	32
85	85	83	81	80	78	76	74	72	69	67	64	61	58	54	50	45	38	32	
80	80	78	77	75	73	71	69	67	65	62	59	56	53	50	45	40	35	32	
75	75	73	72	70	68	66	64	62	60	58	55	52	49	45	41	36	32		
70	70	68	67	65	63	61	59	57	55	53	50	47	44	40	36	32			
65	65	63	62	60	59	57	55	53	50	48	45	42	40	36	32				
60	60	58	57	55	53	52	50	48	45	43	41	38	35	32					
55	55	53	52	50	49	47	45	43	40	38	36	33	32						
50	50	48	46	45	44	42	40	38	36	34	32								
45	45	43	42	40	39	37	35	33	32										
40	40	39	37	35	34	32													
35	35	34	32																
32	32																		

70° Temp + 35% RH = 40° Dew-Point Temp

Courtesy of DOW Building Materials

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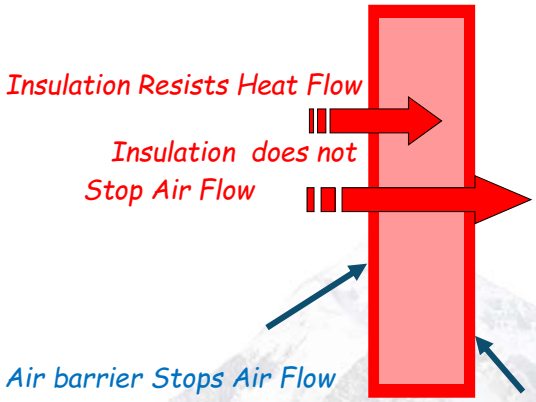
Air Barrier or Vapor Barrier that is the Questions?



solid materials are best at blocking air flow
- OSB, Drywall, T-ply

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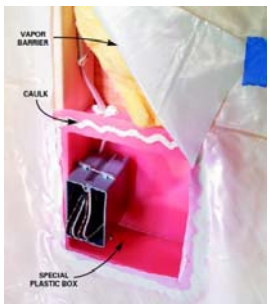
What we don't do…..



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5 key Air Barriers Attributes

What we can do….

- Continuity: The most important element in 3D structures with so many different components to ensure alignment between insulation and the air ABS
- Impermeability: The ABS must be impermeable to Air after installation.
- Strength: The ABS must be designed to transfer the full designed wind load, stop external or internal air movement into the assembly, and continue to be impermeable
- Durability: The ABS must continue to be impermeable throughout its service life, or at the IECC says, "over the useful life of the building."
- Stiffness: The ABS must be stiff enough so that irregularities in the building found at installation of the ABS do not change its permeance

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6 Recommendations for Vapor Management

What we should do…..

- Encouraging drying mechanisms over wetting prevention mechanisms
- Avoid using vapor barriers where vapor retarders will provide satisfactory performance
- Avoid using vapor retarders where vapor permeable materials will provide satisfactory performance
- Avoid the installation of vapor barriers on both sides of assemblies
- Avoid the installation of vinyl wall coverings on the inside of air-conditioned assemblies
- Encourage ventilation meeting ASHRAE Standard 62.2 or 62.1
  - Now a mandatory part of Code

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Conclusion

Understanding Building Science

- Systems thinking
  - Synergy
- Applied Building Science
  - Control and Predictability
    - Heat Flow
    - Air Flow
    - Moisture Flow
- Sound/well defined building envelope
  - Insulation and Air barrier

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Tunnel House

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Thank you!

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