Welcome

Houses That Work

Continuing Education Credits

www.eeba.org

The EEBA High Performance Builder Certification

- The Houses That Work Building Science workshop
- The HERS Associate Course
- The High Performance Mechanical Systems course

The Houses That Work Building Science Workshop

- 3 modules:
  - The building science principles and rules
  - Building Enclosure details that work
  - Mechanical and sustainable elements

Who's here and What would you like to talk about??

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Four Module Agenda

- Compelling Industry trends
- The Essential High Performance elements in a home
- Basic building science to effectively manage the flow of **Heat, Air and Moisture** in buildings
- Creating building enclosures that work for healthy, safe durable, efficient and sustainable homes.
  - Foundation systems
  - Above grade wall systems
  - Windows
  - Roof and attic systems
- Heating, Ventilation and Air Conditioning Systems (HVAC) that work in high performance homes
- Then a final summary, including a discussion of process changes you will want to undertake to implement all that you have learned.

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What is our goal?

"Create an enclosure that separates the indoors from the outdoors...and is safe and healthy for the people inside."

In addition to:

Creating a high performance home that is; energy efficient, durable, healthy, aesthetically pleasing, respectful to the environment and profitable...

in short, **HOUSES THAT WORK**

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House Systems

What's Changed in homes in the last 35 years?
What impacts does that have?

What's the decision tree?

- Decisions made on price
- Decisions made on warranty/service issues
- Customers satisfaction/expectations
- Process/cycle times
- Supplier availability

We are here to help reinforce your decision process

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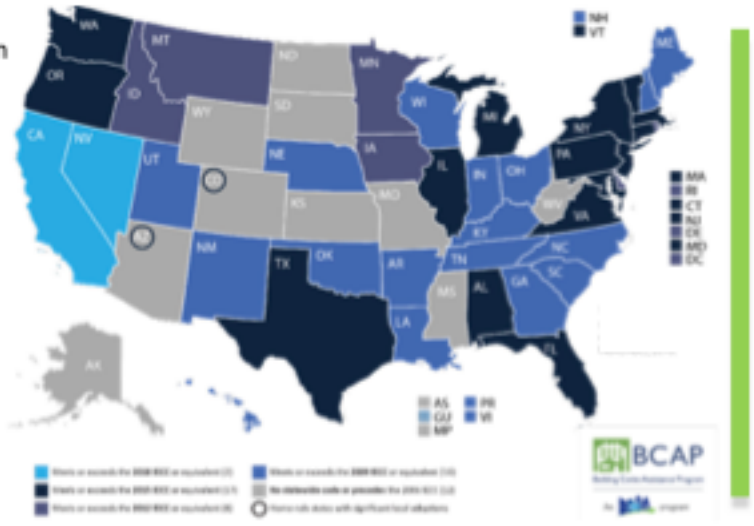
Codes Have Changed

Residential Code Adoption

as of March 2020



There are Programs to Help

RESNET HERS INDEX

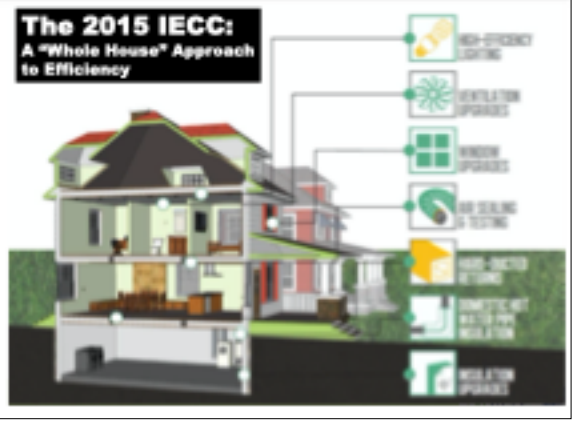
ENERGY STAR

ZERO ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

PHIUS
Passive House Institute US

RESNET. HERS INDEX

Codes respecting the science



Codes will be more Performance Objectives

Climates	2015 IECC HERS Index Scores
Zone 1 — 2	52
Zone 3	51
Zone 4	54
Zone 5	55
Zone 6	54
Zone 7 — 8	53

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What's Changing quicker....
Codes or expectations of consumers?

- Comfort
- Quiet
- Lifestyle
- Investment quality
- Demographics
- Access to information
- Warranty

Defining High Performance Homes….


Tighter Construction


Improved Insulation Systems


Improved Insulation Systems

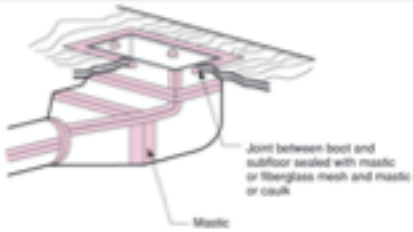

Improved Durability

High Performance Windows

ENERGY PERFORMANCE RATINGS	
U-Factor (U.S./I-P)	Solar Heat Gain Coefficient
0.18	0.22
ADDITIONAL PERFORMANCE RATINGS	
Visible Transmittance	Air Leakage (U.S./I-P)
0.42	0.1
Condensation Resistance	
70	

Efficient Heating and Cooling Equipment

Effective Distribution



Efficient Water Heating

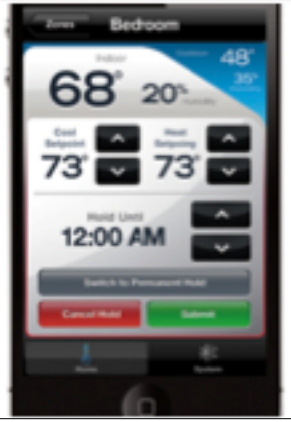
Ventilation & IAQ Systems

Lighting-Energy Efficiency

Efficient Appliances

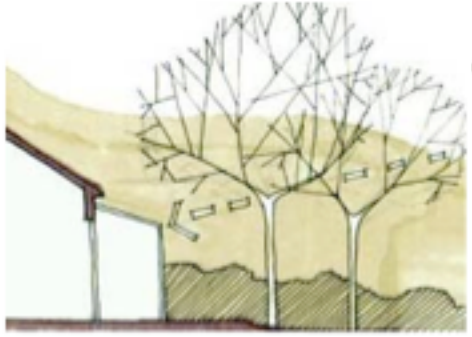
Water Efficiency

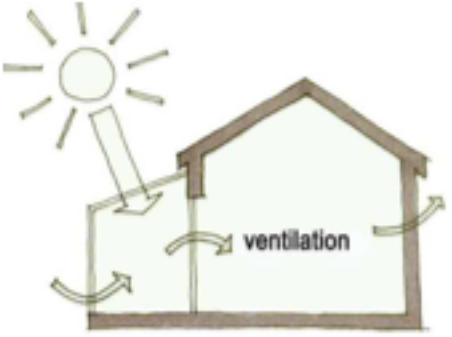
Smart Technology



Sustainable Materials

Site planning





Renewable Energy & Storage Systems

A Complicated Business

- Extensive collection of materials
- Uncontrolled building conditions
- Communication challenges
- Workforce training
- Changing codes
- Elevated consumer expectations

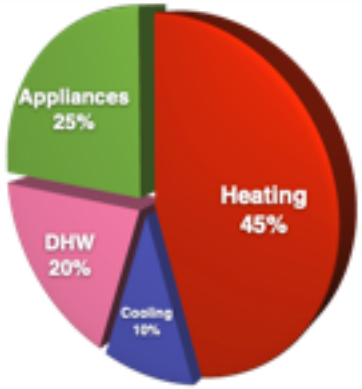
discussing a high performance heating system installation in field

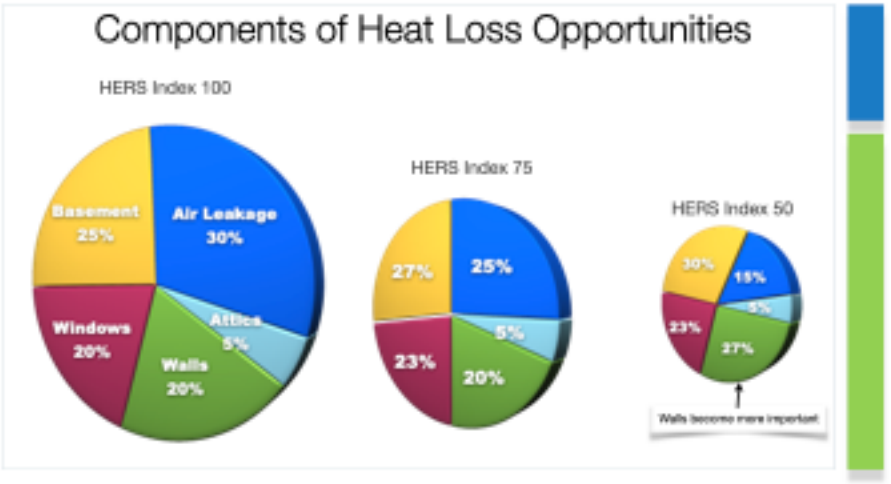
Let's Proceed with Some Science

Energy use in homes - Cold Climate

Typical cold climate home

- This is energy used - the costs of energy will vary
- What would you do first?
- Is usage going up or down?

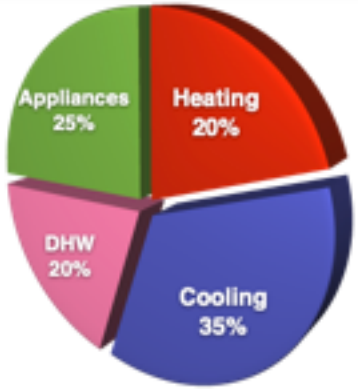




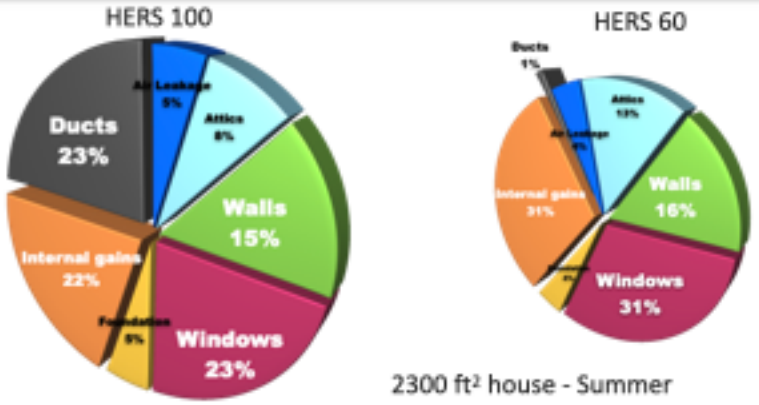
Energy use in homes - Hot Climate

Typical hot climate home

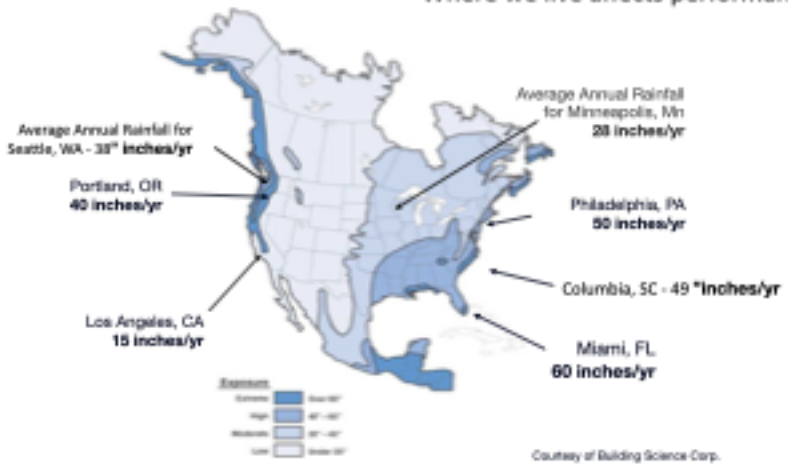
- This is energy used - the costs of energy will vary
- What would you do first?
- Is usage going up or down?



The opportunities for energy improvements



Where we live affects performance.



Design Conditions will affect your decisions

Somewhere, USA

Condition	ASHRAE 99.6% / 0.4%
Design Heating Temperature (F)	24.0 °F
Design Cooling Temperature (F) / Coincident Dew Point	86 °F / 66 °F
Design Dehumidification day (F) / Coincident dew point (F)	69.5 °F / 61 °F
Degree days-heating	4280
Degree days-cooling	279
Precipitation	38" / yr

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Our investment in the structure is significant

We often under invest in managing moisture

The resulting damage can be extensive

What defines durability?

- Materials & Products
  - Are they installed properly?
  - Are they compatible with surrounding materials?
  - Are they replaceable?
- Will they be affected by:
  - Water
  - Heat
  - Radiation
  - Insects

Insects & Rodents

Each climate zone has insects that affect the building and their clients. Understanding their needs is the best deterrent.

The Building Industry is Changing

"You must learn from the mistakes of others. You can't possibly live long enough to make them all yourself."

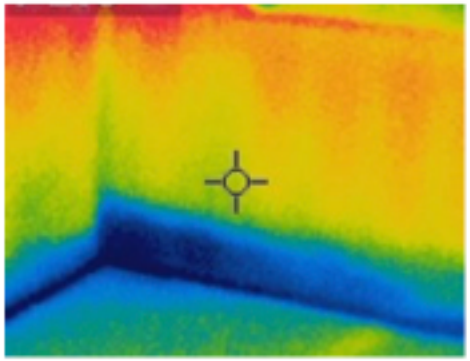
Sam Levenson

Humorist Sam Levenson, 1911-1980.

Take a Strategic Approach

Apply the science to the building enclosure

What rules must be followed?



Building Science Fundamentals

- Heat
- Air
- Moisture

The Physics of Buildings

- Moisture moves from more to less
- Moisture moves from warm to cold
- Heat flows from warm to cold
- CFM (air) out equals CFM (air) in
- Heat, air & moisture are one
- Drain the rain
- Things always get wet - let them dry
- All the action happens at the surface

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Let's start with Heat Flow

Methods of Heat Transfer

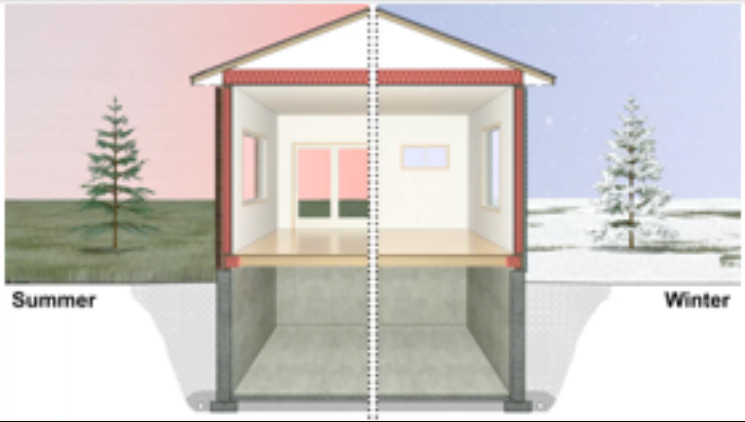
- Conduction

- Convection

- Radiation

Heat Transfer by Conduction

Primary mechanism through walls, floors, attics



Conduction Heat Loss/Gain

Heat flow = $\frac{\text{Exposed Area} \times \text{Temp. Difference}}{\text{R-Value}}$

Example: With R-30 insulation in the attic

Heat Loss through 1000 sq. ft of ceiling, 70 F inside, 10 F outside

=1000 × (70 - 10) / 30 **= 2,000 BTUs/hr**

Conduction Heat Loss/Gain

Heat flow = $\frac{\text{Exposed Area} \times \text{Temp. Difference}}{\text{R-Value}}$

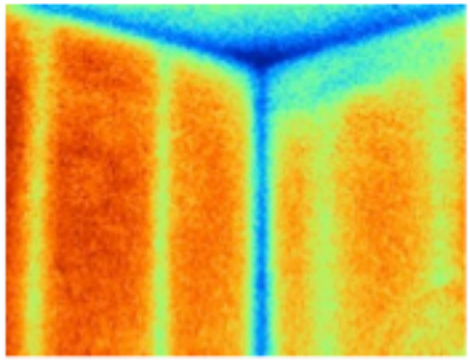
Example: With R-30 insulation in the attic

Heat gain through 1000 sq. ft of ceiling, 135 F in the attic, 75 F in the house

=1000 × (135 - 75) / 30 **= 2,000 BTUs/hr**

=1000 × (135 - 75) / 60 **= 1,000 BTUs/hr**

Thermal bridges

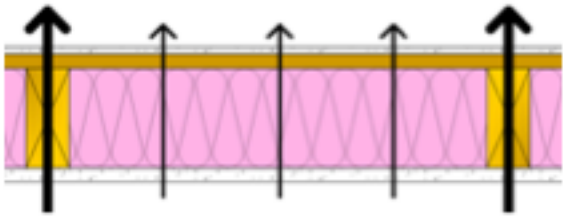


Thermal Bridging- Problem

Heat flows more easily through wood studs = Conduction

2" x 4" stud = R-3.5

Insulation cavity = R-13+

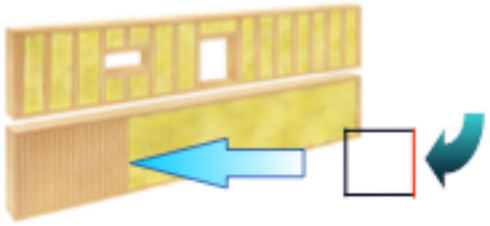


What about...double, triple studs, rim joists, headers and partition wall intersections?

