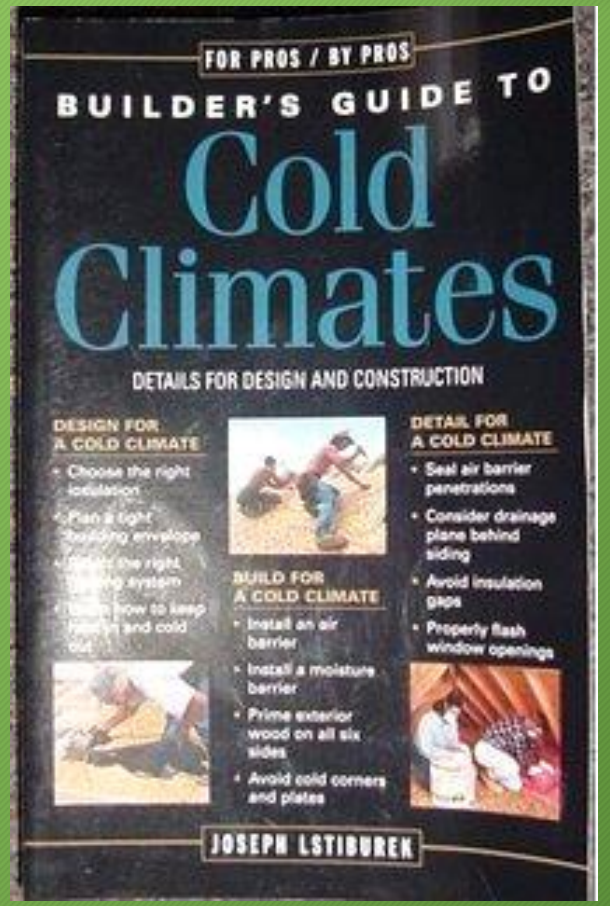
Building Science Bootcamp Better Wall Assemblies

Improving Wall Performance and Energy-Code Compliance

Building Science Bootcamp
Better Wall Assemblies

Builder's Guide to Cold Climates

- All of the information in this training module follows the "best-practices" described in this manual,
- Manuals are by climate/region, and book costs about $100 used online,
- Cities include: Denver, Chicago, Boston, Las Vegas, Phoenix, Houston, Atlanta, etc.



Under previous building codes, **40%** of the average home's energy use for heating and cooling was lost through the walls!

Joseph Lstiburek,
Building Science Corp.

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Traditional Wall Assemblies

Building Code Bare Minimum:

- R20 fiberglass batt in a 2x6 wall cavity,
- OSB sheathing and drywall,
- Interior poly vapor barrier or craft facing,
- Leaky with significant thermal bridging,

Generally speaking, this wall assembly will NOT pass a blower-door test without extensive sealing elsewhere.

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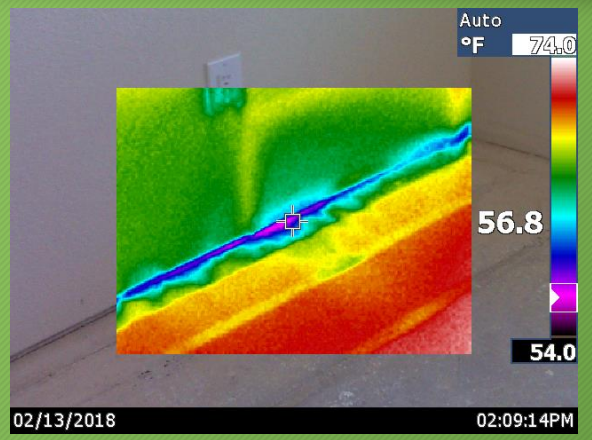
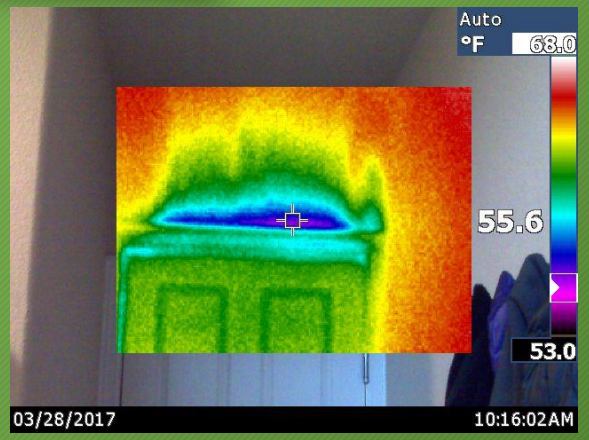
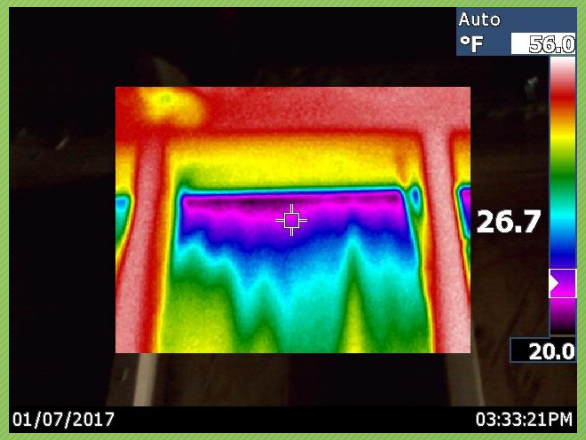
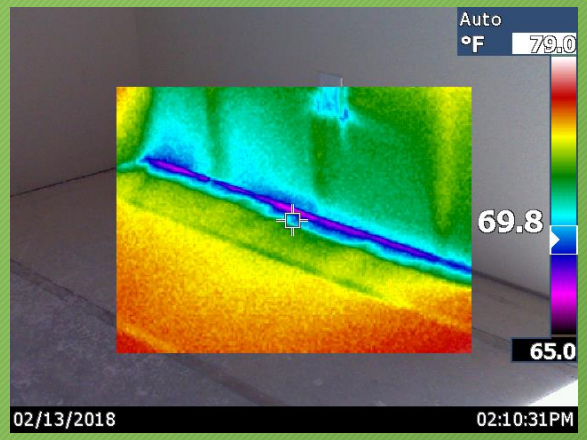
Traditional Wall Assemblies

