High R walls

Dr John Straube, P.Eng.
Building Science Corp
University of Waterloo

www.BuildingScience.com

Building America U.S. Department of Energy Research Toward Zero Energy Homes

Why High R-wall walls

- Preserve your well-being
  - Food, air, water, etc.
- Preserve your wallet
  - Future trends
- Improve your security
  - Can you get your fuel?
- Buildings consume 40% of America's energy

High R= About 2x Code

TABLE N1102.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION U-FACTOR	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[k]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE AND DEPTH	CRAWL SPACE[c] WALL R-VALUE
1	1.2	0.75	0.35[j]	30	13	3/4	13	0	0	0
2	0.65[j]	0.75	0.35[j]	30	13	4/6	13	0	0	0
3	0.50[j]	0.65	0.35[e,j]	30	13	5/8	19	5/13[f]	0	5/13
4 except Marine	0.35	0.60	NR	38	13	5/10	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.35	0.60	NR	38	20 or 13 + 5[h]	13/17	30[g]	10/13	10, 2 ft	10/13
6	0.35	0.60	NR	49	20 or 13 + 5[h]	15/19	30[g]	10/13	10, 4 ft	10/13
7 and 8	0.35	0.60	NR	49	21	19/21	30[g]	10/13	10, 4 ft	10/13

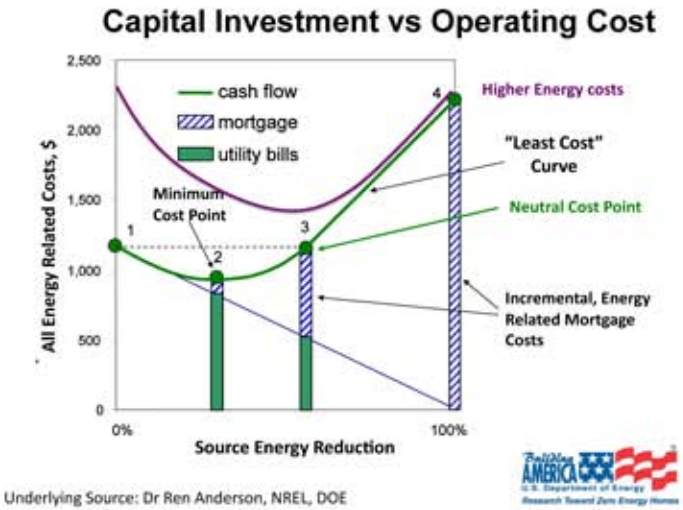
a. *R*-values are minimums. *U*-factors and solar heat gain coefficient (SHGC) are maximums. R-19 batts compressed in to nominal 2 × 6 framing cavity such that the *R*-value is reduced by R-1 or more shall be marked with the compressed batt *R*-value in addition to the full thickness *R*-value.
b. The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration.
c. The first *R*-value applies to continuous insulation, the second to framing cavity insulation; either insulation meets the requirement.
d. R-5 shall be added to the required slab edge *R*-values for heated slabs. Insulation depth shall be the depth of the footing or 2 feet, whichever is less, in zones 1 through 3 for heated slabs.
e. There are no SHGC requirements in the Marine Zone.
f. Basement wall insulation is not required in warm-humid locations as defined by Figure N1101.2 and Table N1101.2.
g. Or insulation sufficient to fill the framing cavity, R-19 minimum.
h. "13+5" means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25% or less of the exterior, R-5 sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25% of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.
i. For impact-rated fenestration complying with Section R301.2.1.2, the maximum *U*-factor shall be 0.75 in zone 2 and 0.65 in zone 3.
j. For impact-resistant fenestration complying with Section R301.2.1.2 of the *International Residential Code*, the maximum SHGC shall be 0.40.
k. The second *R*-value applies when more than half the insulation is on the interior.