Thermal Bridging - Stud Loss

- Without insulated sheathing, a quarter of your walls are not insulated!
- On a square house, it's the equivalent of one whole wall!

25% of the surface Area is wood!



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Effective R-value of 2 x 4 wall- no windows or doors

23% framing-no windows	R-Value	
	Cavity	Studs
Outside air film	0.17	0.17
½" OSB	0.62	0.62
2 x 4 stud-wood	n/a	3.71
cavity insulation*	13	n/a
½" gypsum	0.45	0.45
Interior air film	0.68	0.68
Totals	14.92	5.63
Total wall	9.92	

* denotes "perfect" insulation installation

Remember this number

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There are 3 ways to reduce conduction flow

Increase cavity insulation

Reduce thermal bridges - reduce framing

Add continuous insulation

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Effective R-value of 2 x 6 wall- no windows or doors

23% framing-no windows	R-Value	
	Cavity	Studs
Outside air film	0.17	0.17
½" OSB	0.62	0.62
2 x 6 stud-wood	n/a	5.83
cavity insulation*	21	n/a
½" gypsum	0.45	0.45
Interior air film	0.68	0.68
Totals	22.92	7.75
Total wall	15.26	

* denotes "perfect" insulation installation

Remember this number

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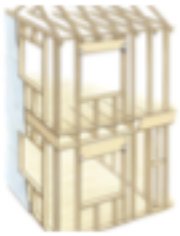
2 x 6 Wall Total Effective R-Value with HD Foam

Framing Percentage	R-Value	
23%	Cavity	Studs
Outside air film	0.17	0.17
Exterior insulation	0	0
7/16" OSB	0.62	0.62
Cladding/Siding	0.62	0.62
Framing - 2 x 6	n/a	5.83
cavity insulation	35	n/a
½" gypsum	0.45	0.45
Interior air film	0.68	0.68
Sub-Totals	37.54	8.37
Total Wall R- Value	18.81	

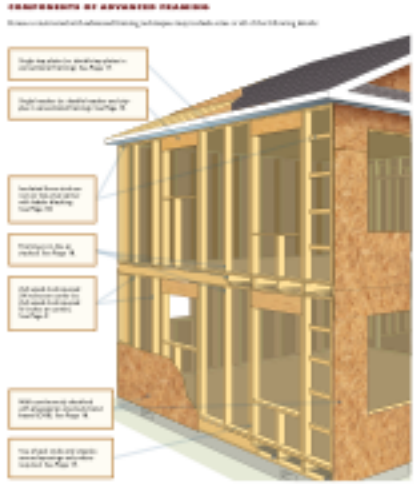
3 Ways to improve Effective R-values

- More cavity insulation
- **Advanced / Optimized framing**
- Continuous insulation



Elements

- **Two stud corners**
- **Ladder framing**
- **Wider stud spacings**
- **Properly sized headers**
- **Single top plates**

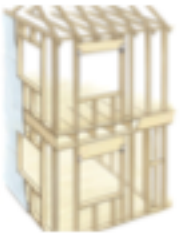


2 x 6 Wall Total Effective R-Value

Framing Percentage	R-Value	
19%	Cavity	Studs
Outside air film	0.17	0.17
Exterior insulation	0	0
7/16" OSB	0.62	0.62
Cladding/Siding	0.82	0.82
Framing - 2 x 6	n/a	5.83
cavity insulation	20	n/a
½" gypsum	0.45	0.45
Interior air film	0.68	0.68
Sub-Totals	22.54	8.37
Total Wall R- Value	16.22	

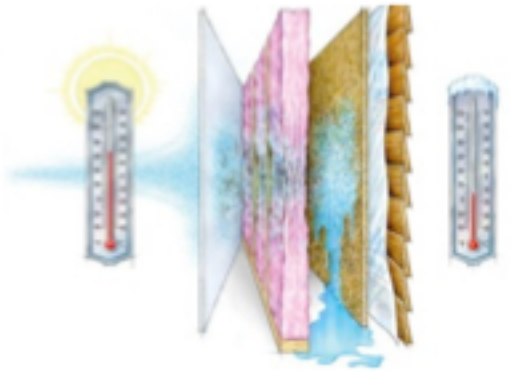
3 Ways to improve Effective R-values

- More cavity insulation
- Advanced / Optimized framing
- **Continuous insulation**



2 x 4 Wall + R5 Total Effective R-Value

Framing Percentage	R-Value	
25%	Cavity	Studs
Outside air film	0.17	0.17
Exterior insulation	5	5
7/16" OSB	0.62	0.62
Cladding/Siding	0.62	0.62
Framing - 2 x 4	n/a	3.71
cavity insulation	13	n/a
½" gypsum	0.45	0.45
Interior air film	0.68	0.68
Sub-Totals	20.54	11.25
Total Wall R- Value	15.54	



The dew point discussion

Vapor Permeance of Materials

Material	Imperial Permeance
6 Mil polyethylene	0.06 Perms
Drywall	20 - 60
Building paper	5-10
Structural Sheathing	
Wood	2 - 8
Plywood	0.75 - 3.5
OSB	0.75 - 2
Insulated Sheathing	
Foil Faced Poly Iso - 1"	0 to 0.01
XPS - 1"	0.75 - 1.5
EPS - 1"	2 - 4
EPS with foil face - 1"	0.5 - 1.5
WRBs	
Spun bonded Polyolefin	20 - 50
Coated Wraps	6 - 14

Construction Instruction®
Building Science for Everyone, Everywhere

Condensation

The more insulation, the greater the risk

Insulated Sheathing will be Normal

It doesn't have to be foam

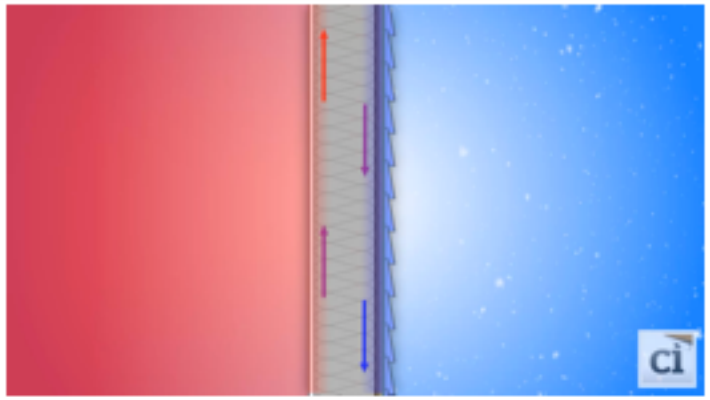
Advanced wall systems improve effective R-values

Effective R-Value of framed walls

Wall Options	Total Effective R-Value
Traditional 2 x 6 with R20 Batt insulation	15
Zero Energy Ready Wall for "Mild Climates":	
2" x 4" w/ R-15 Cavity + R-10 cont. ext. insulation	21
Zero Energy Ready Wall for "Cold Climates":	
2" x 6" w/ R-23 cavity + R-10 cont. ext. insulation	27

Heat Transfer by Convection

Convection loops occur in air gaps



There are 3 ways to reduce convection flow

No gaps or voids

Seal the holes

Use inert gases - windows

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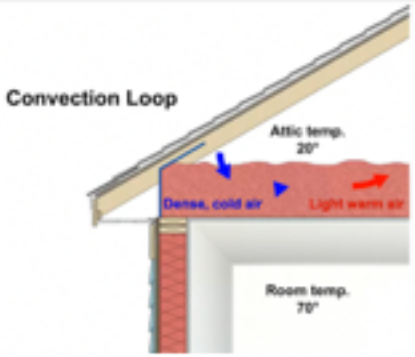
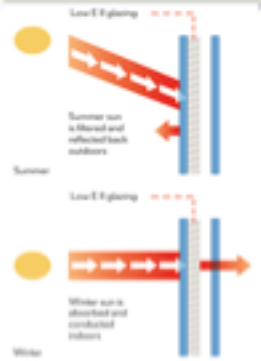
Convective loop in attic insulation

- Mitigated by adding more insulation
- Avoid wind washing of insulation

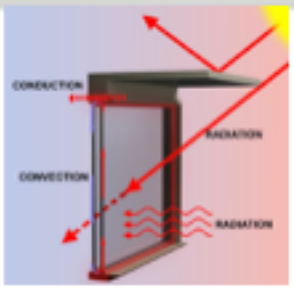


Heat transfer by Radiation - surface to surface

There are 3 ways to optimize radiation flow



Selective Low E coatings



Proper shading

Radiant barriers

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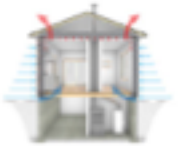
Choose appropriate windows for your climate

Now consider Air Flow

Methods of Air Flow

- Wind



- Stack

- Mechanical

Reasons we want houses to be tight

- Most cost effective energy saving measure - 20% - 30% savings
- Makes homes quieter and cleaner
- Makes homes more "comfortable"
- Reduces water entry - homes last longer
- Makes homes healthier - controlled air quality
- Environmental benefits because we are not wasting energy

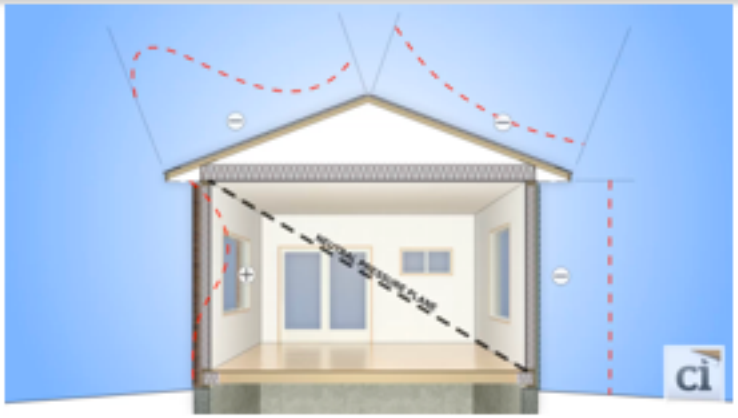
Are there any concerns of Houses Being "Too Tight"?

From an Energy Perspective we would like houses to be very tight

What are possible concerns about house being tight?

- Indoor Air Quality
  - Moisture problems
  - Chemical pollutants
- Combustion Safety
- "The walls have to breathe"

Wind effects are highly variable



Stack effect
- pressures created by air temp. differences

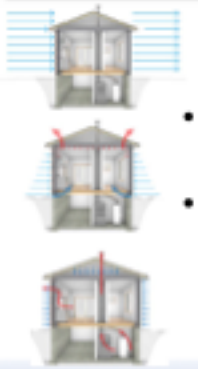
Mechanical systems may adversely affect performance

Neutral pressure plane of building

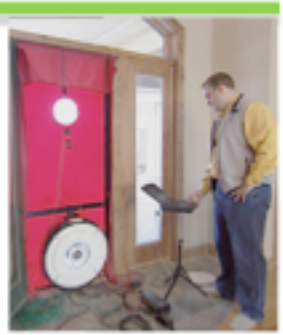
- The neutral pressure plane will change
- Wind, stack & mechanical effects
- Its locations determines which holes leak and in which direction

Moisture laden air flow can create problems

Managing Air Flow



- Its difficult to manage the varying pressures
- Its most cost effective to make buildings tighter - seal the holes



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Finally…
Moisture Flow

A very complex subject

Forms of Moisture

- Solid

- Liquid

- Vapor

Water in liquid form is the most concerning

Managing water is critical to sustainability

4 Moisture Flow Mechanisms

- Liquid Flow (gravity driven)
  - Rain
- Capillary
  - Material wicking
- Air Transport
  - Pressure induced flows of moisture laden air
- Diffusion
  - Vapor pressure drive

Liquid flow is the most important

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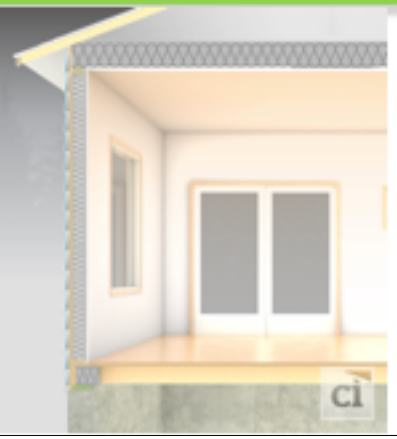
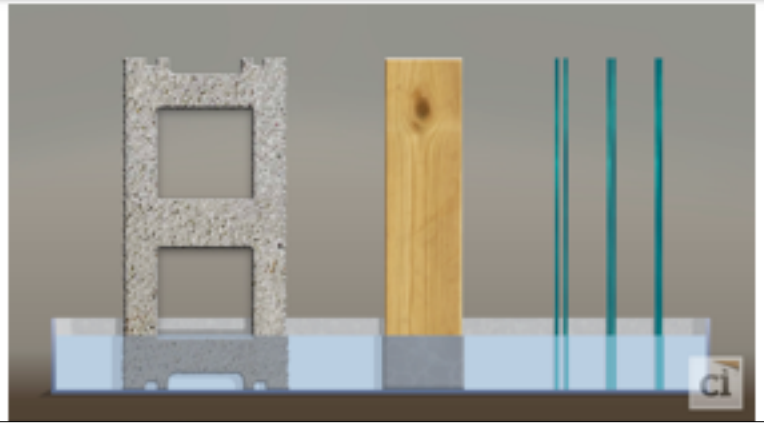
Managing liquid water flow

Deflection
Drainage
Drying
Durability



Capillary Flow



Capillary Flow

- Wood & concrete wick water
  - In wood water can climb in excess of 300 ft!
  - In concrete water can climb in excess of 1,000 ft!

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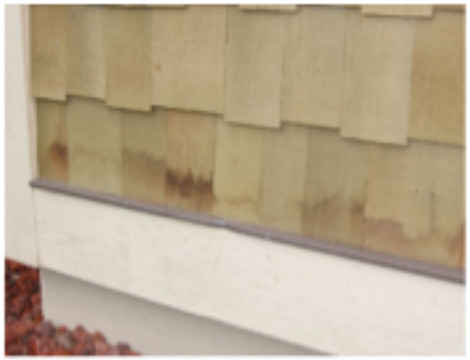
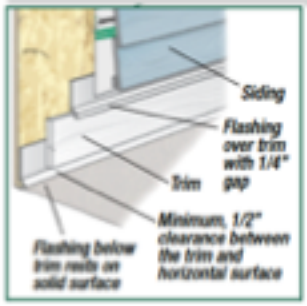
Capillary Flow



There are 2 ways to manage capillary flow



Create 1/4" to 1/2" gaps

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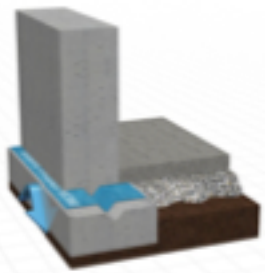
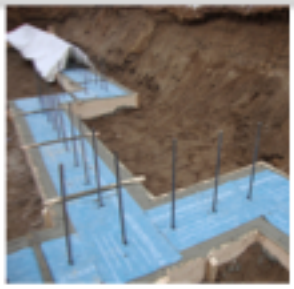
There are 2 ways to manage capillary flow





Use capillary break materials

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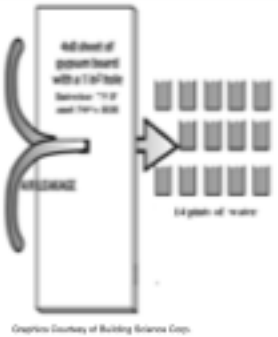
Air Transport of Water Vapor



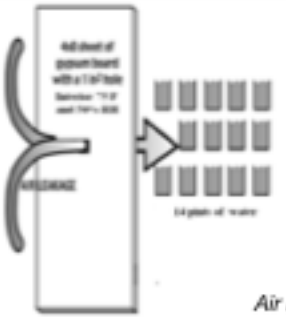
- Air Leakage
  - Moisture flow through a 1in² hole by air leakage
- Flow quantity
  - 14 Pints of water in a two week period

Construction Instruction®
Building Science for Everyone, Everywhere

Condensation

The more insulation, the greater the risk

Air Transport of Water Vapor



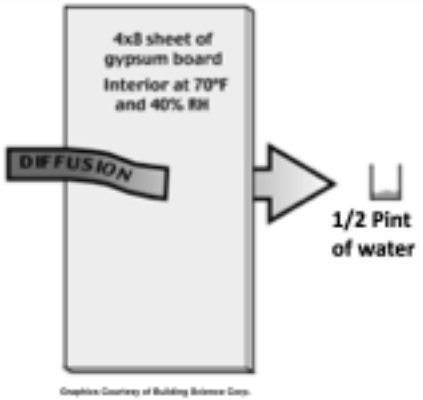
- Air Leakage
  - Moisture flow through a 1in² hole by air leakage
- Flow quantity
  - 14 Pints of water in a two week period

Air barriers are far more important than vapor retarders in most cases

Diffusion of Water Vapour through Materials

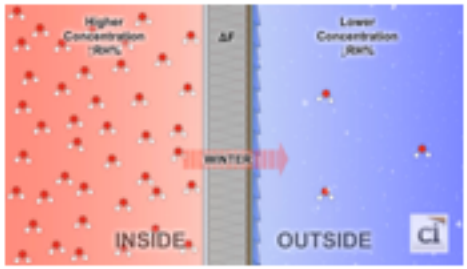
Diffusion

- Migration of moisture by means of vapor pressure differential
- Occurs in either direction based on climate conditions and interior levels of humidity
- One season

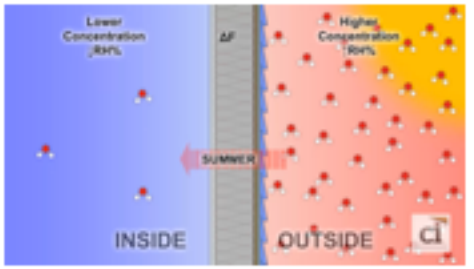


Graphics Courtesy of Building Science Corp.