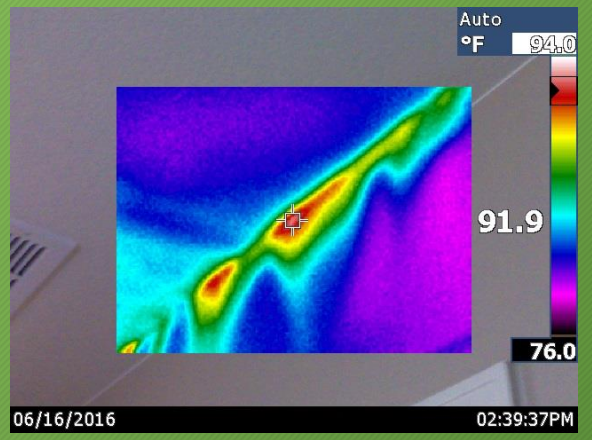
These walls are **leaky**, as building-tightness testing reveals with infrared camera: bottom & top-plates and door frames, etc.

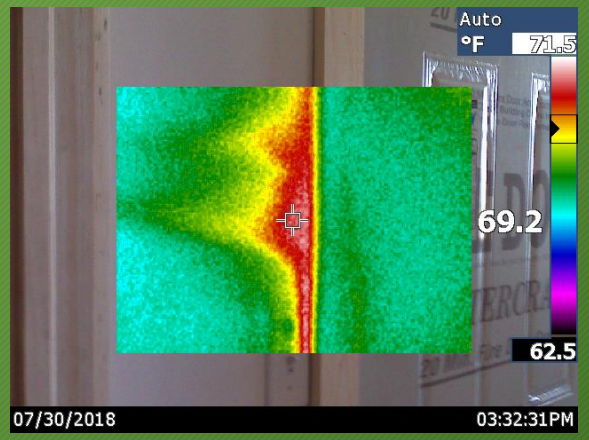












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Blow-In-Blanket (BIBS):

Pros:

- Higher R-value, and produces a very-tight wall assembly, with minimal additional air-sealing,
- Usually pass blower-door tests,

Cons:

- More expensive and time consuming, about 50% more,
- Requires additional training and lower staff turnover to make $$$
- QC important to avoid settling.

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Flash-and-Batt:

Pros:

- Hybrid approach uses 1”-2” spray-foam with blow-in-blanket fiberglass (BIBS),
- Both very tight with high R-values,
- Cost less than full-depth foam,

Cons:

- Significant contractor investment in spray foam equipment, BIBS training,
- Need well trained installers, and other foam safety concerns.

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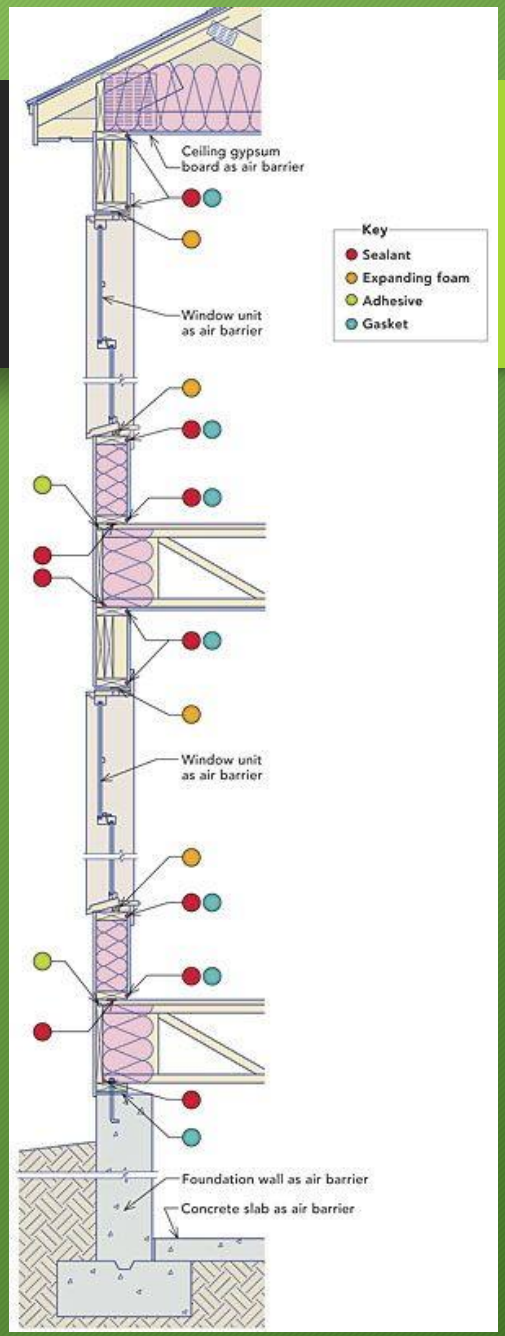
Air-Tight Wall Assemblies