Insulation: how much

- How much? Much *more than normal practise*
- Comfort & moisture –
  - **True** 10 is usually enough in Zone 6/7, but …..
- For energy / environment / economics
  - as much as *practical*
- Practical constraints likely the limit
  - How much space available in studs?
  - Moisture concerns
  - Fastening, windows: exterior sheathing of 1.5"/4"
- Increased insulation can reduce HVAC purchase/ install cost as well as operating!

Building Science

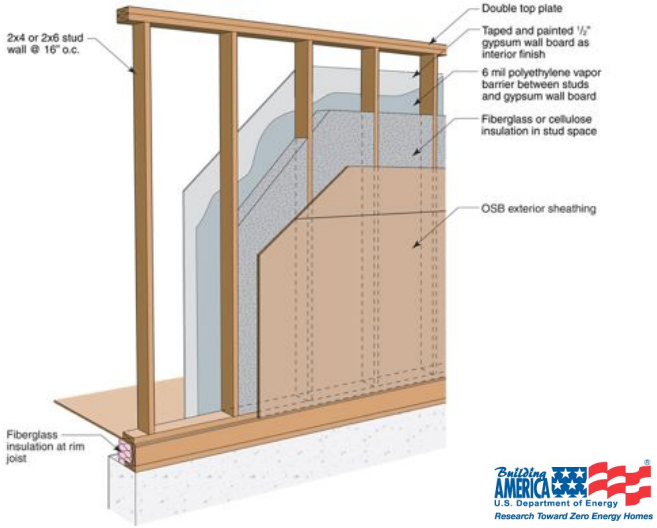
Building America U.S. Department of Energy Research Toward Zero Energy Homes



Underlying Source: Dr Ren Anderson, NREL, DOE

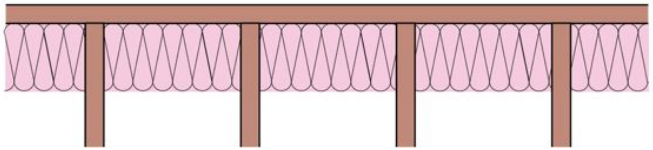
But there are Complications

- Add up the R-values of the layers to get the total R-value of the assembly
- **BUT** the actual thermal resistance of an assembly is affected by
  - **Thermal Bridges**
  - **Thermal Mass**
  - **Air Leakage**
  - **Temperature**

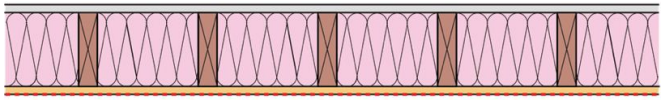


Computer Modeling Study

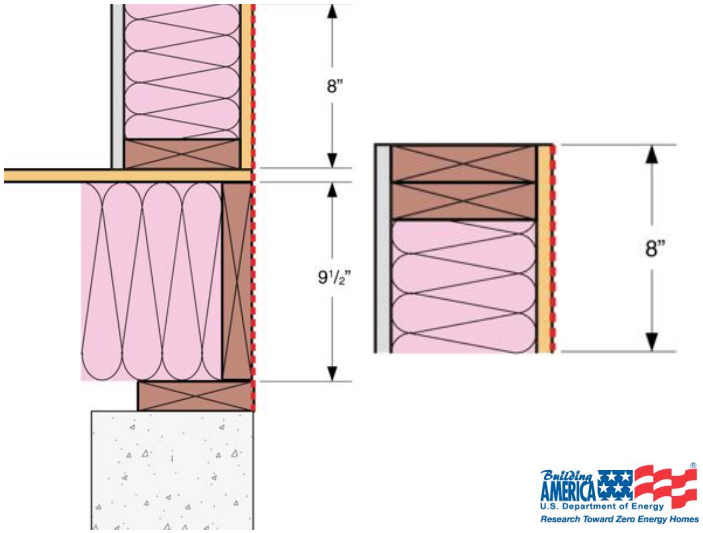
- Used 2D models to build up 3D results
- Considered 16% and 25% framing factors
- Standard conductivity values for wood
- Rated R-value for insulation