Vapor Diffusion is Complex



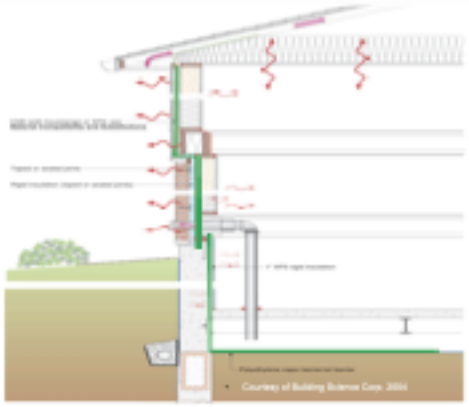
Winter



Summer

Vapor Diffusion

- Diffusion is a "weak" wetting mechanism
- It can be a useful drying mechanism



The Physics of Buildings

- Moisture moves from more to less
- Moisture moves from warm to cold
- Heat flows from warm to cold
- CFM (air) out equals CFM (air) in
- Heat, air & moisture are one
- Drain the rain
- Things always get wet - let them dry
- All the action happens at the surface

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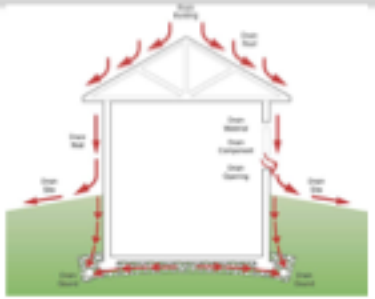
NOW THAT WE KNOW THE BUILDING SCIENCE BASICS....

We can begin to create walls, roofs and foundation systems that work

From the Ground Up

- Manage water
- Manage thermal
- Manage air

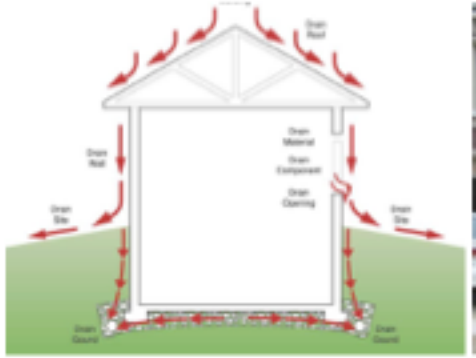


Graphics from EEBA Water Management Guide

When below grade....

- Remember the rules:
  - Moisture is present
  - Insects are close by
  - Soil gas can enter
  - Surfaces can be cool
  - Concrete wicks water
  - Foundations can be very challenging

Drain the Building



Graphics from EEBA Water Management Guide

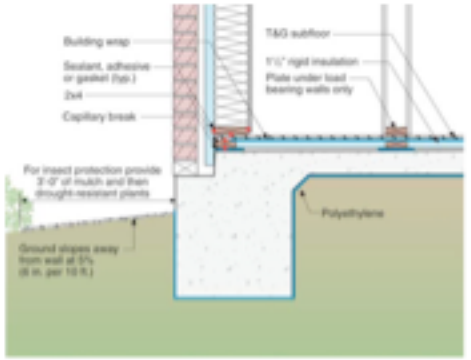
Full basement

Crawl spaces

Slab on Grade

It starts with proper grading & drainage

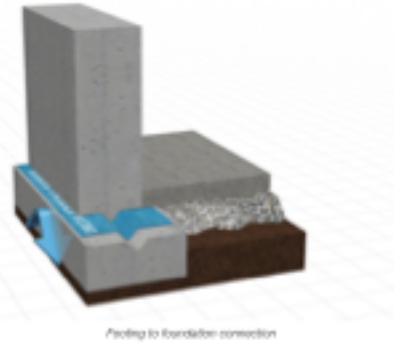
- 5% - 6" over 10'
- At least 4' to 6' away



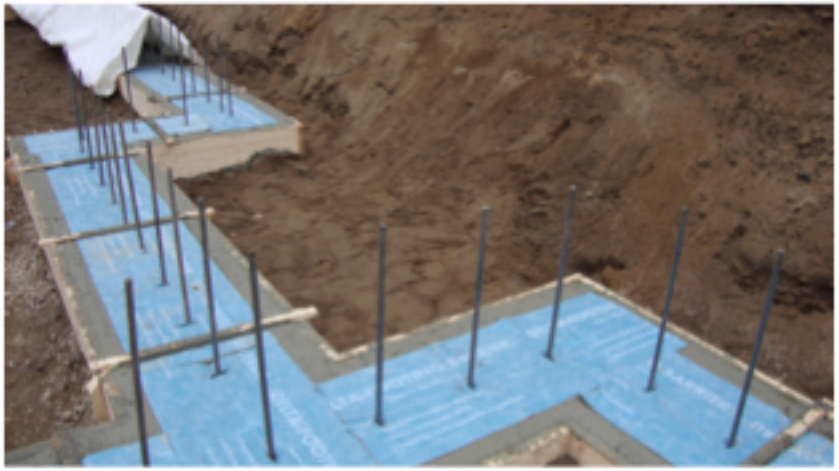
Landscape too close to the foundation

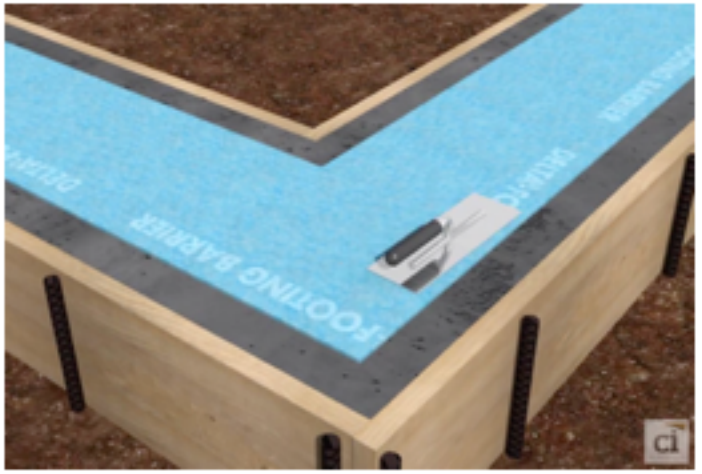
Capillary break applied between footing and foundation wall

- Required whenever one porous component meets another
  - Footing/slab to foundation wall
  - Foundation wall to framing
  - Under slabs-on grade

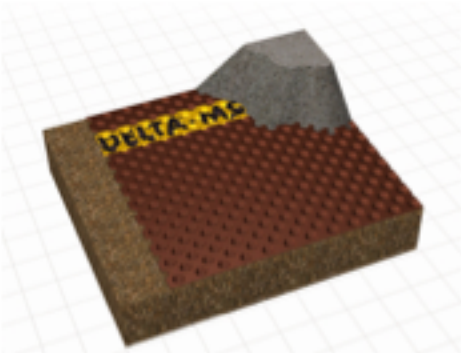


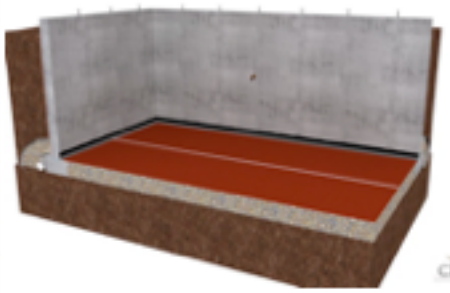
Footing to foundation connection

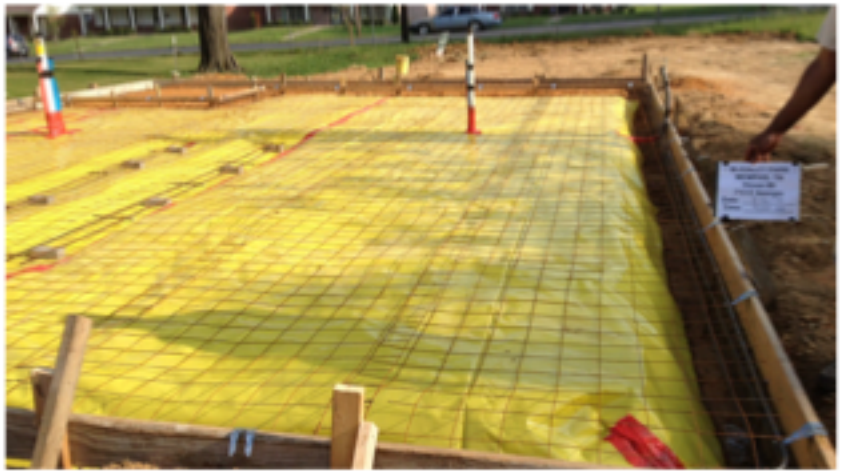




Membrane under-slab

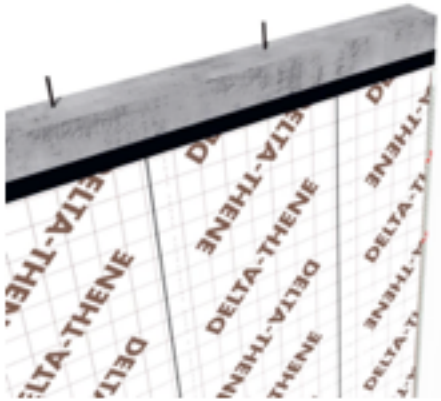






Drainage is very helpful

DELTA-DRAIN TO BE INSTALLED IN ROWS FROM
BOTTOM TO TOP OF WALL, OVERLAPPING SHINGLE-STYLE

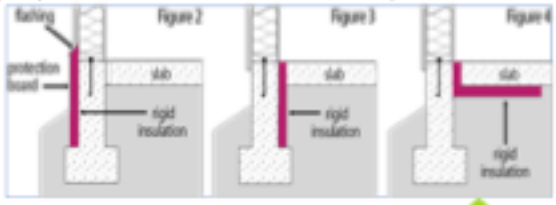


Foundation Insulation is Cost Effective

A case for insulating slabs

Insulation - Slab Perimeter

- Heat loss is significant - 15% - 20% - in the heating season through an un-insulated slab (FOREVER!!)
- Heat gain is significant - 10% or more in the cooling season
- Slab perimeter insulation strategies (vertical, horizontal, interior, exterior)



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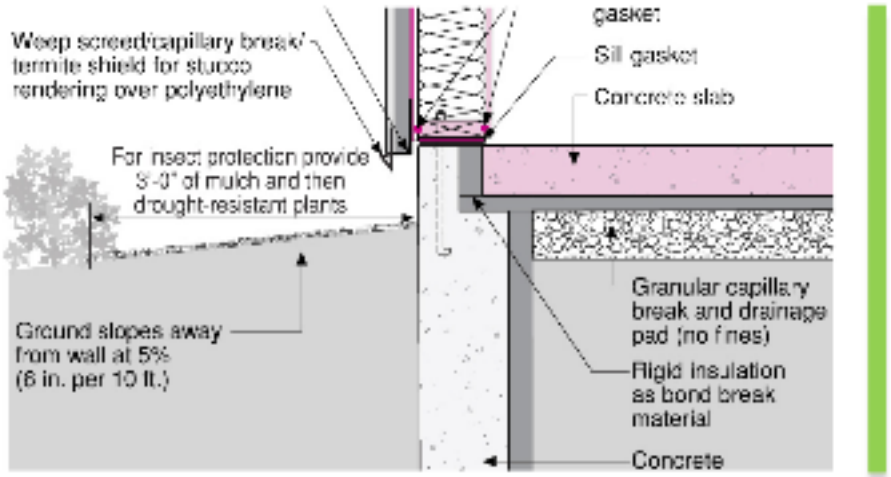
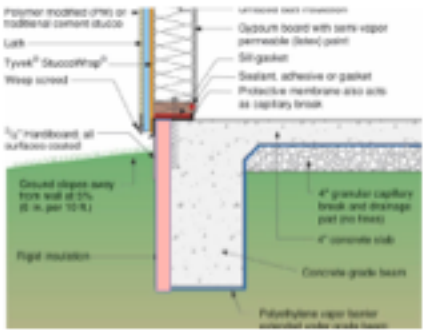


Slab

- Foam at slab edge
- Vapor barrier under concrete slab
- capillary break - stone; provides drainage



Always install vapor protection directly under slabs

Watch this quick video with my partner and EEBA certified trainer.
At our Construction Instruction Live experience centre he has created a helpful mockup of a foundation slab assembly where he can test and assess slab moisture

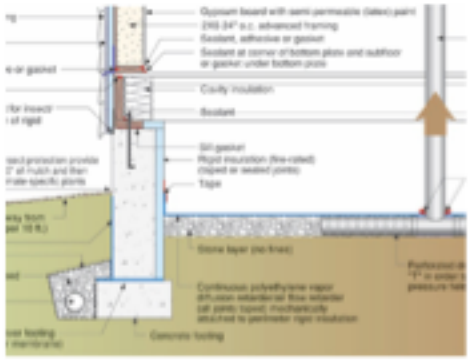
Lets turn out attention to crawlspaces

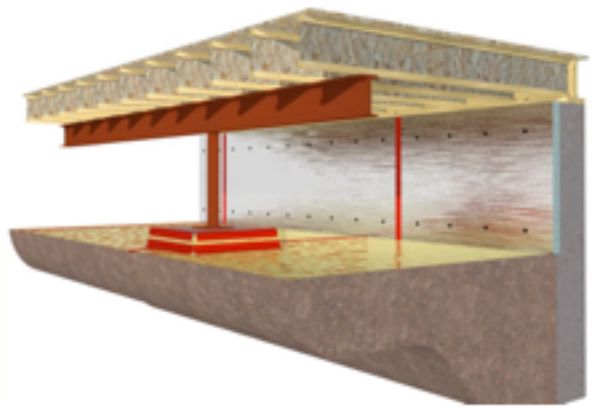
Crawlspaces - Vented or Unvented?

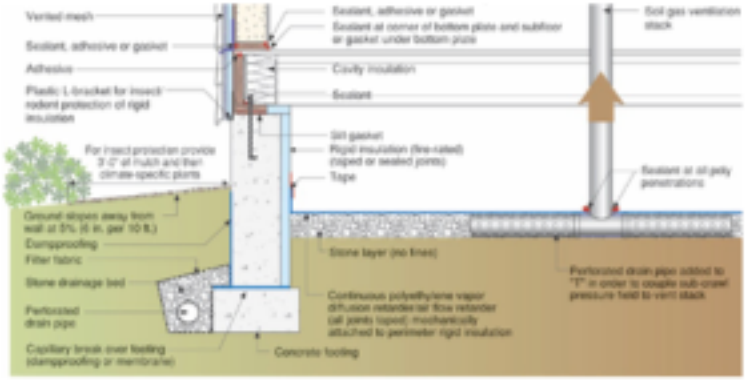
Same house, same time of year, which one is right?