Exterior Air-Barrier and Water-Resistant Sheathing:

- Pros: OSB wood-chips are individually water-proofed before laminated into sheets,
- Exterior air-barrier enhances R-value of wall-cavity insulation.
- Eliminates sealing almost all of the leak-points at far right >>>
- Cons: Over twice the cost in materials and labor of OSB!

Which approach looks easier, this one or that one?



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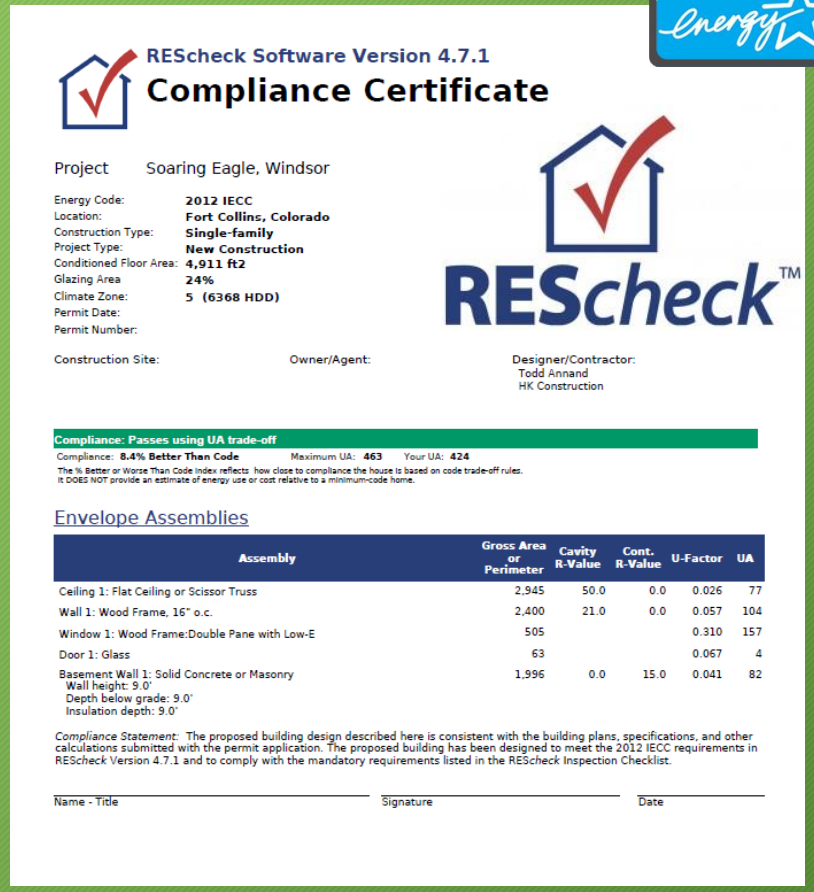
Air-Tight Wall Assemblies

Cost-saving trade-off:
Inexpensive fiberglass-batts are acceptable with ZIP system, and may eliminate need for up to 22 other points of sealing, but...

Framing sub-contractors may not have training or experience with newer best-practice building methods:

Building Energy Codes
Three Ways to Meet the Energy Codes

- **Prescriptive Path:** Follow specific requirements for Insulation R-value and Window U-factor with no exceptions,
- **Total UA Alternative:** Use **RES***check*, to calculate average U-factor for the whole building (UA), with trade-offs allowed for flexible building design to meet codes,
- **Simulated Performance Alternative**, use certified **RESNET Energy Rater** to calculate the **HERS Score** and passing score varies by building department.