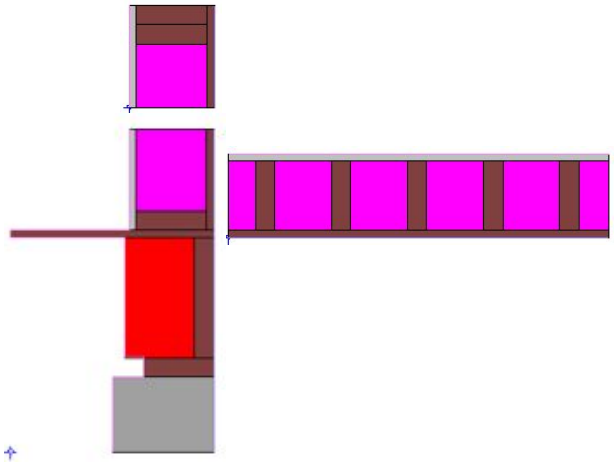


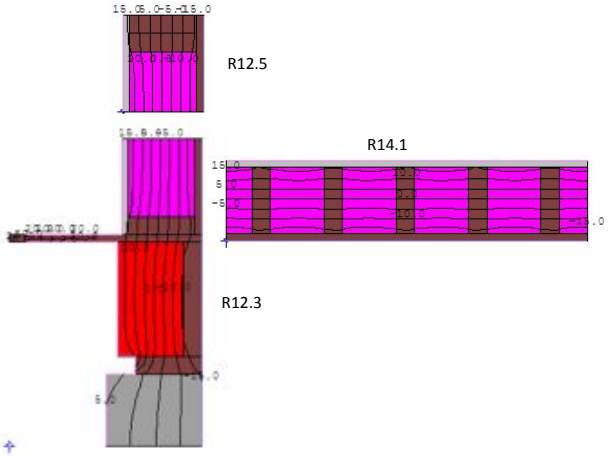
Plan View @ rim joist/ floor

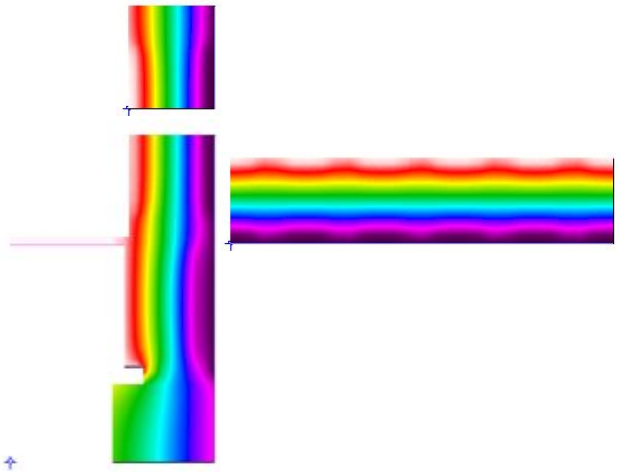


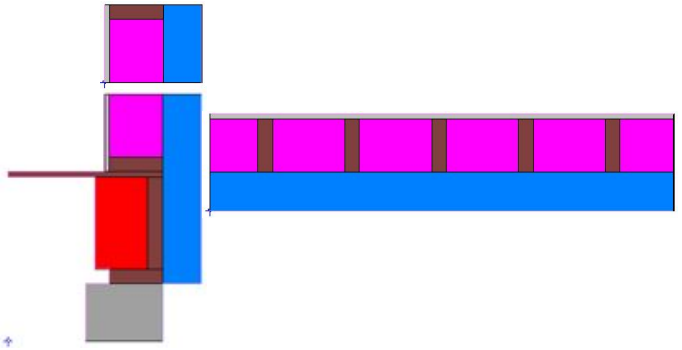
Plan View @ wall

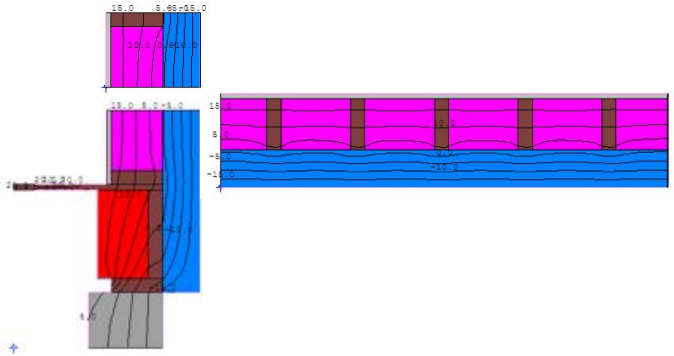


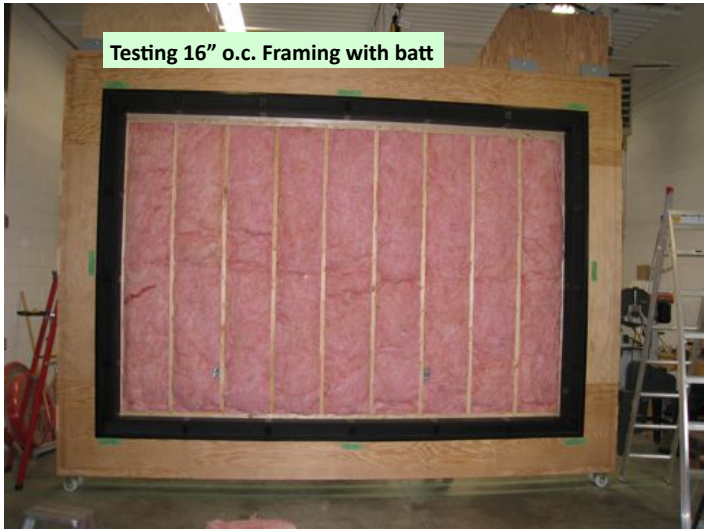






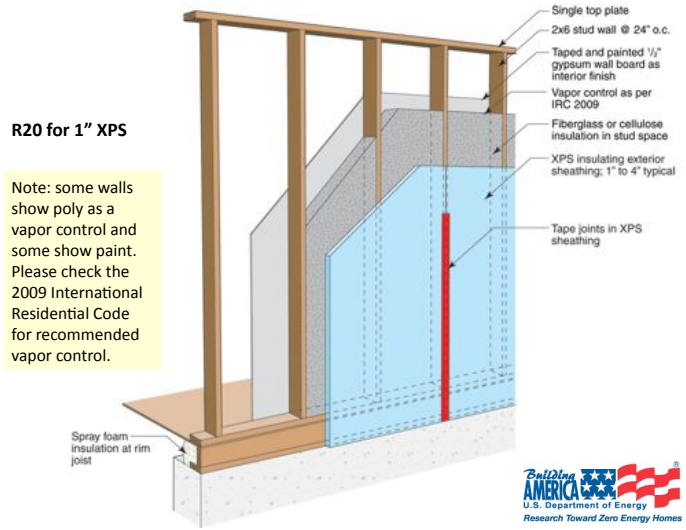





Testing 16” o.c. Framing with batt

Experimental Verification

- C518 tested each material used in wall sample at temperature being tested
- Therm predicts better than 5% of measured overall True R-value
- Will be testing more high-R walls in the future



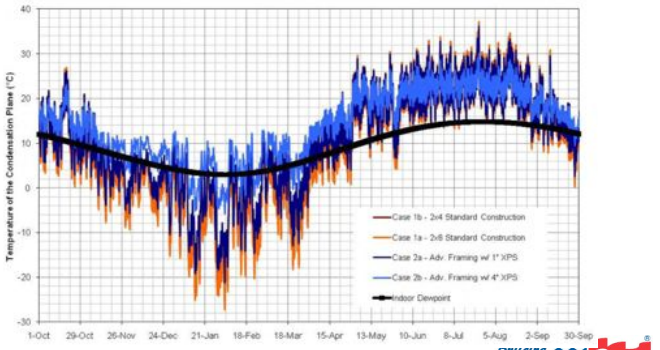
R20 for 1" XPS

Note: some walls show poly as a vapor control and some show paint. Please check the 2009 International Residential Code for recommended vapor control.