Insulating a crawl space floor is difficult and often ineffective

Crawlspaces - Best practice

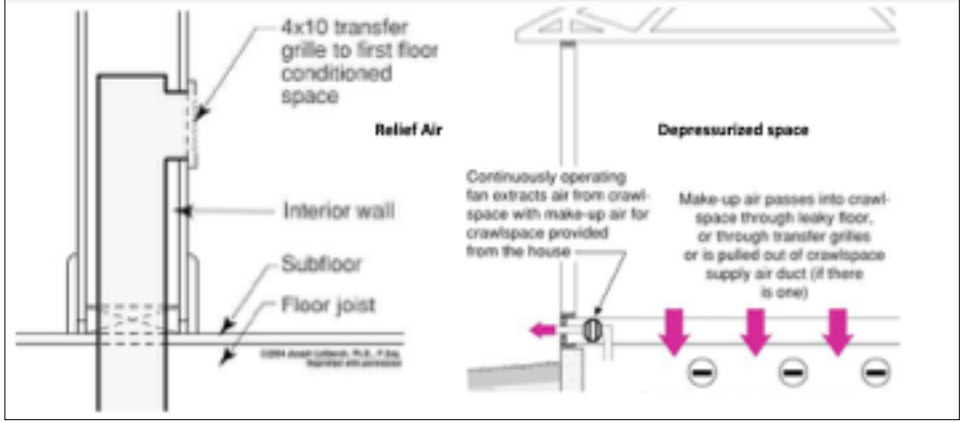






Crawlspaces must have designed ventilation and well installed moisture control

Design a system that provides ventilation using house conditioned air



The third type of foundation would be the full height basement

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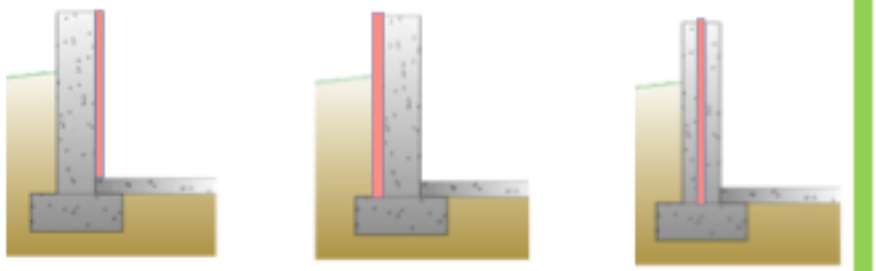
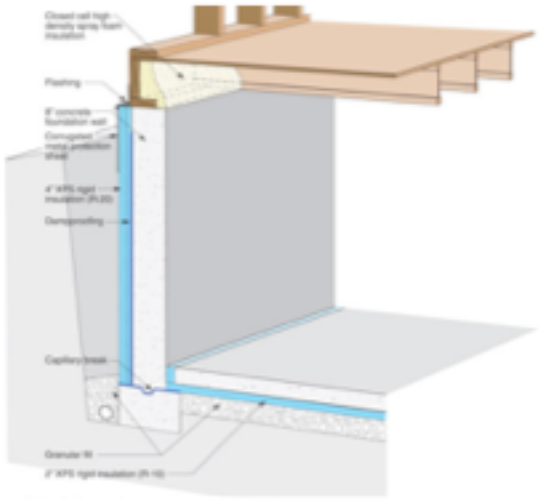
Foundation type, climate and soil conditions all affect performance

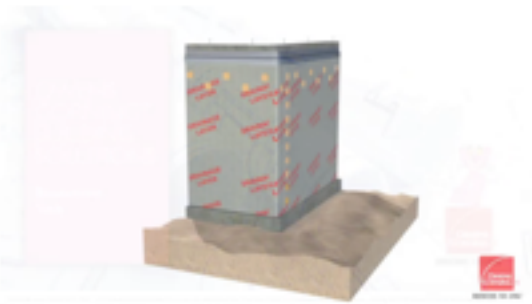


Internally Insulated | Externally Insulated | Insulated inside the wall

Exterior Insulation is the best option

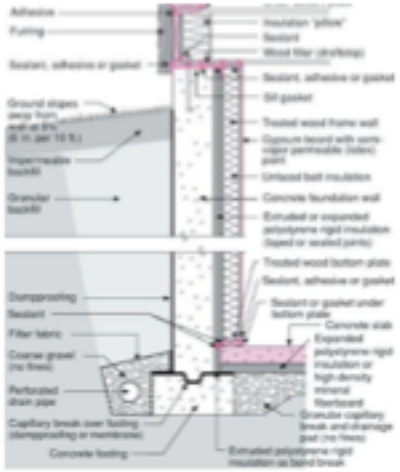


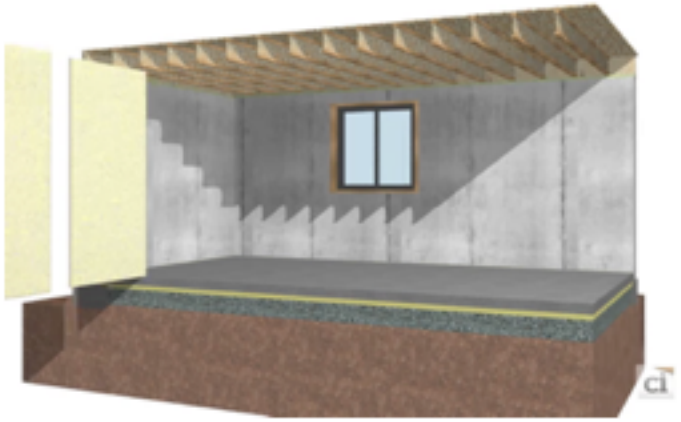
Basement Slab Insulation



Interior insulation is possible

- Foam based solutions are best



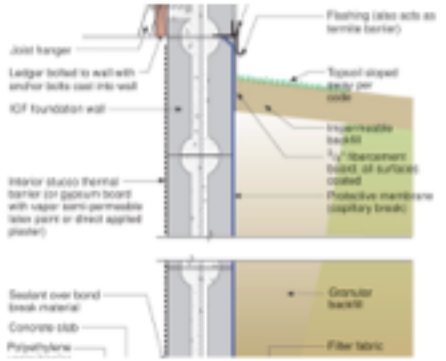


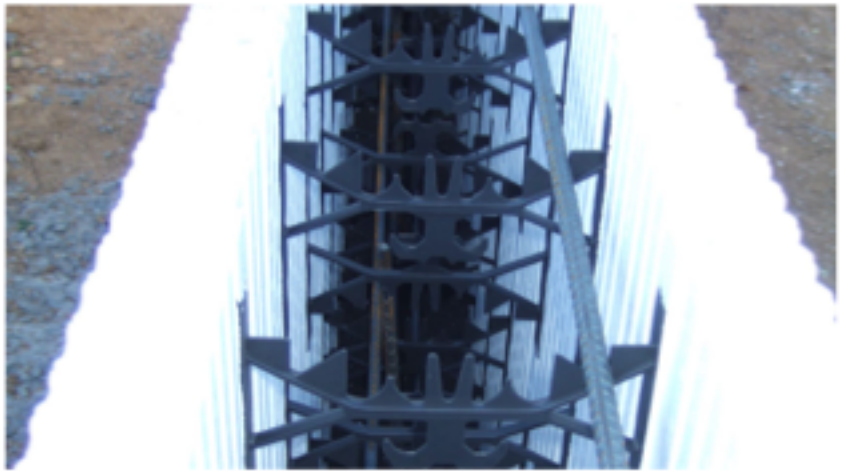
Insulated Concrete Forms

- An innovative and proven technology for foundations and walls

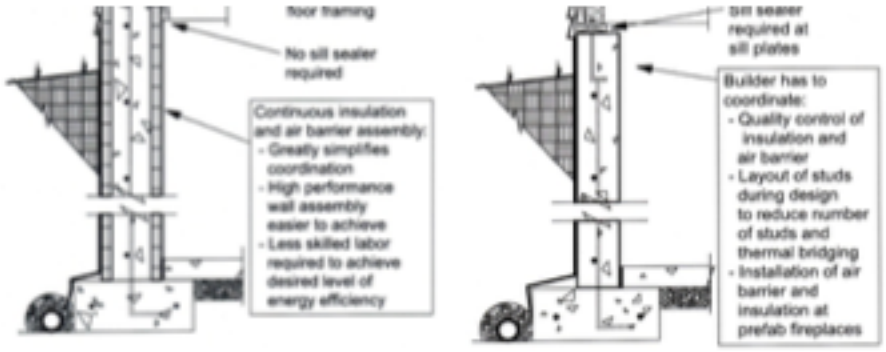
Insulated Concrete Forms

- Allows for controlled drying towards the interior
- Insulation and foundations in one system
- Interior finished can be directly applied
- Remember the capillary break



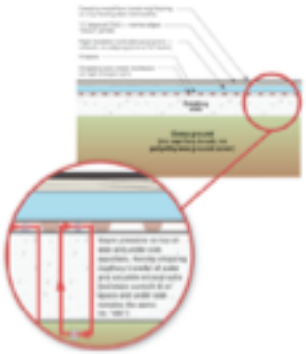


ICF versus conventional



What do you do with an existing basement floor?

Membrane over slab



Paperless Gypsum

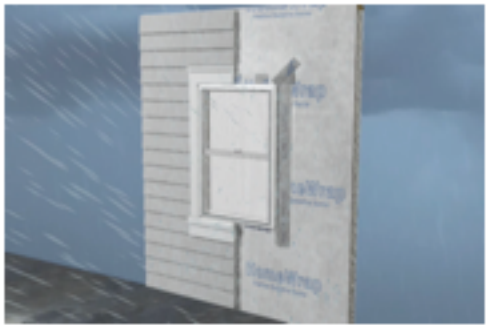
Let's move up and look at above grade walls

A wall system needs to perform

- Provide strength & rigidity
- Be durable
- Control light & solar gain
- Control noise
- Control rain penetration
- Control air flow
- Control heat flow
- Control water & vapor flow

Protecting walls from Liquid Water

Cladding is 1st line of defence
Water gets behind all types of cladding by:
Liquid
Capillary
Air pressures

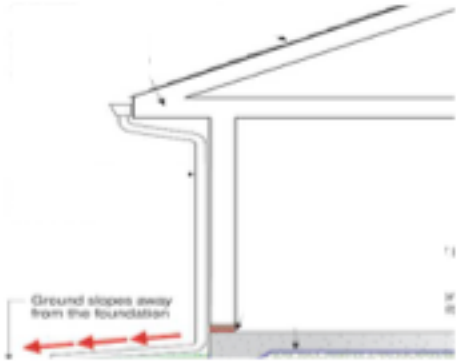


Methods of flow

Water is a powerful force in all it's forms

Follow the path of water; will it create a problem?

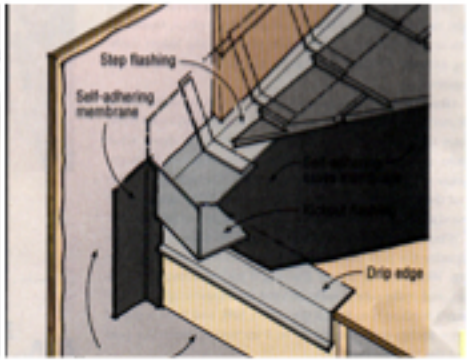
Gutters are important to any water management strategy



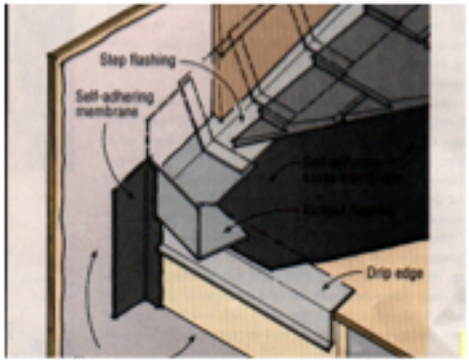
Flashing & Gutters must effectively redirect water

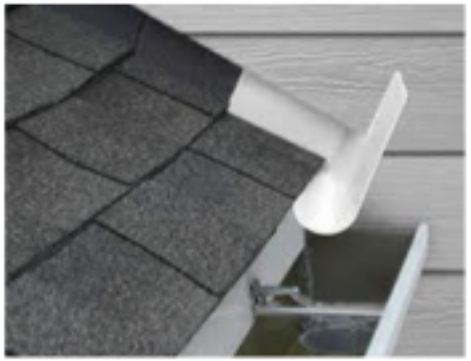
The interface between walls & roofs

Concentrate on the path of flow...



Kick-out Flashing - Simple and effective





Flashing must be integrated with the drainage plane

Drain the Assembly

Drainage is pretty simple

Venting our Cladding

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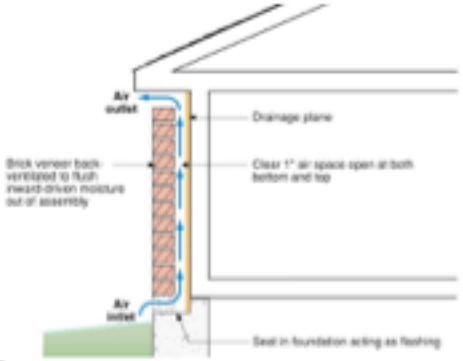
Air Flow assists drying

Create intentional airflow
When using brick
& stone & siding in:
Humid summer climates
Rainy climates
Wood sheathing applications



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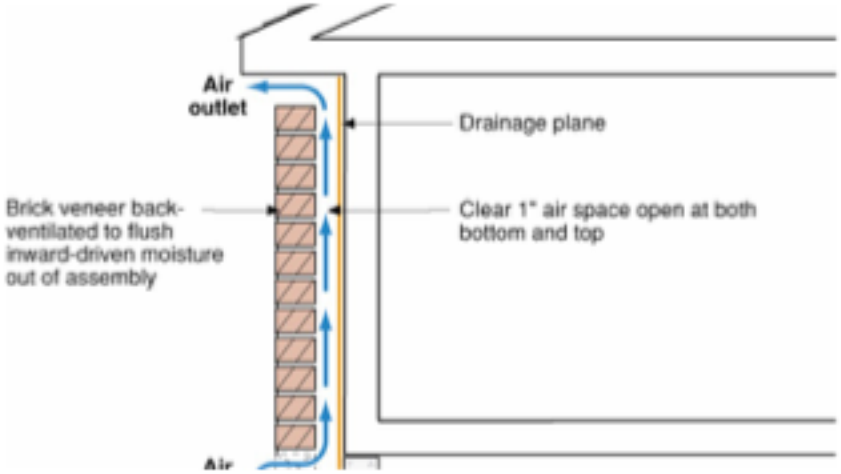
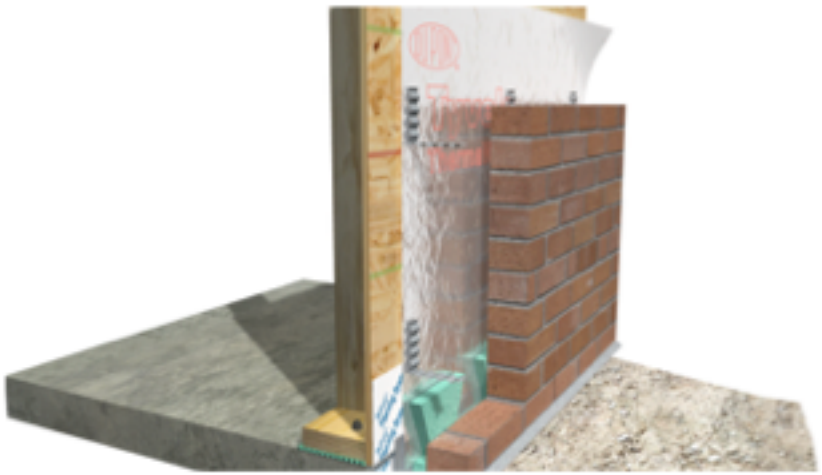
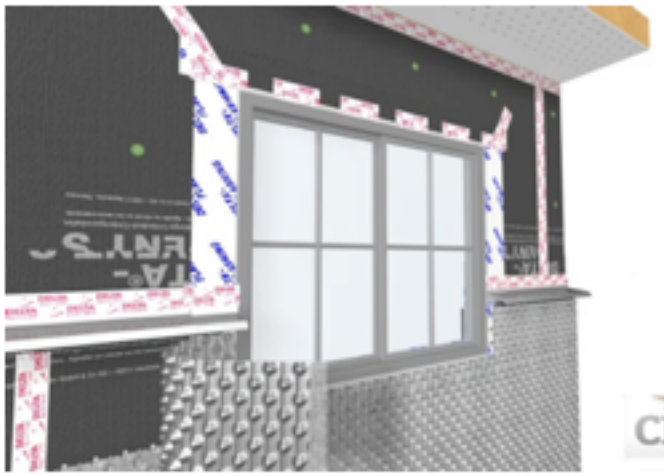
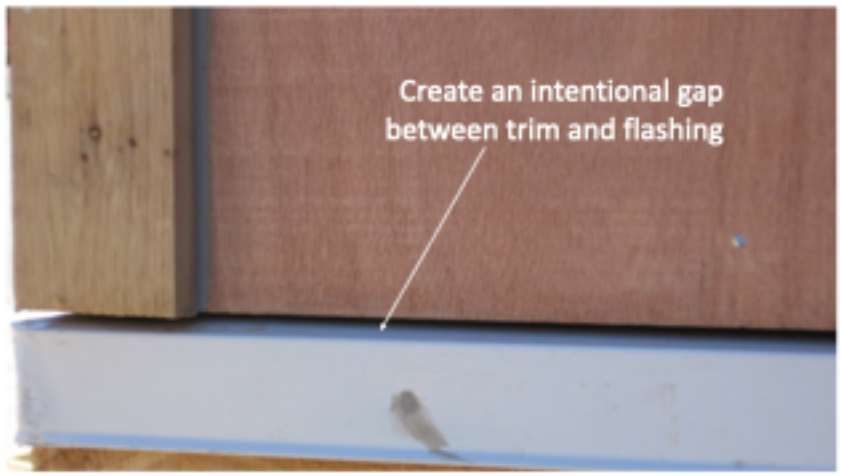






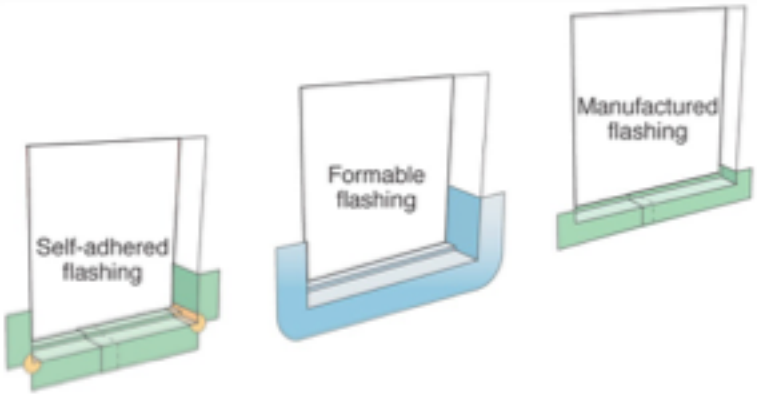


Its all about the details

Inadequate pan flashing

The Details Demonstrating a method

Site-Constructed or manufactured pan flashings for window and door openings in frame walls



Allow for drainage at the base of windows

Use low pressure, low expanding foam around openings to complete the air barrier

Window Installation-Great Job!