REScheck Software Version 4.7.1

Compliance Certificate

Project Soaring Eagle, Windsor

Energy Code:	**2012 IECC**
Location:	**Fort Collins, Colorado**
Construction Type:	**Single-family**
Project Type:	**New Construction**
Conditioned Floor Area:	**4,911 ft2**
Glazing Area	**24%**
Climate Zone:	**5 (6368 HDD)**
Permit Date:	
Permit Number:	

REScheck™

Construction Site: Owner/Agent: Designer/Contractor: Todd Annand HK Construction

Compliance: Passes using UA trade-off

Compliance: **8.4% Better Than Code** Maximum UA: **463** Your UA: **424**

The % Better or Worse Than Code index reflects how close to compliance the house is based on code trade-off rules. It DOES NOT provide an estimate of energy use or cost relative to a minimum-code home.

Envelope Assemblies

Assembly	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	U-Factor	UA
Ceiling 1: Flat Ceiling or Scissor Truss	2,945	50.0	0.0	0.026	77
Wall 1: Wood Frame, 16" o.c.	2,400	21.0	0.0	0.057	104
Window 1: Wood Frame:Double Pane with Low-E	505			0.310	157
Door 1: Glass	63			0.067	4
Basement Wall 1: Solid Concrete or Masonry Wall height: 9.0' Depth below grade: 9.0' Insulation depth: 9.0'	1,996	0.0	15.0	0.041	82

Compliance Statement: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the 2012 IECC requirements in REScheck Version 4.7.1 and to comply with the mandatory requirements listed in the REScheck Inspection Checklist.

Name - Title Signature Date

Certified Energy Raters can be found online at *resnet.us*

RES*check* is a free online program found at *energycodes.gov*

Key Energy Concepts: U-Factors Versus R-Values

Heat Flow Resistance Calculations:

- **U-factor is the rate of energy conduction** through building materials, expressed as a decimal, and equates to the percent lost, so a ***0.32 U-factor = 32% energy loss***,

- **R-value is the INVERSE of the U-factor**, so ***R-20 = 1/20, which = 0.05 U-factor***,

- Wood-framed walls w/windows will often have an overall R-value of only R10, resulting in a 10% rate of loss, meaning 100% of the energy escapes every 10-hrs, ***That's 360 times per winter!***

R-value	Losses	Reductions
0.32U window	32%	68%
0.25U window	25%	75%
R5 Insulation	20%	80%
R10 Insulation	10%	90%
R15 Wall	07%	93%
R20 Wall	05%	95%
R25 Wall	04%	96%
R38 Attic	03%	97%
R50 Attic	02%	98%

(based on temp delta of 40° degrees)

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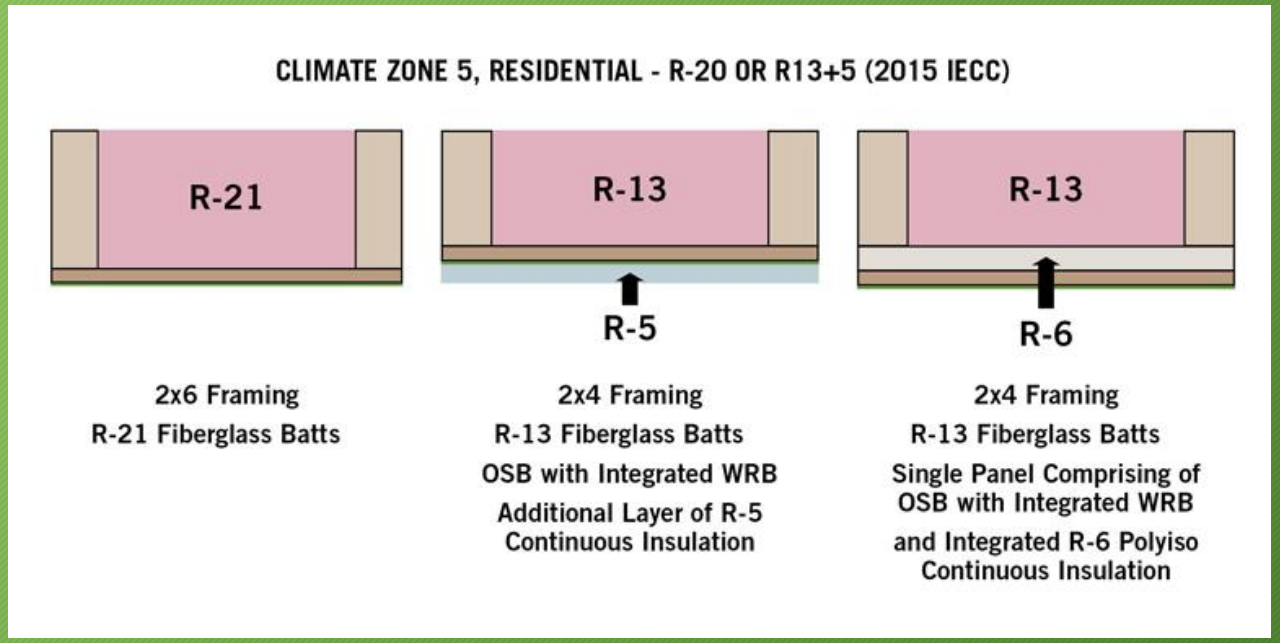
Basic vs. Better Wall Assemblies

Building Code 2015 IECC:

- Vast majority of builders opt for R21 fiberglass batts & 2x6 studs,
- Original wall insulation standards assumed 2 x 6 studs would be spaced 24” on center, not 16” o.c.
- **Pros:** simple and inexpensive,
- **Cons:** leaky and actual R-value significantly lower, more like **R10**.