Durability

- Insulating makes in/out face of enclosure cold
  - Gypsum board or OSB in normal walls
- Condensation occurs on cold surface
- Drying occurs slowly when cold
- Ergo... Insulating makes things wetter!
- Air & water vapor moves through fiberglass and cellulose
- Foam stops air and slows vapor

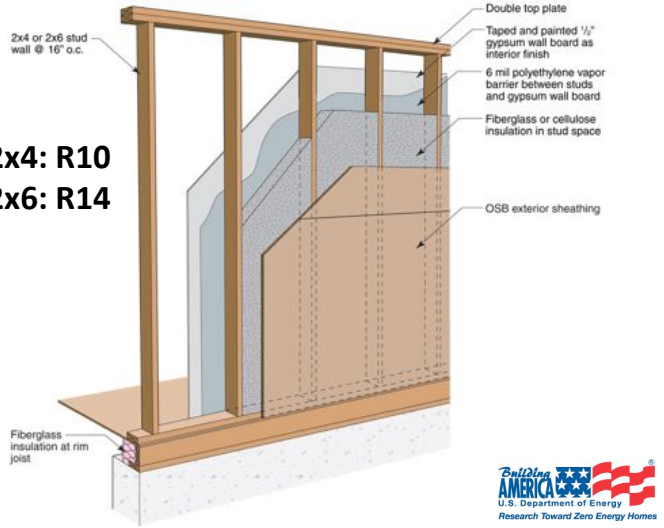
Air Leakage Condensation Potential



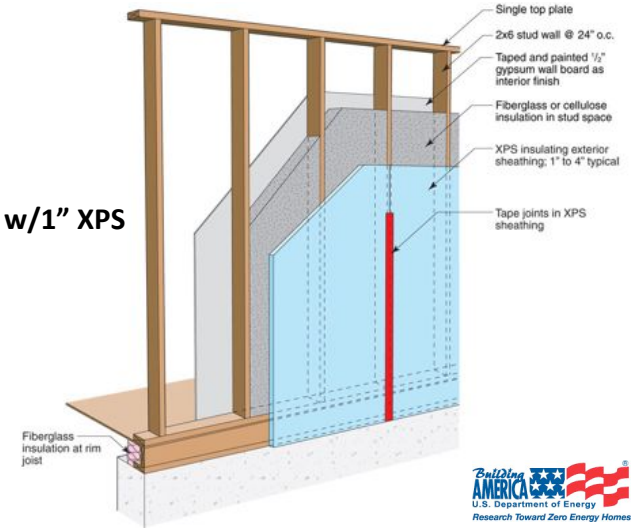
True R-value

- Includes realistic framing factors
  - 3D heat loss
  - Realistic framing factors
  - (16% advanced framing, 25% normal)
- Should include airtightness
  - But we don't have a metric yet
- Durability also matters
  - No one metric will work