Holes Add Up

Some Holes will need special attention

It takes commitment

Even small holes matter

Air Barriers

- Air Barriers are systems of materials
- Designed and constructed to control air flow between a conditioned space and an unconditioned space
- Air barrier system is the primary air enclosure boundary that separates indoor (conditioned) air and outdoor (unconditioned) air

Define breaks and create a plan to manage them

Common Holes We Miss

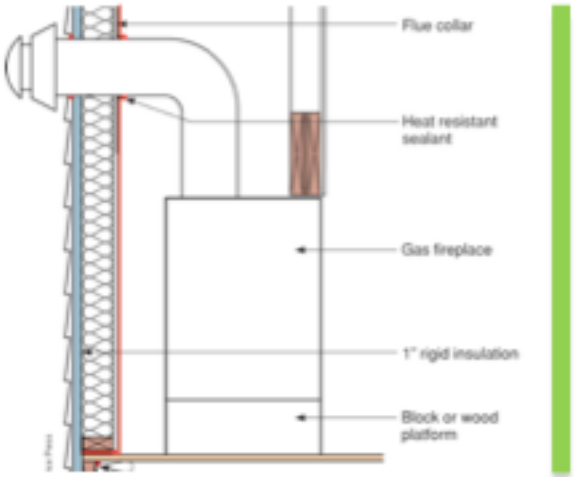
Plumbing
HVAC
Electrical
Framing Holes
Soffits
Behind Tubs
Chimney Shafts
Cantilevers

Air Sealing Bang-For-Your-Buck Ranking

JOINT/OPENING	CFM50[1]	ACH50[1]
top plate-to attic	0.29 to 0.68 per foot	0.29 to 1.6
duct boot	7.7 per boot	0.13 to 0.26
recessed light	9.1 per light	0.15 to 0.31
band joist (top & bottom)	0.86 per foot	0.37 to 0.42
garage-house common wall	0.60 per foot	0.14 to 0.26
sheathing-to-plate (top & bottom)	0.074 to 0.62 per foot	0.040 to 0.38
window/door framing-to-sheathing	0.031 to 0.11 per foot	0.020 to 0.10
between exterior top plates	0.10 to 0.11 per foot	0.033 to 0.046
corners (interior pointing)	0.024 to 0.21 per foot	0.0021 to 0.032
corners (exterior pointing)	0.054 to 0.45 per foot	0.0069 to 0.11
bottom plate-to-subfloor	0 to 0.11 per foot	0 to 0.11
vertical sheathing joints	0.010 to 0.090 per foot	0.011 to 0.11
sill plate-to-foundation	0 to 0.030 per foot	0 to 0.025

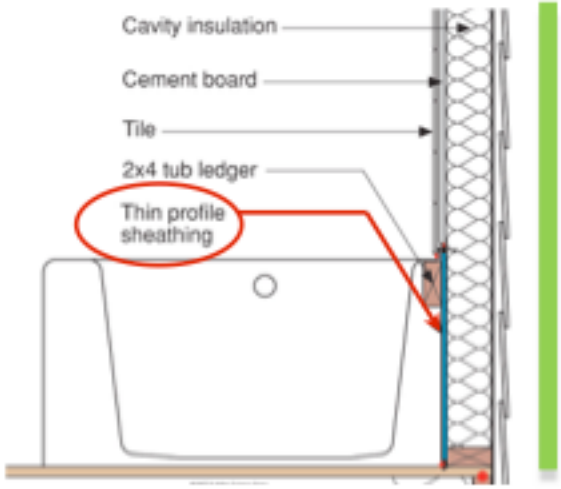
A very helpful OC research project

Air barrier at fireplace



Chimney shafts and penetrations

Tub Air Sealing



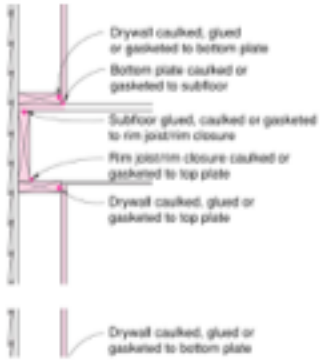
Provide rigid blocking

House to garage connections

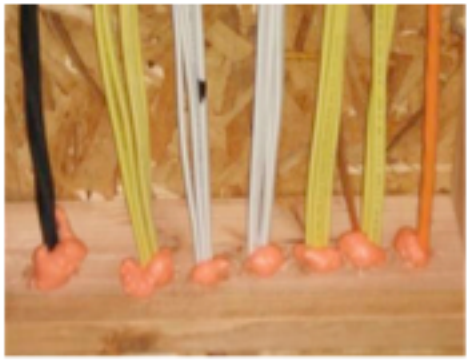
Air-seal connections at house to garage

Air Flow Barrier-Interior

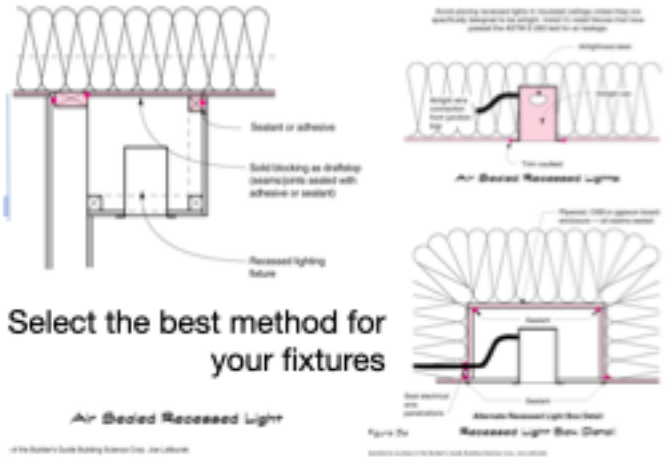
- Airtight Drywall Approach
- Connecting and sealing the materials to stop air flow
- Must be continuous through all penetrations



Plumbing, electrical & HVAC penetrations need attention

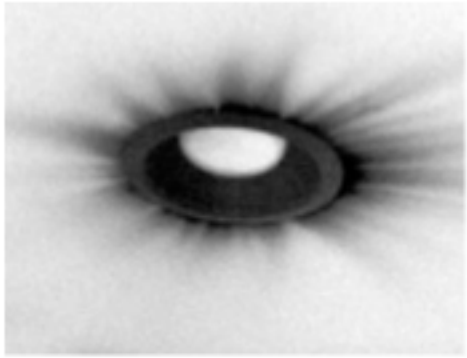


Soffits and knee-walls need to be prepared early



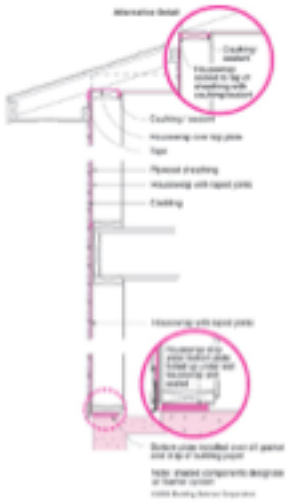
Select the best method for your fixtures

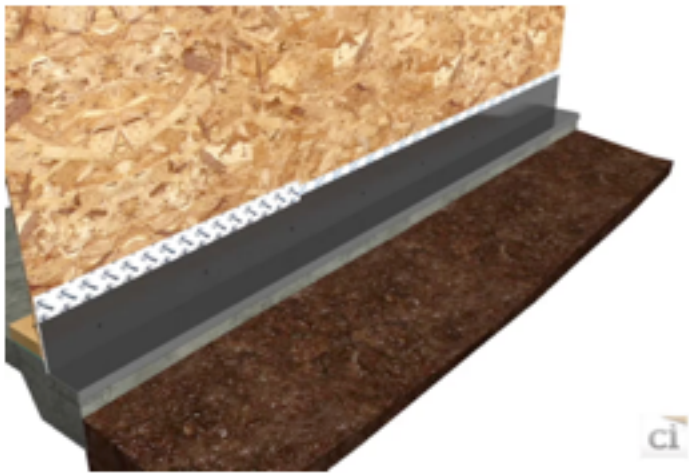
Air Leakage at recessed light



Air Flow Barrier-Exterior

- A well detailed house wrap or weather barrier can also be an effective air barrier
- It must connect to the foundation and the ceiling air barrier
- Must be durable through the construction process





Tight Construction

HOW TIGHT - Residential

• US IECC 2012	5 ACH@50 Zones 1,2
	3 ACH@50 Zones 3+
• "Canadian Code"	3.0 ACH@50
• ENERGY STAR	2.5 ACH@50
• Zero Energy	1.5 ACH@50
• Passive House	0.6 ACH@50

A game changing solution

AeroBarrier is a convenient, cost effective approach that seals homes in less than 3 hours and provides verification that the air-tightness requirement has been achieved.

Changing the Way Homes are Built with:

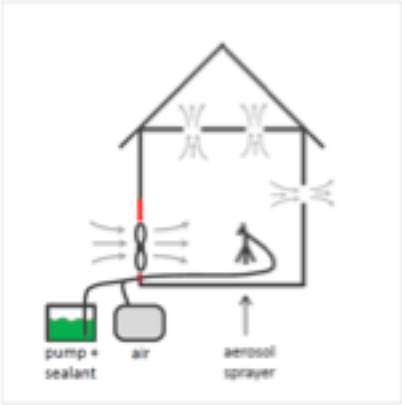
- Consistently tighter building envelopes
- Verified and documented results
- A single process
- Time saving

The AeroBarrier process

STEP 1:

Prepare house for sealing. Cover all intentional openings (drains, bathroom vents, etc.) and horizontal surfaces, set up sealing equipment, and pressurize the building / home.

Typically 100 Pascal

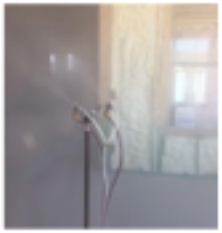


Deploy the nozzles

Up to 8 tripods

2 nozzles each

Air and sealant to each



Holes that the Sealant is really good at - 1/2" or under

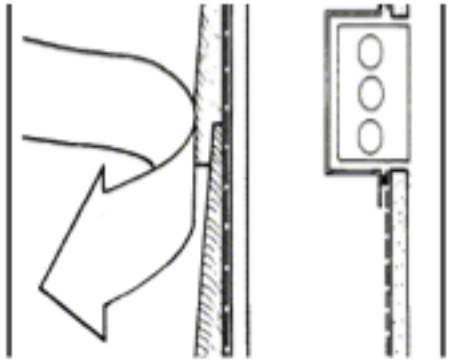
The AeroBarrier process

Verified Results!

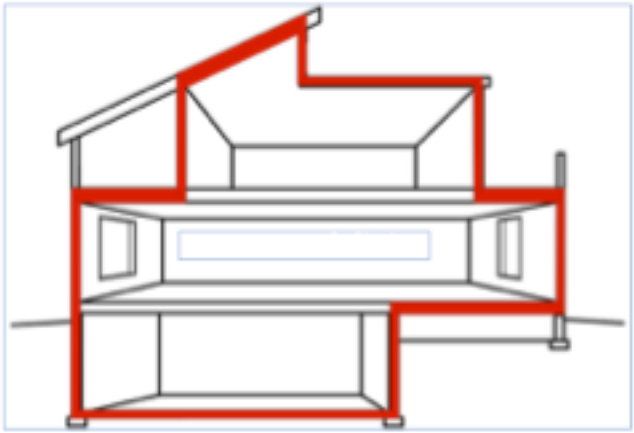
Every seal provides a certificate of completion outlining the sealing work. Pre and post-leakage are captured and the seal duration and leakage reduction are all displayed on the graph

Air Sealing Summary

- Reduce energy loss
- 1/3 of htg/clg bill can be from air leakage
- Reduce infiltration of harmful air
- Garage connection
- Improved comfort
- Less drafts
- Less noise & dust



Insulation Installation



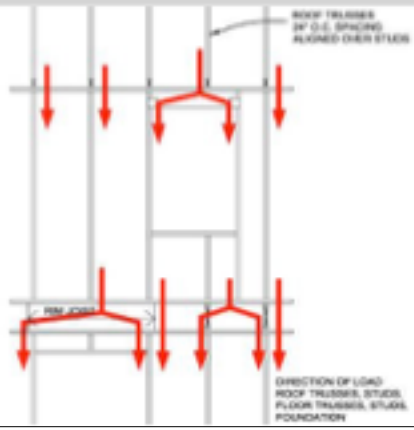
Framing for Insulation- Wall systems

- Provide structural integrity, but insulate areas we sometimes miss.

Where 4 is good....

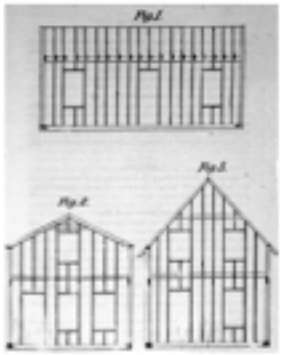
9 or more has got to be enough!

Simplified Framing



Carpentry Made Easy

William Bell,
1858



A 3 stud corner

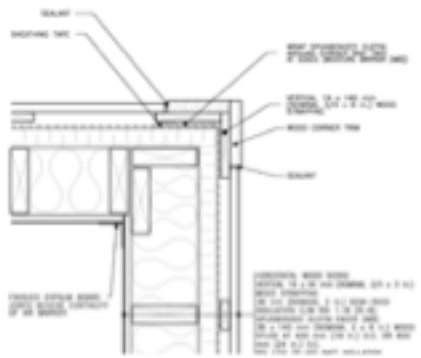
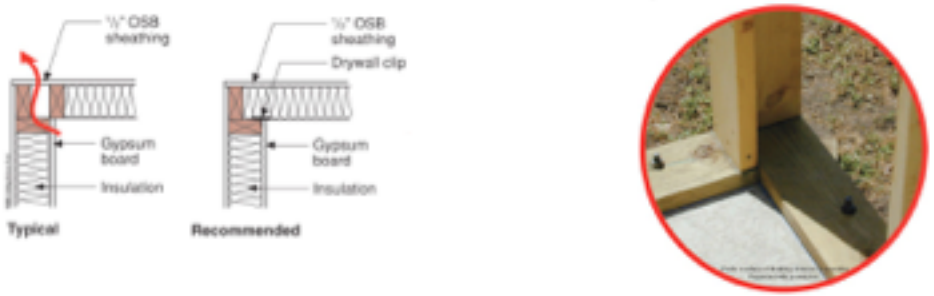
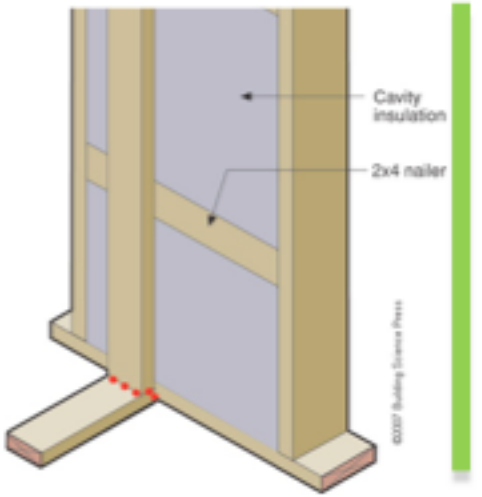


Diagram from CMHC Best Practices

Two-stud corner



Ladder Blocking



In the field

Insulation Must....