Which one of these walls has the best R-value?

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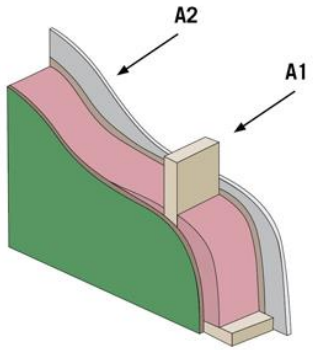
Thermal Bridging in Walls

2 X 6 Wall:

R-20 cavity without foamboard = **R15** **wall assembly** due to thermal bridging:



U-FACTOR EXAMPLE 1 - CAVITY INSULATION ONLY

WALL COMPONENT	A1	A2
CONTINUOUS INSULATION	R-0.0	R-0.0
OSB SHEATHING	R-0.62	R-0.62
FRAMING OR INSULATION	**R-6.88**	**R-20**
DRYWALL	R-0.45	R-0.45
TOTAL R-VALUE	R-7.95	R-21.07
U-FACTOR (1/R)	U-0.126	U-0.048
% OF WALL AREA	22%	78%

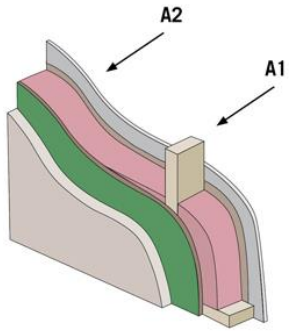
Calculation: Area weighted average U-factor

U = (0.22 x 0.126) + (0.78 x 0.048)

U = 0.065 Effective R = 1/U = 15.38

2 X 4 Wall:

R-13 cavity w/exterior ¾" foamboard = **R16** **wall assembly** and less bridging :



U-FACTOR EXAMPLE 2 - CAVITY INSULATION PLUS CONTINUOUS INSULATION

WALL COMPONENT	A1	A2
CONTINUOUS INSULATION	R-5.0	R-5.0
OSB SHEATHING	R-0.62	R-0.62
FRAMING OR INSULATION	**R-4.38**	**R-13**
DRYWALL	R-0.45	R-0.45
TOTAL R-VALUE	R-10.45	R-19.07
U-FACTOR (1/R)	U-0.095	U-0.052
% OF WALL AREA	25%	75%

Calculation: Area weighted average U-factor

U = (0.25 x 0.095) + (0.75 x 0.052)

U = 0.063 Effective R = 1/U = 15.87

The 2x4 wall with continuous exterior insulation has the slightly higher R-value.

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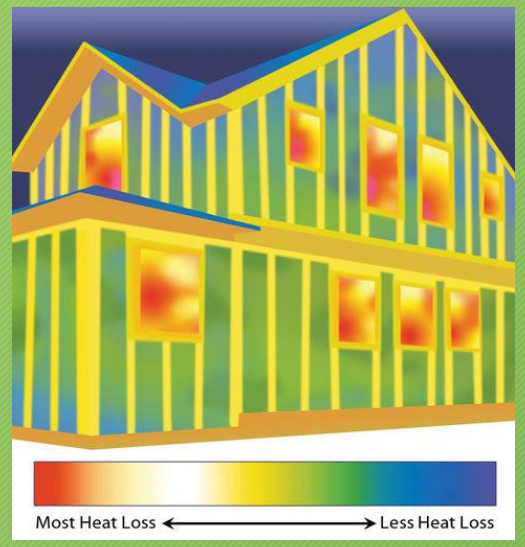
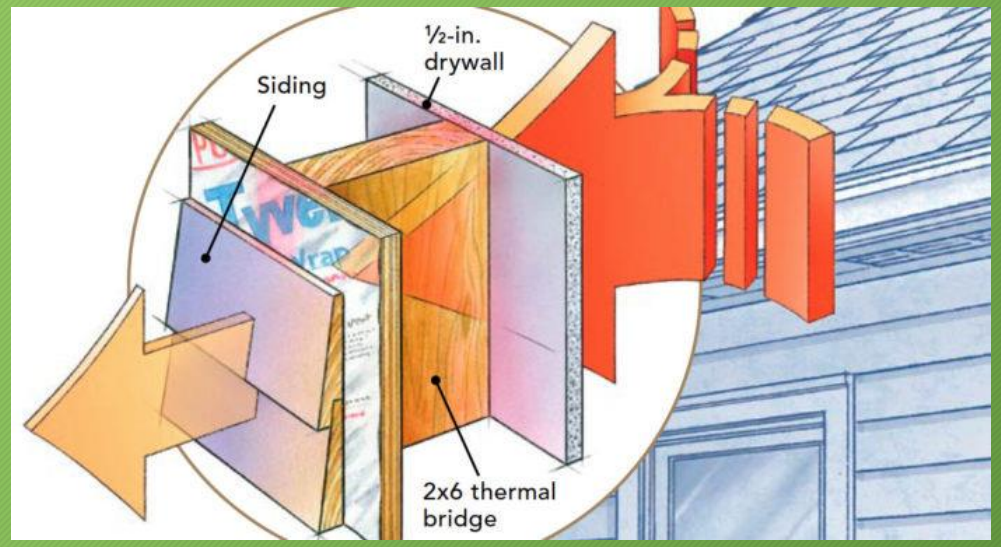
Key Energy Concepts – Thermal Bridging