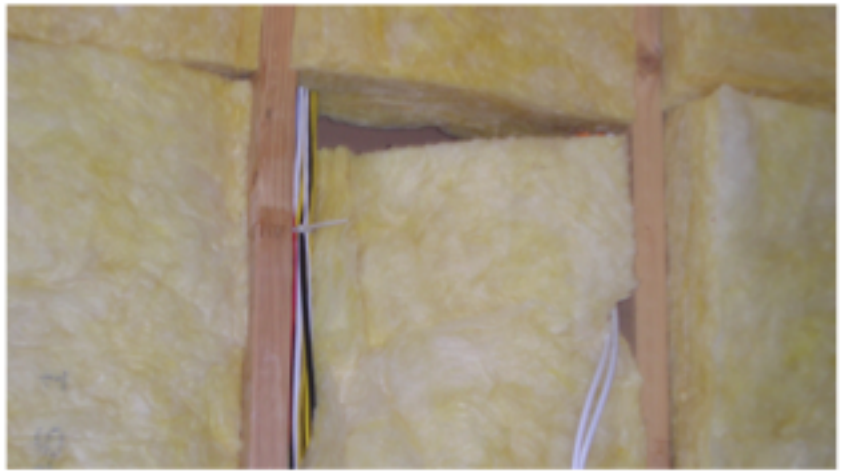
Be installed properly:

- No compressions
- No voids
- Touching all 6 surfaces
- Be properly mixed (foams)
- Be compatible with other materials
- Be combined with an air barrier or be one
- Not be subjected to constant wetting cycles

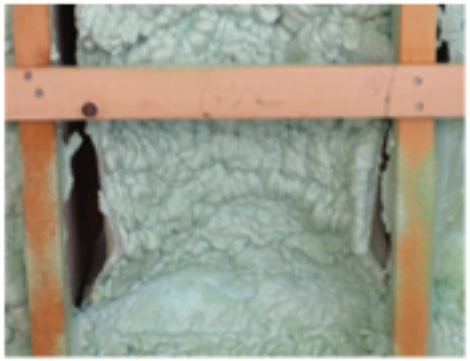
EEBA

Poor installation affects comfort, performance and durability

Compressions and voids reduce performance



Poor Spray foam installation



Insulating is a system

More choices offer better performance

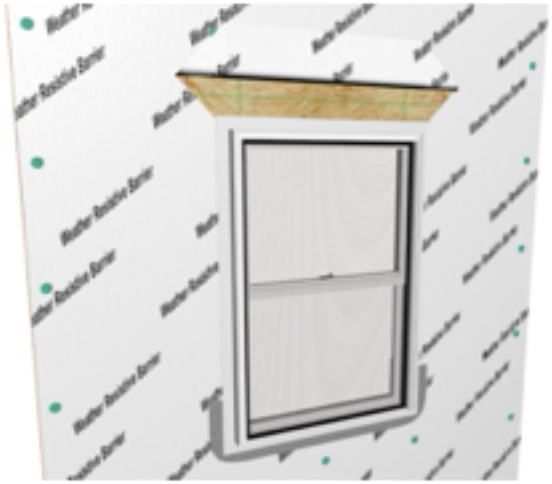
Careful installation of all insulating systems are essential for good performance

Blown cellulose insulation

High density blown fiberglass

SPF- spray polyurethane foam

Again....benefits of exterior insulation



Insulated concrete forms resolve issues

Structurally insulated panels provide high R-Value assemblies

Window Systems

Windows

- Provided natural light and ventilation
- Passive solar heat
- Architectural element
- 1/3 to 2/3 thirds of total AC loads

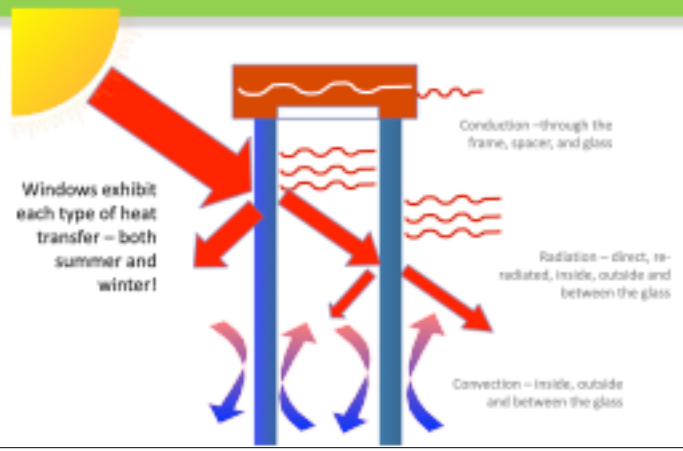
What defines high performance windows?

- Heat gain & heat loss reduction
- Energy efficiency
- UV light reduction
- Durability
- Wind and rain resistance

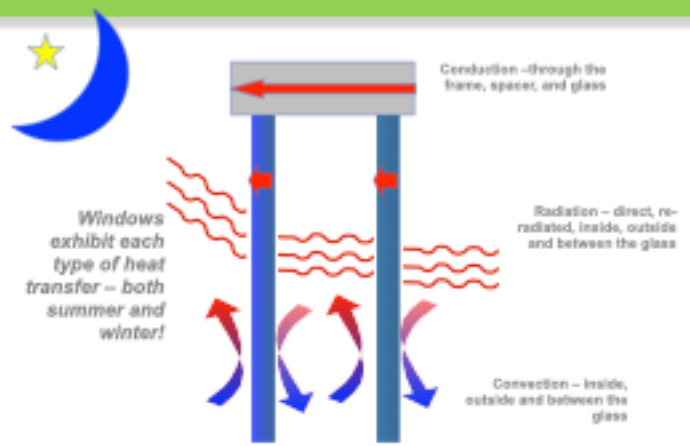
Four technologies are common:

1. Low emissivity coatings
2. Insulated spacers
3. Gas filled
4. Insulated frame tech.

Summertime Heat Gain



Wintertime Heat Loss

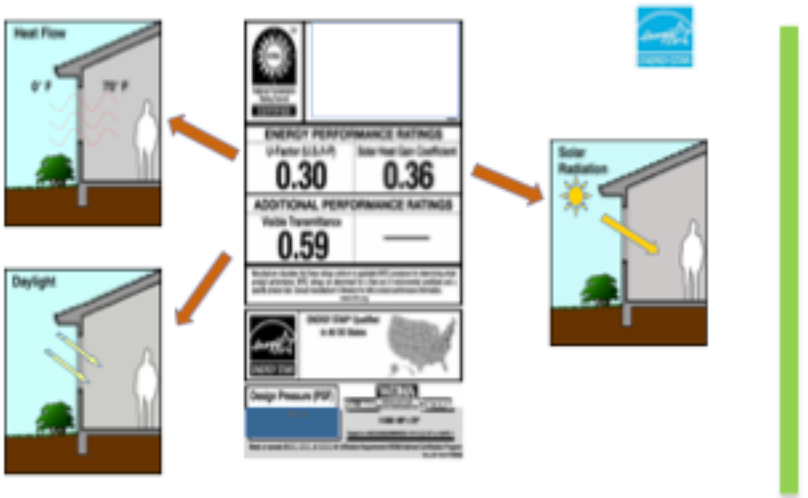


Where is the 2018 code headed- Glazing

Fenestration	Window U-Factor		Window SHGC		Skylight U-Factor	
Climate Zone	2009	2012	2009	2012	2009	2012
1	1.2	0.65	0.3	0.25	0.75	0.75
2	0.65	0.4	0.3	0.25	0.75	0.65
3	0.5	0.35	0.3	0.25	0.65	0.55
4	0.35	0.35	NR	0.4	0.6	0.55
5	0.35	0.32	NR	NR	0.6	0.55
6	0.35	0.32	NR	NR	0.6	0.55
7	0.35	0.32	NR	NR	0.6	0.55

= increased

EEBA



A Tale of Two Houses

House before & after improvements

Standard Clear Double Glazed

U = .65

SHGC = .68

4.0 Ton AC Unit

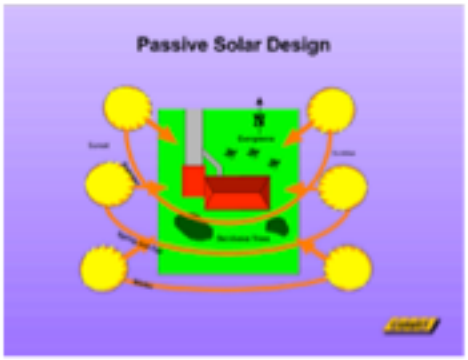
Double Glazed Low-e, Low SHGC

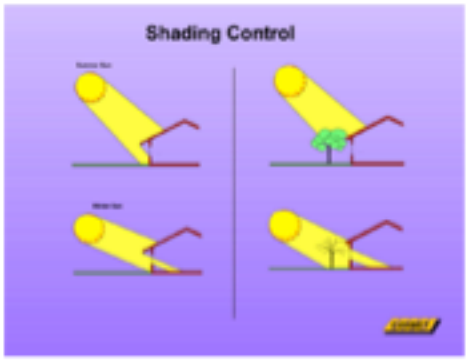
U = .32

SHGC = .32

2.5 Ton AC Unit

In your experience how much control do you have on orientation, site-scaping & house design?





Roof Systems

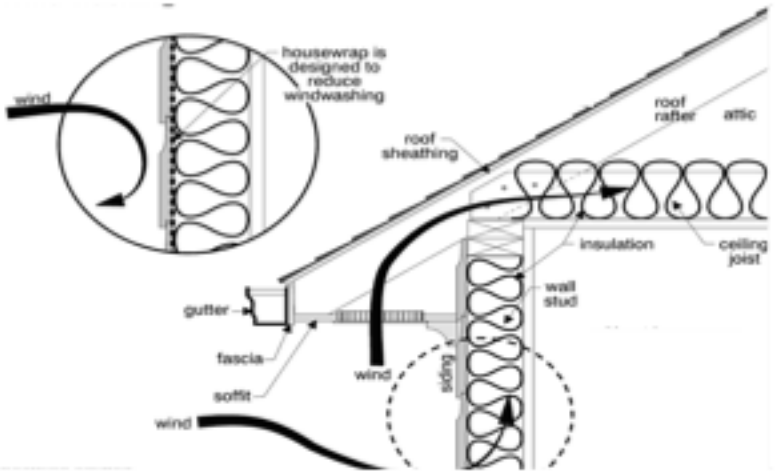
- These need attention too.....

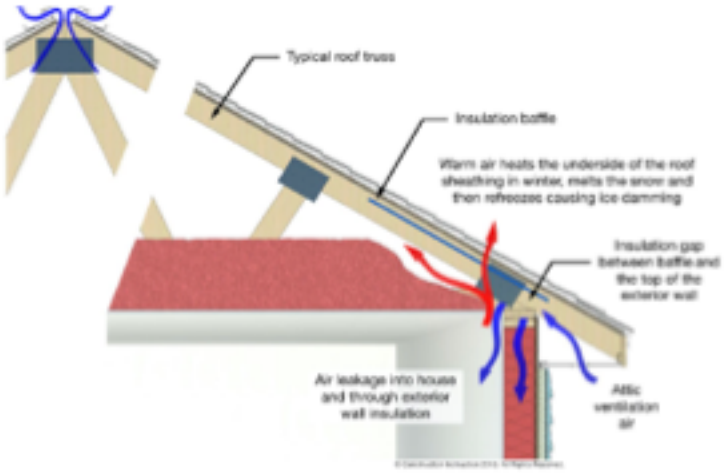
What does a roof system need?

- Protection from rain penetration
- Drainage
- Flashing
- Durability
- Ventilation (always needed?)
- Proper insulation levels

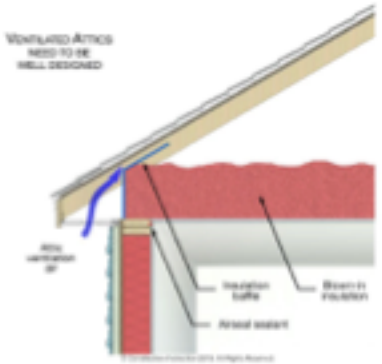
Sound like our wall systems?

Hipped roof details make insulating difficult

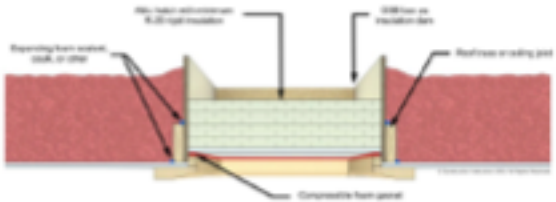


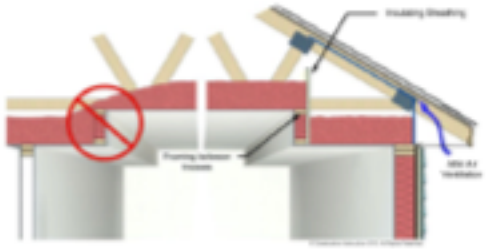


Ventilated attics need good design



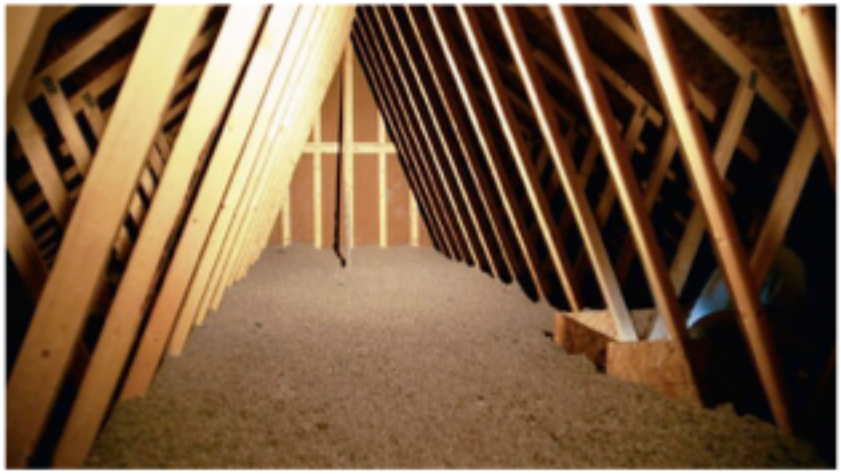
Attic Ventilation Strategies

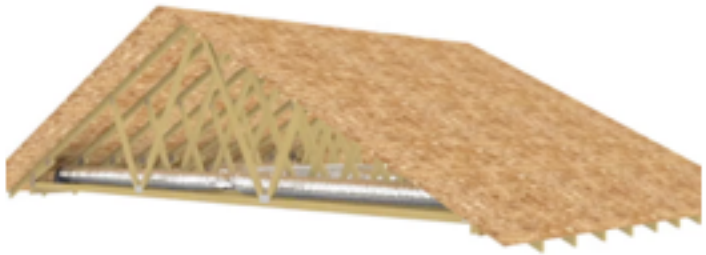




Airsealing at wall to roof interface


24
22
20
18
16
14
12
10
8
6
4
2





Ducts and Air Handlers in Conditioned Space

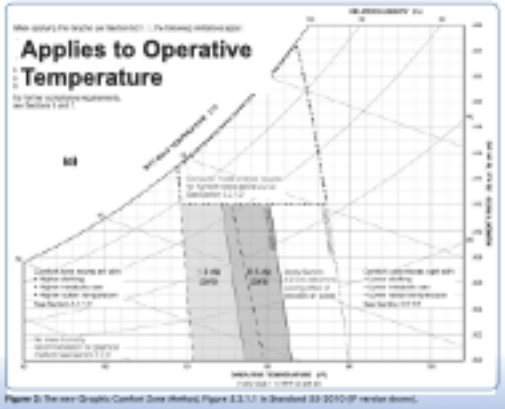
Conditioning the Indoors

- Heating,
- Cooling,
- Ventilation and
- Indoor air quality
- Hot water

Let's Start with Defining Comfort

- Air temperature
- Humidity
- Air speed - drafts
- Surrounding surface temperatures
- Gender, age, activities of occupants
- Metabolic rate & clothing

Comfort – Finding the sweet spot



Operative Temperature

Operative temperature:

- The average of the **mean radiant** and ambient air temperatures, weighted by their respective heat transfer coefficients.
- Thermostats respond to air temperature
- Human **thermal comfort** responds to operative temperature

Be Aware…

- Energy Efficiency ≠ Comfort
- Builders typically have more comfort complaints than high bill complaints
- If you can't provide comfort, energy efficiency could be set back 20 years
- Need to remember comfort fundamentals

Can we meet the expectations of our customers?

ACCA Comfort Guidelines

Comfort – A starting point

Parameter	Setting	Range
Temperature		
Summer	75 °F	+/- 3 °F
Winter	72 °F	+/- 3 °F
Humidity		
Summer	50%	+/- 5%
Winter	35%	+/- 5%
Foot Comfort	63 °F	+/- 3 °F

Heating & Cooling Systems

Fuel choices

- Electric
- Gas
- Oil
- Wood
- Solar
- Combinations

Distribution choices

- Central Forced air
- Radiant
  - In-floor
  - Baseboard
- Ductless
- Space heaters

1) Get heating & cooling capacity right

ACCA Sizing Standards

Heat Flow Formulas

Conduction heat flow (through walls, ceilings, floors)

= (Surface Area x Temp. Diff.) / R-value

Radiant flow (through glass)

= Surface area x Solar incidence x **S**olar **H**eat **G**ain **C**oefficient

Heat flow by air (via air leakage or ventilation)

= Volume of air (CFM) x Temp. Diff. x 1.1

HEATING – Get the Size Right

- Do Room-by-Room heat loss & gain calculation

Based on:

- Design Day - Winter
- Conduction losses through enclosure
- Air leakage through enclosure
- Heat losses through ducts in unconditioned space

Minneapolis, MN
- design conditions

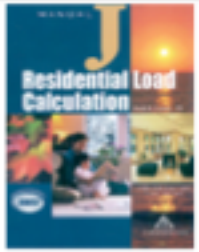
Condition	ASHRAE 99% / 1%
Winter, design dry bulb (F)	-15°F
Summer, design dry bulb (F)	91°F
Summer, design wet bulb (F)	71.6°F
Degree days-heating	7981
Degree days-cooling	682
Precipitation	28"
Solar incidence - South, July	110 BTUs / sq.ft

Proper Manual J Calculations

- Numerous software packages exist
- All rely on proper data input and appropriate assumptions

Common Errors:

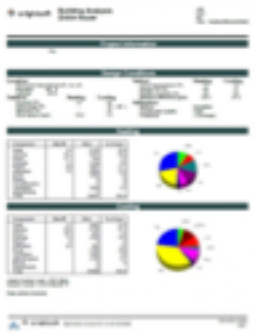
- Fudging design day conditions
- Using default values for air tightness, windows, insulation
- Using improper ventilation rates



Don't tolerate oversizing; Manual J compliant programs have safety factors built in already

Impact of Improper Sizing

- Short cycling
- Poor humidity control
- Poor temperature control
- Noise
- Extra cost for equipment & duct work
- Possibly higher energy bills