Thermal Bridging:

- Reduces *rated vs effective* R-Values,
- Wood-framed buildings often exceed 25% framing-factor, so more energy losses,
- Commercial steel-framed buildings have huge losses through thermal bridging.





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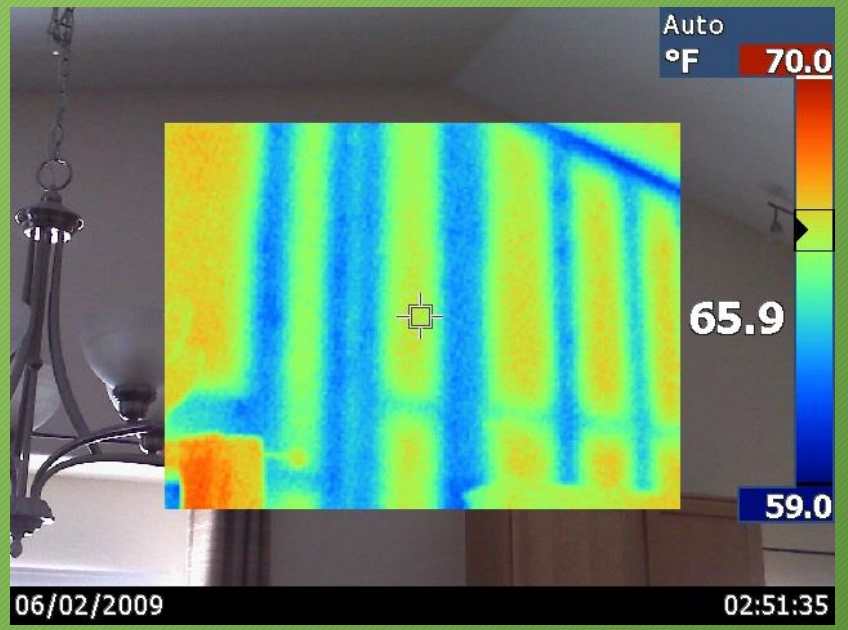
Thermal Bridging in Wall Assemblies

Examples of **thermal bridging** observed with an **infrared camera***,
in local new construction during winter weather conditions:



**It's also a $5,000 stud-finder!*

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Thermal Bridging in Wall Assemblies

Calculate Average U-factor (UA):

$$\frac{((U1 \times A1) + (U2 \times A2) + (U3 \times A3))}{\text{Total Area}}$$

Typical 2,300 sq ft residential home:

(0.32u windows x 250 sq ft) +
(0.05u wall insulation x 1500 sq ft) +
(0.126u x 500 sq ft wood-framing)
2,250 sq ft

Total UA = 0.097 (or R-10)

Not much room for insulation in these walls:

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Thermal Bridging in Framing

Framing-factors, as a percentage of total wall area, often exceed standard **framing factor of 23% used to develop energy codes**.

Therefore U-factors are much lower than predicted.
Framing factors can easily run as high as 40% in multi-family, and homes w/complex floor plans with abundant windows/doors.

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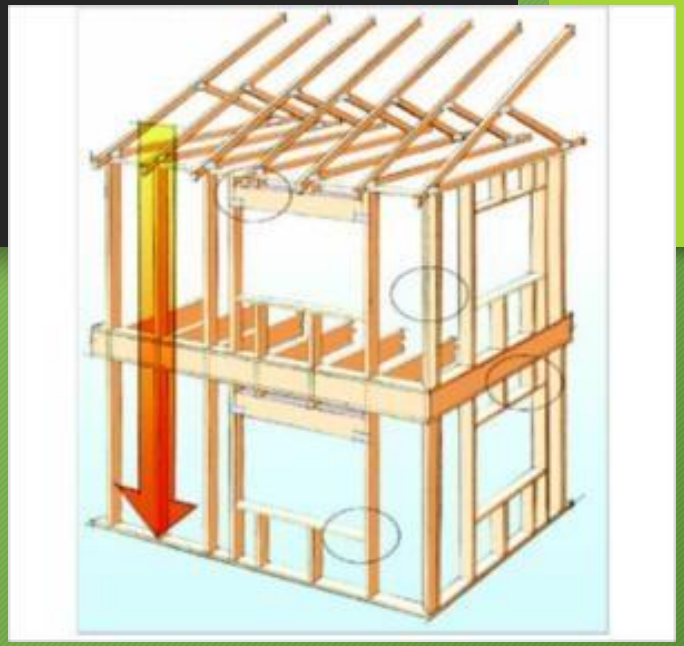
Very Low Thermal Bridging



Advanced Framing: for less thermal bridging…

- Aligns lumber with loads from floor-to-roof,
- Rafters align with wall studs, which align with floor joist,
- “California corners” and insulated headers
- Framing-factor of only 15% improves U-values,
- Saves materials and labor.

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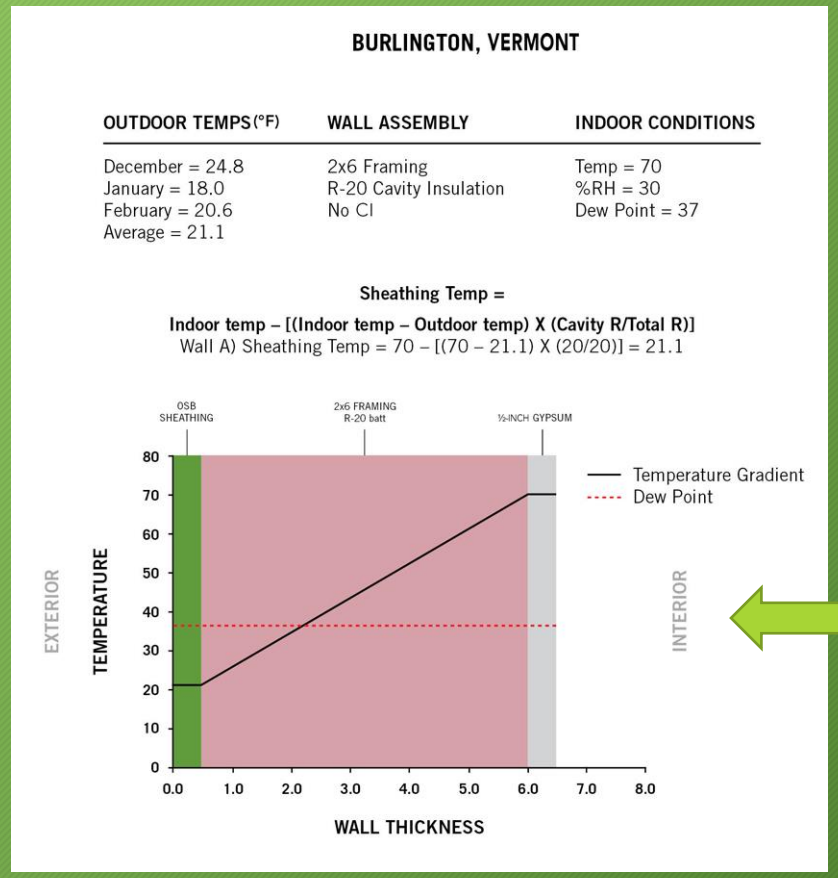
Dew Point in Wall Assemblies

Back to Basics:
Hot Goes to Cold, Wet Goes to Dry

As warm moisture is drawn into the wall, it must be prevented from moving to the cold side of the wall, cooling below dew point, and condensing in the wall assembly.

Keeping the moisture above dew point allows it to evaporate, or “dry to the inside” and warm-side vapor barriers keep moisture sufficiently insulated from the outdoors.



Moisture cools as it moves through the wall insulation towards the cold outdoors:

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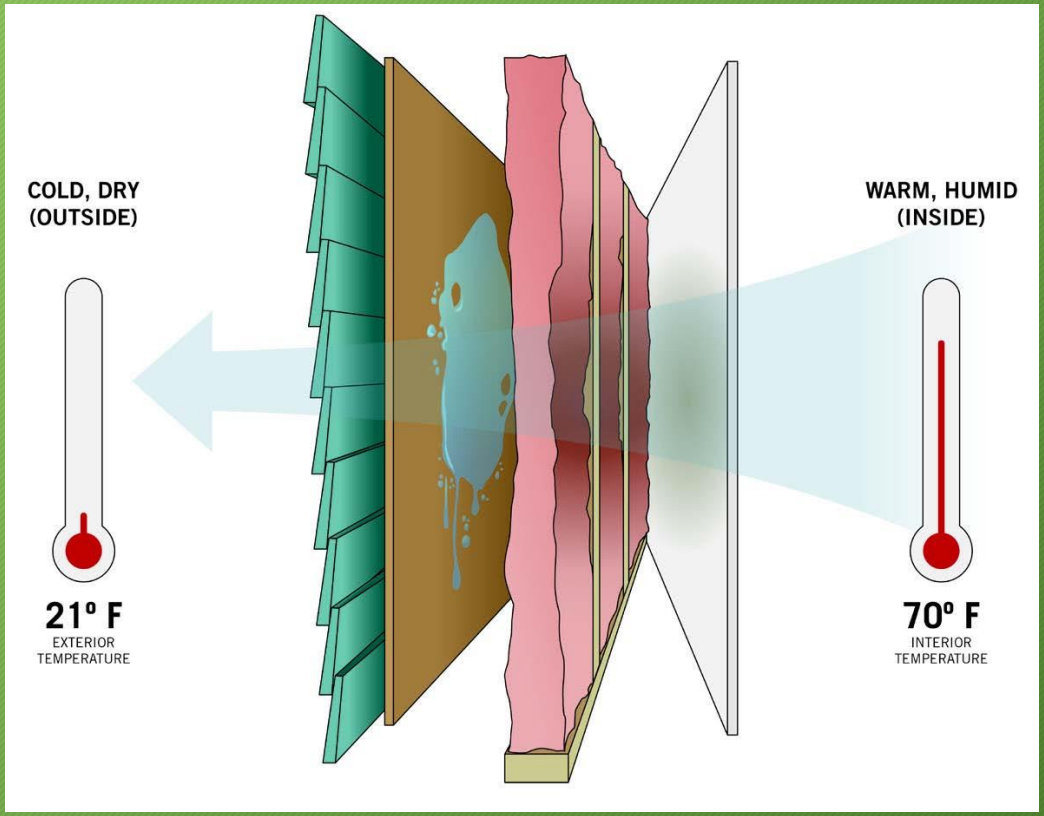
Dew Point in Wall Assemblies