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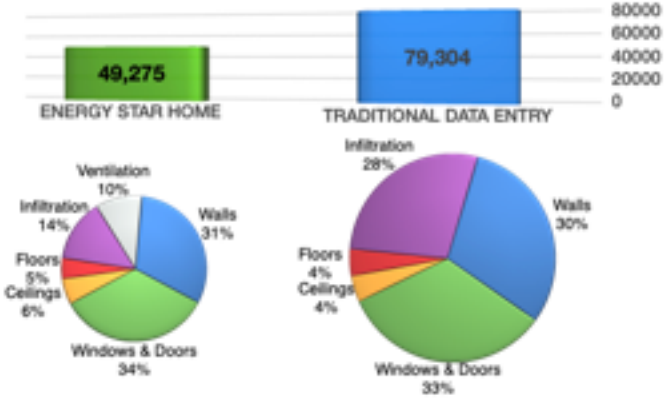
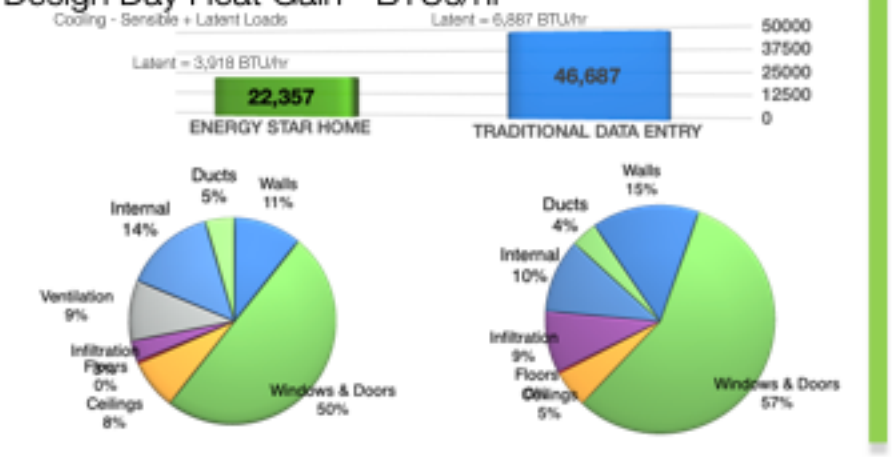
Parameter	Actual	Traditional
Design Temp (W) Design Temp (S)	-15 °F 91 °F	Its cold here: -22 °F Its getting hotter: 97 °F
Indoor Design (W) Indoor Design (S)	70 °F 75 °F	People are picky: 72 °F 72 °F
Orientation	North Front	Worst Case - East Front
Windows	From NFRC label U=0.28, SHGC=0.28 Overhangs used	Default U=0.41, SHGC=0.32 Overhangs not used
Air tightness	Actual 2.0 ACH50	Default 7.0 ACH50
Insulation	R50 ceilings R25 walls R 15 foundation	R44 ceilings R19 walls R 10 foundation
Ventilation	ERV - 75 CFM	Exhaust fans - 75 CFM

Design Day Heat Loss - BTUs/hr



Design Day Heat Gain - BTUs/hr



Provide your Contractor with Good Information

- Insulation levels
  - Wall and attic insulation levels
  - Foundation insulation
- Window data - use NFRC ratings
  - Solar heat gain coefficients
  - U values
- House Air leakage
  - This is often the single biggest variable
  - Provide blower door test values

EEBA

Approved Software Guides Better Inputs

- Insulation levels
  - Wall and attic insulation levels
  - Foundation insulation
- Window data - use NFRC ratings
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  - U values
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  - Provide blower door test values

More specifics on how

Approved Software Guides Better Inputs

- Insulation levels
  - Wall and attic insulation levels
  - Foundation insulation
- Window data - use NFRC ratings
  - Solar heat gain coefficients
  - U values
- House Air leakage - (this is often the single biggest variable)
  - Provide blower door test values

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2) Select the right equipment

ACCA Equipment Selection

Good System Selection

Heating and cooling systems come in specific sizes

(2, 2.5, 3 ton, or 45, 70, 90 Thousand BTUs for example)

- For heating it is acceptable to select a system that is within 110% -125% of the design load - slightly oversized
- For cooling choose a system that is between 90% - 110% of design load
- Other issues:
  - Equipment location (garage, attic, crawl...)
  - Blower type (ECM, PSC, HV...)
  - Filtration needs

Good System Selection

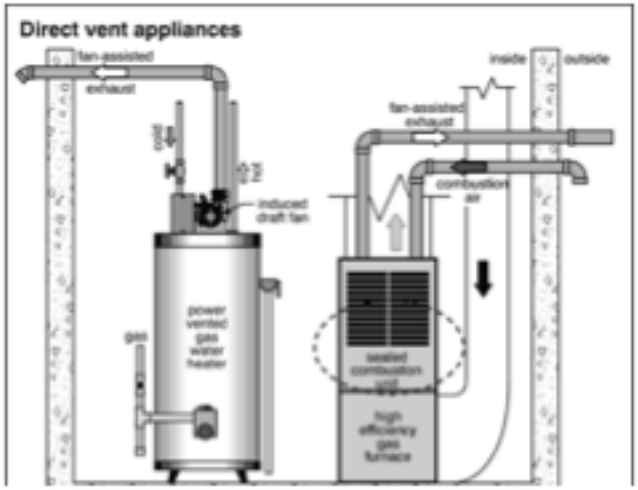
- Use manufacturer's technical manuals to match:
  - Required heat output
  - Required cooling output
    - Sensible & latent (moisture) loads
  - Fan / airflow delivery capacity and static pressure

Preferred furnace choices

- Sealed combustion chamber
- Venting system decoupled from house pressures
- Efficiencies of 90%+
- High efficiency blower motors - ECM
- Two/multi stage heating

Combustion Safety

- Easy Stuff!!
- Switch to closed combustion equipment or heat pumps
- Furnaces, water heaters, fireplaces
- Even if the equipment is located in the garage or attic
- Properly vent gas cooking appliances
- These better choices have the added benefit of improving efficiency and effectiveness

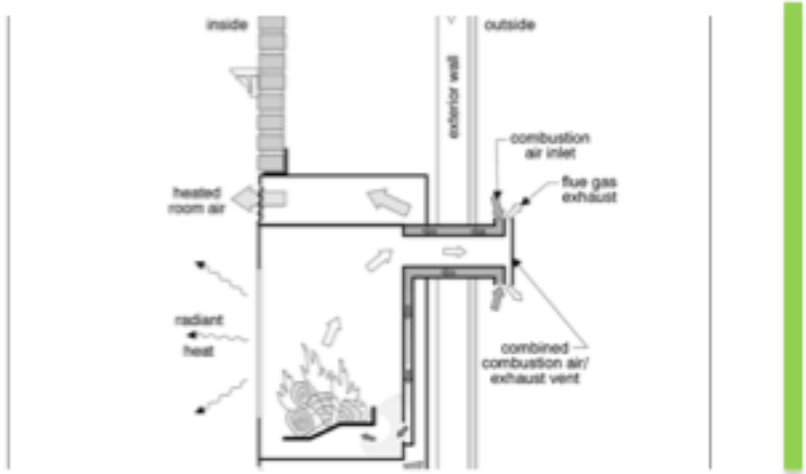


Power Vent Water Heaters

- New models are much quieter
- Enable long venting
- Can overcome significant negative pressures
- Usually they are electronic ignition
- Look for new ENERGY STAR qualified products
- Tank or tankless options

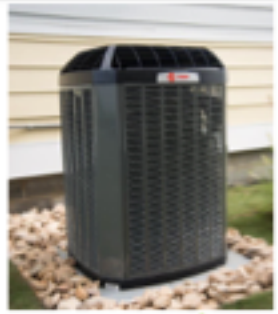
Heat Pump Water Heaters are an Option

- New models are much quieter
- Energy Factors of >2.0
- Provides some cooling capacity
- Can provide dehumidification capacity



Preferred AC choices

- Outdoor condenser matched to indoor coil
- SEER ratings of 14+
- High efficiency blower motors - ECM
- Two - stage cooling
- Dehumidification cycles



EEBA

New Realities in HVAC Design & Performance

High Performance homes need more efficient motors!

- Capable of meeting small loads, part loads and full loads!
- Use1/5 of original PSC motor types.
- Run efficiently at a variety of speeds (Modulation)
- Equipment lasts longer
- Enables balanced temperatures throughout home
- Enhances Ventilation "Effectiveness"

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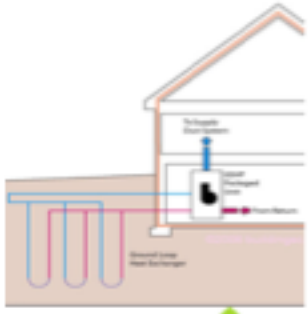
What about Heat Pumps?

- Is it the first thing to do?
- Reliance on electric grid
- Can do water or air
- High Performance homes help reduce capital cost
- "250% to 400%" efficiency



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Energy Efficiency

- Heat pumps are hard to overlook
- COPs of 2 to 4
- Be mindful of rating points and operating conditions – cold weather

Example of a different strategy - Ductless opportunities

- Provides zoning
- Can target specific high load areas
- In very high performance homes, it could provide all heating & cooling needs

3) Design the ducts correctly

ACCA Duct Design

Distribution Systems

- HVAC contractor must use the heat loss/gain calculations to properly size duct work
  - It is critical to consider the entire system and process.
    - Layout & location of distribution system
    - Materials used - flexible duct or sheet metal, insulated or non-insulated
    - Impact on pressurization of rooms or spaces
    - Effective occupant comfort control

BTU/hr Carrying Capacity

Duct size	Airflow CFM	25 °F Cooling	45 °F Heating	55 °F Heating
4"	30-40	800 -1100	1485 -1980	1815 - 2420
5"	50-60	1300 -1650	**2375 - 3960**	3025 - 3630
6"	90-110	2475 -3025	4455 - 5445	5445 - 6710

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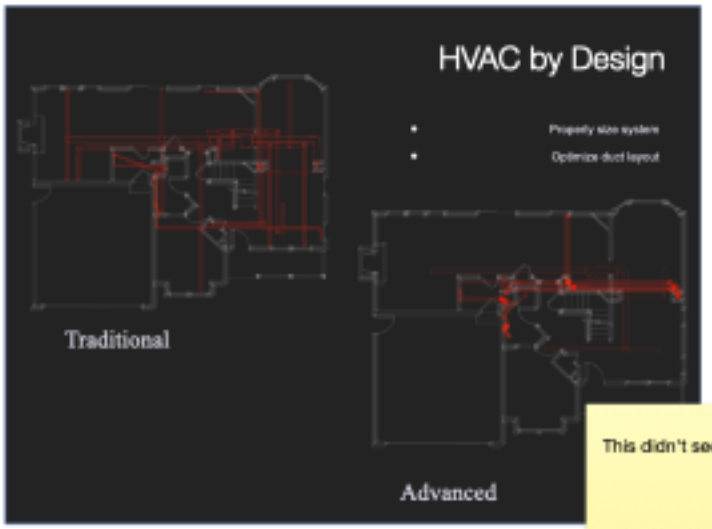

This didn't seem to impress

Ducts in Conditioned Space
4 options
attics are an option

It can raise the value of a home

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Ducts in conditioned space will be cooler in summer, warmer in winter

Using floor cavities is an option

It can raise the value of a home

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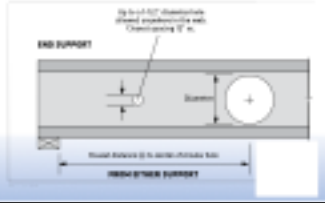
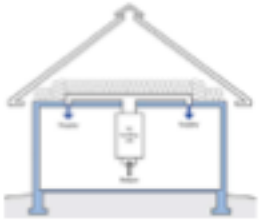
Layout your floors to accommodate duct work



Buried Ducts are an Option

- Mastic with a brush is quickest & best

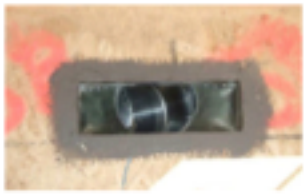


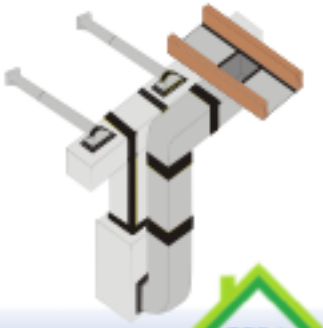
Seal Ducts

- Mastic with a brush is quickest & best

Sealing Ducts Matters!!!

- Getting air where you need it
- Allowing balancing & seasonal adjustment to work
- Empowers zoning to work





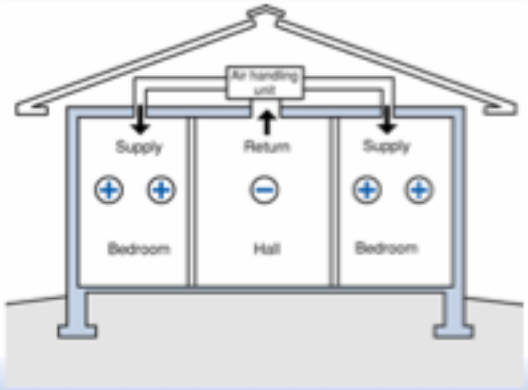
Zoning will become more important

- Matching seasonal load adjustments
- Example – basements
- Accurate delivery of part loads
- Making best use of equipment capacity

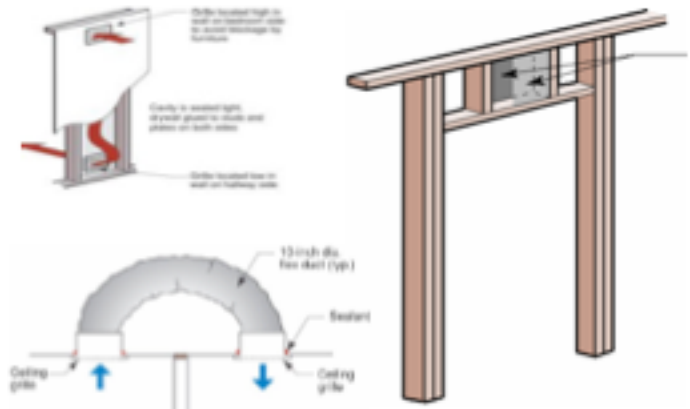
Ducted Returns will become expected

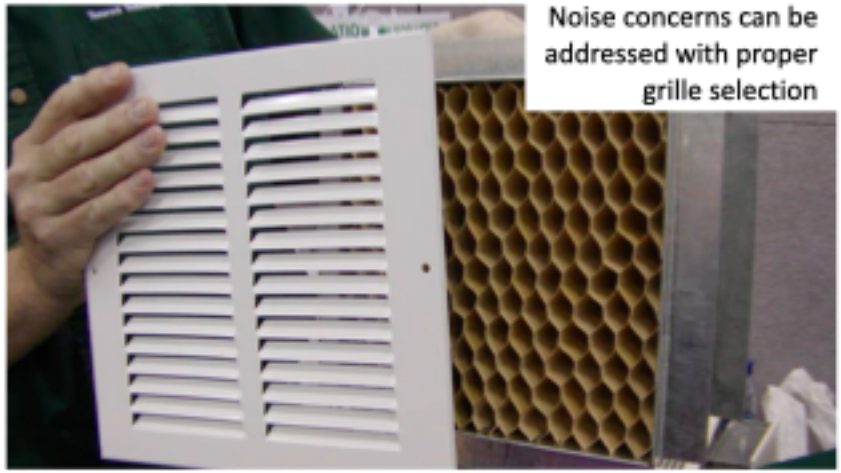
- A good choice is to hard duct returns...strategically to a centralized location

Return Air Paths



Graphics Courtesy of Building Science Corp.





Noise concerns can be addressed with proper grille selection

Radiant in-Floor Heat

- Heat surfaces, not air
- Lower noise
- Comfort on concrete floors
- Ideal for basements & "floor warming"
- Requires additional systems for AC, humidity control and filtration

Controls

Smarter Controls

- Anticipating change
- Outdoor reset
- Time of use rate decisions
- Programming & integrating functions
- Fan cycles
- Humidification
- Dehumidification
- Ventilation
- Real time diagnostics

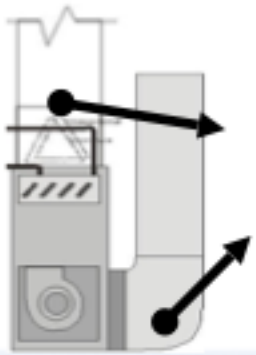
Verification / Commissioning

5 key tests

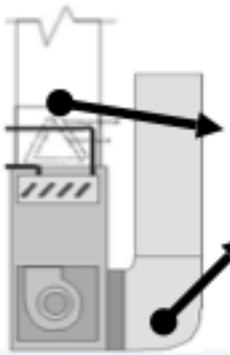
Testing for performance - 1) Flow at the air handler

2) Air flow at grilles or registers

3) Pressures at the air handler



4) Temperature rise / fall across the air handler



5) Refrigerate Verification

EPA's Indoor air PLUS Program

An excellent opportunity for builders & HVAC contractors

- Moisture control
- HVAC: heating, cooling, ventilation, filtration
- Combustion and garage isolation
- Commissioning the building
- Radon control
- Pest barriers
- Healthy building materials

look for

ENERGY STAR

Valuable Resources

- √ Moisture control
- √ HVAC: heating, cooling, ventilation, filtration
- √ Combustion and garage isolation
- √ Commissioning the building
- √ Radon control
- ▪ Pest barriers
- ▪ Healthy building materials

ENERGY STAR Certified Homes, Version 3 (Rev. 07)
HVAC System Quality Installation Contractor Checklist [1]

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Lets think about water heating

5 key tests

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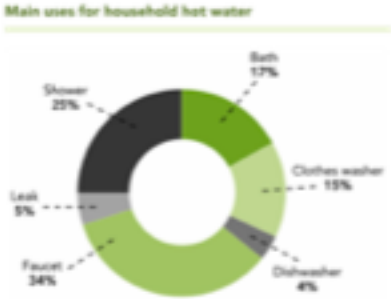
Hot Water Usage Relevance

- Hot water use is still on its way up
- Wait times are an issue
  - Waste of water
  - Perception of energy waste



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Minimum 2016 Requirements			Example EF
Gas	**Storage:** <55 US gal. >55 US gal. **Tankless:**	EF = 0.675 – (gal x 0.0015) EF = 0.8012 – (gal x 0.00078) EF = 0.82–(gal x 0.0019)	40 US gal = 0.62 60 US gal = 0.75 Typical = 0.80
Oil		EF = 0.68–(gal. x 0.0019)	50 gal = 0.585
Electric	<55 gal. >55 gal.	EF = 0.960–(gal x 0.0003) EF = 2.057–(gal x 0.00113)	40 gal = 0.95 60 gal = 1.98

What's the Right Choice?

- Fuel access?
- Number of people?
- Patterns of use?
- Space / location limits?
- Climate zone?
- Efficiency of the home?
- Other mechanicals?
- Expectations of clients?
- Other?

Traditional Tank
EF < 0.60

Tankless = +0.80

Condensing
water heater =0.86

Solar Thermal Water Heaters

- A great preheat strategy for tankless, storage water heaters & HPWHs – increases their capacity
- 50-60% of annual hot water needs are easily provided
- Excess hot water can be used to heat swimming pools
- Requires freeze protection & annual maintenance

IAQ & Ventilation

Indoor Air Quality is Important to our Clients

20% of households have someone with asthma, allergies or respiratory problems

...poor IAQ may cost 10's of billions annually in lost productivity
EPA

Air cleaners are a $1.2 Billion industry

IAQ...Why is it a bigger issue than ever?

Change in the **way we build**
- Tighter
- More chemicals
- Air conditioning

Change in the **way we live**
- 90% of time indoors
- Don't open windows
- More moisture

Change in **products we use**
- Carpets &furnishings
- Cleaners & hygiene
- More "stuff" inside

IAQ Control Strategies

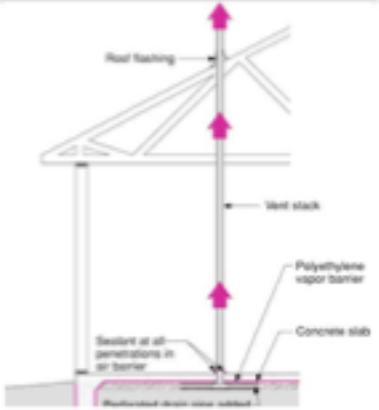
REMOVE
SEAL
VENTILATE
FILTER

IAQ Control Strategies

1. **Remove Pollutants**
2. **Source control**
   - "Seal" or Isolate
   - If you can't remove it find a way to isolate or seal it
3. **Ventilate**
   - Dilute pollutants with "fresh" outdoor air
   - Point source removal
4. **Filter**

Radon Control

- Seal slab and foundation wall cracks
- Seal sump pits
- Provide sub-slab depressurization
- Properly ventilate houses
- Proper perimeter drainage systems
- Poly and stone under slabs



Ventilation

Ventilation - a system or means of providing fresh air.

Webster New Collegiate Dictionary

We used to ventilate with windows, now we don't

All homes need Capacity for Mechanical Ventilation

- To control moisture
- To remove common pollutants
- To ensure good indoor air quality for occupants

How Much Ventilation?
ASHRAE 62.2 - 2013

Whole House - Continuous "Capacity"

Based on # of occupants & size of home

CFM = (# of bedrooms + 1) x 7.5 + (0.03 x cond. ft²)

OR USE THE TABLE

Controls moisture and common occupant pollutants

Floor Area Sq. ft	# of Bedrooms		
	1	2-3	4-5
<1500	60	75	90
1501 - 2500	90	105	120
2501 - 3500	120	135	150
3501 - 5000	165	180	195

Ventilation Sizing Example

Continuous Capacity

= (4+1) x 7.5 + (0.03 x 3000)

= 128 CFM

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Local Exhaust Ventilation

HVI

ASHRAE 62.2 minimum requirements for bath rooms & kitchens

ASHRAE 62.2 Minimum Exhaust Flow Rate

	Continuous	Intermittent
Kitchen	60 CFM	100 CFM
Bathroom	20 CFM	50 CFM

HVI Kitchen Range Exhaust Flow Rate

Location of Range	Recommended per Linear Ft of Range	Minimum per Linear Ft of Range
Against a Wall	100 CFM	40 CFM
In an Island	150 CFM	50 CFM

For Gas Ranges recommend 100 CFM / 10,000 BTUs of burner capacity

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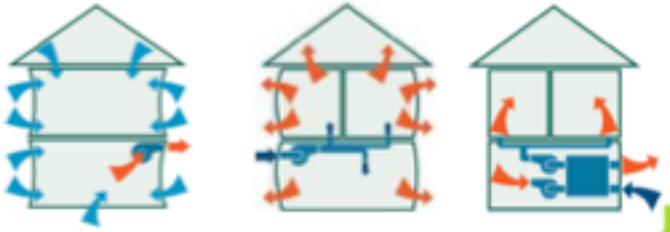
Ventilation Strategies may impact air leakage patterns

Negative Pressure
- In humid climates can pull moist air into building envelopes

Positive Pressure
- In cold climates can force moist air into building envelopes

Balanced
- Best in all climate zones



The tighter the house, the greater the pressure effect

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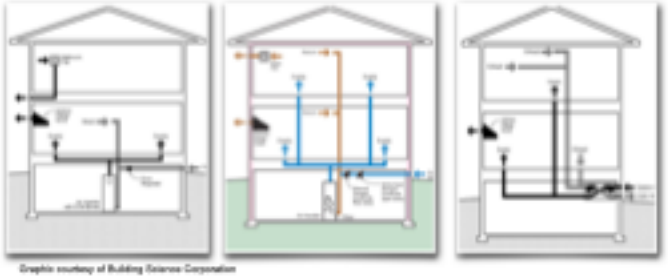
Types of Mechanical Ventilation



Exhaust Supply Balanced

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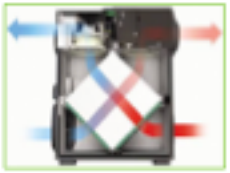
Ventilation Opportunities

Rated, Tested, Labeled Product

- Always use HVI Certified fans
- Choose ENERGY STAR Qualified Fan and HRVs





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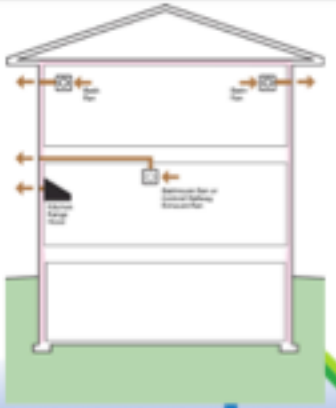
Exhaust Only Ventilation

- Specify good quiet fans in bathrooms and kitchen
- Bath fans with sound ratings under 1.5 sones
- Can be used for point source control or general ventilation
- Use timers or other controls to extend usage
- Recall that large exhaust fans can cause negative pressure



Control Strategies for "Continuous" Exhaust

Fan manufacturers have many new, helpful control strategies

- Continuous Low
- High speed occupancy
- Cycle timed



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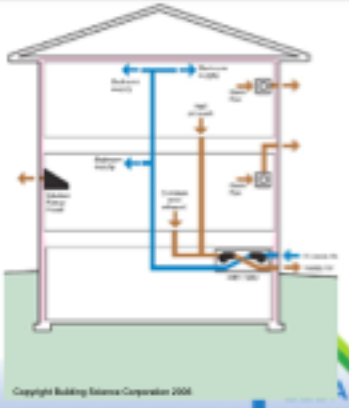
Balanced ventilation with heat or energy recovery

- Remote mounted multiple room pick-up and delivery
- Draw from the common area and supply to all bedrooms
- Central fan integration is also used



Installation Options

- There are different options for installation depending on application needs
- Often the furnace duct system is used to distribute fresh air
- When possible, run exhaust ducts from bathrooms & kitchens

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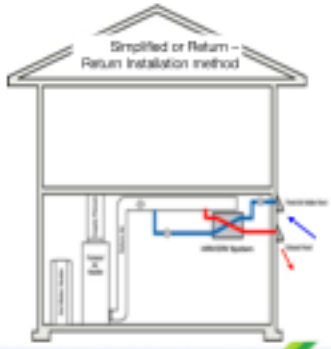
Balanced Ventilation with Heat Recovery

- HRVs / ERVs for continuous ventilation
- Choose Home Ventilating Institute (HVI) certified
- Select units with the right air flow.

HVI
HOME VENTILATING INSTITUTE



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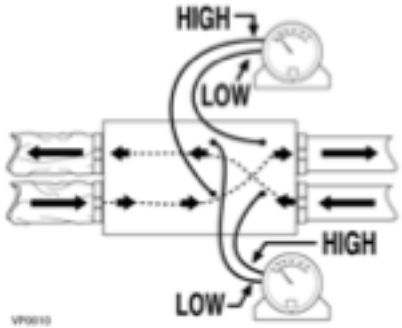
HRVs / ERVs - Balancing Flows



Ventilation Impact on Heat / Cool Loads

75 CFM of ventilation will increase HVAC loads

Cold Weather

At -20 °F

- Ventilation adds 7300 BTUs to heating loads
- Ventilation can remove up to 7 gallons of water per day

Hot Weather

At 105 °F and dry

- Ventilation adds 2500 BTUs (1/5 of a ton) to cooling loads
- At 95 °F and humid
- Ventilation adds 4500 BTUs (just over 1/3 of a ton) to cooling loads
- 2/3 of this load is latent (moisture)

These loads can be reduced by up to 80% through the use of heat / energy recovery technology

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The Cost of Ventilation – 75 CFM continuous

Electric costs Gas heat costs	$0.06 / kW $1.20 / Therm	$0.12 / kW $1.20 / Therm	$0.18 / kW $1.20 / Therm
North (Duluth, MN)	$225/yr	$260/yr	$290/yr
Mixed (Louisville, KY)	$145/yr	$195/y	$240/yr
Hot, Humid (Miami, Fl)	$ 125/yr	$195/yr	$285/yr

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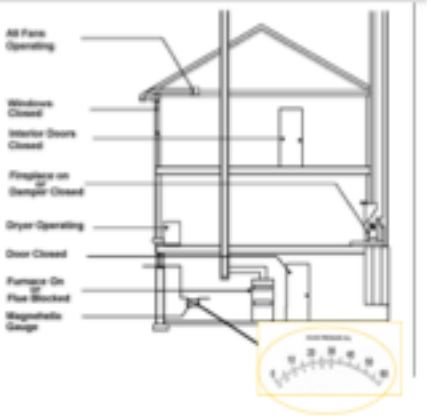
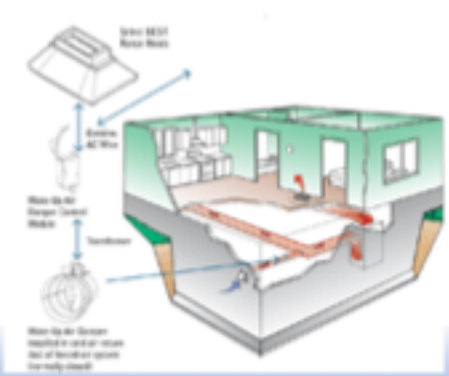
Depressurization Testing

- Use a pressure gauge to measure pressure between outside and inside
- Turn on exhaust fans
- If pressure is below 5 Pa (0.02" w.g.) then no action is required (typically)
- Otherwise provide make-up air



What about make-up air?

Fan manufacturers have new, helpful strategies



Over 400 CFM ??

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The importance of Dehumidification

Sensible loads are down:
- Better windows
- Better walls
- Better ceilings

Latent loads are up:
- More time indoors
- More plumbing
- More consistent ventilation

HVAC design must include dehumidification, to supplement air conditioning

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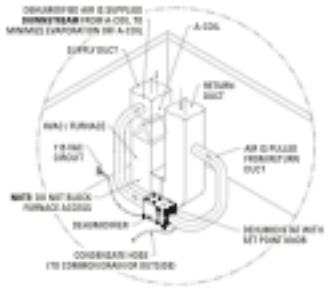
Dehumidification Strategies

Strategies:
- 2 stage AC units with humidity controls
- ERVs for ventilation
- Portable dehumidifiers
- Whole house dehumidifiers

Whole House System Advantages:
- High moisture removal capacity
- Up to 120 pints per day
- Can be integrated with AC controls
- May allow downsizing of AC system by 1/2 to 1 ton
- Filtered and drained near the central system



Critical Dehumidification Applications

- Basements in cold climates for spring and fall
- In hot, humid climates to supplement AC & ventilation loads
- **In coastal climates to aid drying of construction moisture**

Filtration

- Filtration at the furnace works and is cost effective
- Commonly located in the return duct of the air handler
- Choose a filter with a rating of MERV 13 or better
- The better the filter, the more it restricts air flow, understand the appliance needs

Filtration Options

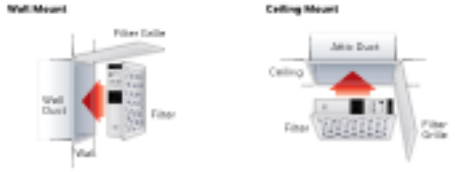
1" – 4" Pleated Filters
- MERV 8-13
- May restrict air flow

1" Electrostatic
- MERV 6-10
- Simple, washable
- May restrict air flow

Electronic Filter
- No MERV ratings
- Good at removing small particles
- Needs cleaning every 6-8 weeks
- May give off small amounts of ozone

Media Filters offer flexibility

Air Handler Cabinet



Return Air Grille Filter

Consider Pressure Drop across the filter:
Less than 0.2" W.C. should be adequate

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Summary

- Creating better envelopes
- Include ventilation on every project, performance and rationalize costs
- Choose effective, efficient, quiet fans and appliances
- Challenge your mechanical contractor to participate in your quest improving total system performance

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Changing your process
Where does actual change begin?

Who will be responsible for change?

Select key people

- Top management
- Top field staff
- Key sub-contractors
- Testing professionals
- Architects & designers
- Sales management staff

Creating a plan to move forward

- Define the concerns, plan for the solution and set a timeframe

What Now?

Tomorrow

- Evaluate flashing
- Review insulation quality
- Review duct installations
- Test a few homes to establish your basis

Two Weeks

- Review bids for change
- Create internal teams responsible for change
- Set goals for future direction

Create goals and prioritize them by both complexity and risk

Short Term Goals **Timeframe: 1 to 6 months**

Construction Detail	Best Practice	Complexity (1-Basic, 5-Complex)
Combustion safety		
Atmospherically vented furnace	Sealed combustion furnace	1
Return plenum connected to garage	Seal duct with water-based mastic, like RCD#8	3
"Fresh" air intake connected to garage	Seal all duct seams with water-based mastic and protect duct with dropped soffit	2
Leaky house/garage wall connection	Continuous air sealing	2
Water Management		
Flashing at Roof/Wall Connections	Kick-out flashing, proper lapping of Tyvek and step flashing, raw wood attached to Hardie w/o priming,	2
Window flashing	Pan flashing, proper installation sequence and integration with Tyvek	4
Penetration flashing	Correct hole sizes, Tyvek Flex Wrap patches, Tyvek tapping detail	2
Flashing attention to detail	Taping seams & tears, proper lapping, ensuring full coverage	1
Thermal Shell Improvements		
Walls	Ensure insulation is installed properly - must be full depth, no gaps, or compression	2
Attics	Insulation must be installed to consistent depth, proper sequencing of Framing and Mechanical trades	2
		3
Air Sealing		
Bypasses	Seal large air leaks with combination of proper blocking and gun foam	2
Key leaks	Seal house to garage connection	2

Create goals and prioritize them by both complexity and risk

Long Term Goals **Timeframe: 12 to 24 months**

Construction Detail	Best Practice	Complexity (1-Basic, 5-Complex)
Testing and Commissioning		
Set performance goals	Testing a handful of current homes will benchmark current construction, only then will you be able to make performance goals	3
Energy Star certification	First "Energy Star Prowler" in Portland	4
Marketing of High Performance		
How do you tell your story?	Differentiate yourself in the Portland market	4
	Engage sales people with selling high performance	

Marketing for Performance

Selling the benefits of health, safety, durability & performance

Marketing and communicating

Communicating to buyers

The High Performance Home Investment - a "no brainer"

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Get Started !!

- Develop new standards for performance
- Train your crews and subcontractors
- Reward new ideas to improve a technique
- Demonstrate new features in models
- Market your leadership position
- Document performance improvements
- Solicit customer testimonials

Thank You

EEBA Certification Series

- The Houses That Work Building Science workshop
- The HERS Associate Course
- The High Performance Mechanical Systems course

For more information:

www.eeba.org