Colorado is a heating dominated climate, and it's usually more humid inside the buildings than it is outside in winter due to humidification, people, showering, cooking, etc.

Therefore, our vapor barriers belong on the warm, interior side of the wall, to avoid risk of condensation in the walls.



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Dew Point and Condensation

Too-thin exterior foil-board insulation acts a “cold-side” vapor barrier and promotes condensation in the wall. The building wall components stay cold, wet and rot quickly.

Green Builders Who Got it Wrong, Knowing which Foam Board to use is Critical!

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Dew Point and Continuous Insulation

Exterior Continuous Insulation:

- Must be "vapor open" *OR*
- Sufficient R-value to keep the interior condensing foam surface warm, and above dew point,

For Climate Zone 5:

- 2x4 walls need R-5 foam board,
- 2x6 walls need R-10 foam board,

Best for different siding options:

- ¾" foam board = wood siding,
- 1½" foam board = stucco.

Clear plastic film is peeled off and removed from this ¾" foam board prior to installation, making it *"vapor-open"*

Knowing which foamboard to use is critical!

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Above-code Wall Assemblies:

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Advanced Framing + Continuous Insulation

Habitat for Humanity Gets it Right!

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Thermal Bridging in Steel-Stud Walls

Steel studs in commercial buildings reduce effective R-value by 40% to 70%

Continuous exterior insulation is critical to effective climate control, energy efficiency.

Effective Insulation/Framing Layer R-Values

Steel-framed wall information adapted from ANSI/ASHRAE/IESNA Standard 90.1-2007 Table A9.2B.

Stud Wall Framing Type	Nominal Cavity Depth (inches)	Actual Cavity Depth (inches)	Rated R-Value	Effective R-Value at 16 in. on Center[1]	% Change (Rated vs Effective)	Effective R-Value at 24 in. on Center[2]	% Change (Rated vs Effective)
Batt Insulated Cavity							
Steel	4	3.50	R-11	R-5.5	-50%	R-6.6	-40%
Steel	4	3.50	R-13	R-6.0	-54%	R-7.2	-45%
Steel	4	3.50	R-15	R-6.4	-57%	R-7.8	-48%
Steel	6	6.00	R-19	R-7.1	-63%	R-8.6	-55%
Steel	6	6.00	R-21	R-7.4	-65%	R-9.0	-57%
Steel	8	8.00	R-25	R-7.8	-69%	R-9.6	-62%
Wood	4	3.50	R-11	R-9.3	-15%	R-9.5	-14%
Wood	4	3.50	R-13	R-10.8	-17%	R-11.1	-15%
Wood	4	3.50	R-15	R-12.3	-18%	R-12.7	-15%
Wood	6	5.50	R-19	R-16.0	-16%	R-16.3	-14%
Wood	6	5.50	R-21	R-17.5	-17%	R-17.9	-15%
Wood	8	7.50	R-25	R-21.1	-16%	R-21.5	-14%

** Rating for airspace per ANSI/ASHRAE/IESNA Standard 90.1-2007.*

[1] Per the ASHRAE Handbook of Fundamentals, a residential wall framing factor of 25 percent is assumed for conventional framing at 16 in. on center.

2 Per the ASHRAE Handbook of Fundamentals, a residential wall framing factor of 22 percent is assumed for conventional framing at 24 in. on center.

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Thermal Bridging in Steel-Stud Walls

Commercial and Institutional Buildings:

- High R-value vapor-tight foamboard,
- High R-value vapor-open rockwool,
- Multi-family high-rise apartments as well,
- Walls have no measurable energy heat gains or losses.

Exterior 2” poly-iso foil-board at Front Range Community College Medical Campus, Fort Collins, CO

Exterior rockwool at Steamboat Comm Center

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Key Window Concepts

To Learn More about Energy Codes or Green Building, please contact:

Community Development

https://www.larimer.org/building

Building: 970-498-7700 or

Planning: 970-498-7683

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