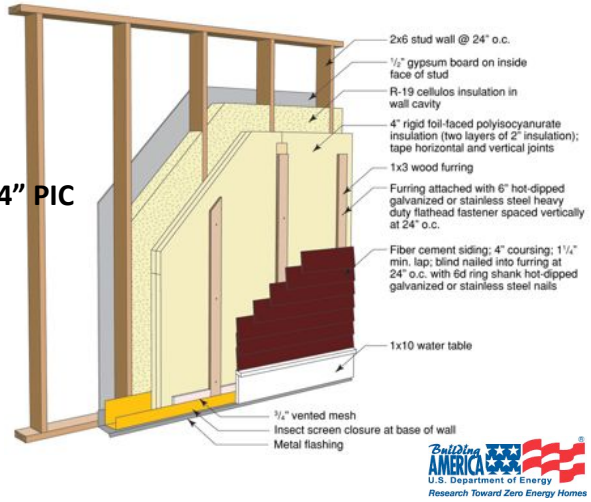
2x4: R10
2x6: R14

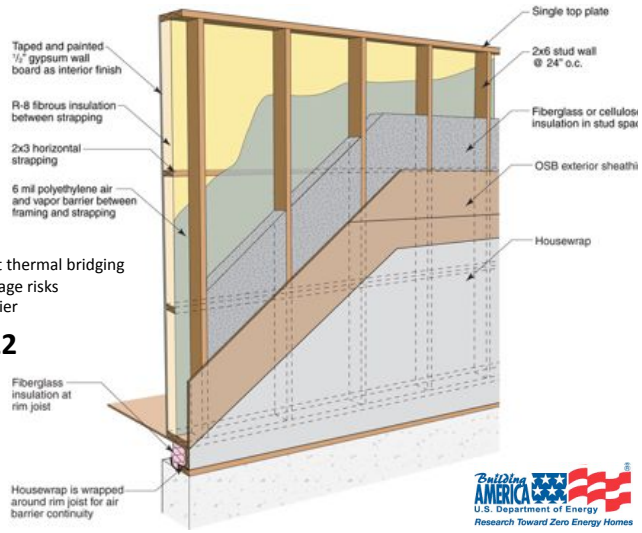


R20 w/1” XPS



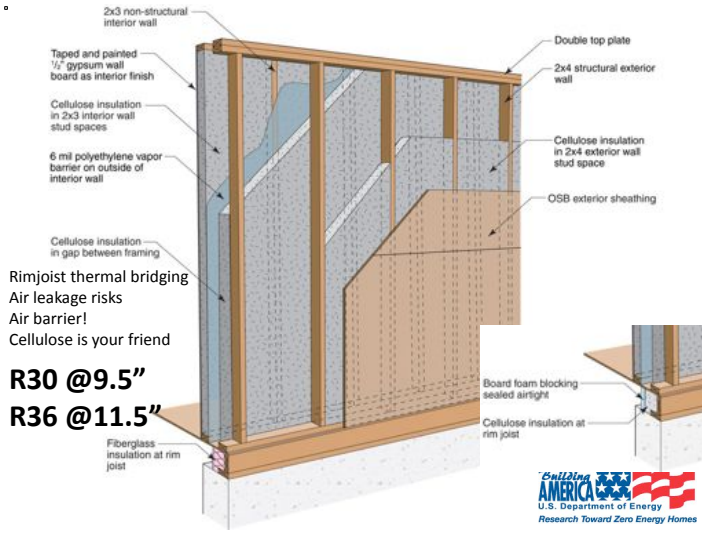
R40 w/4” PIC





Rimjoist thermal bridging
Air leakage risks
Air barrier

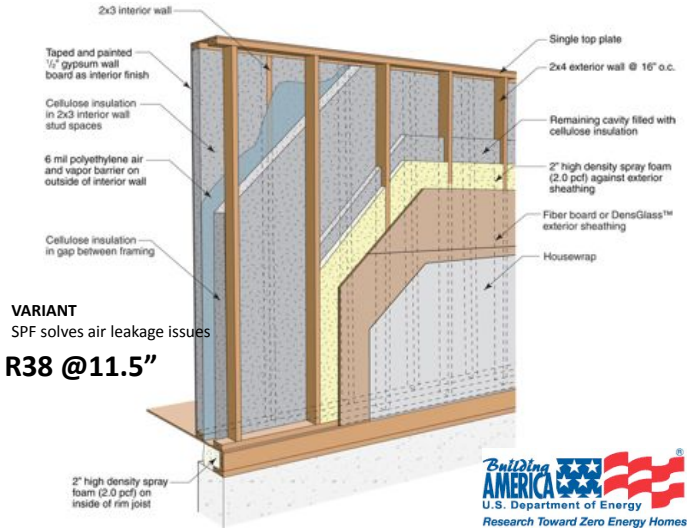
R22



Rimjoist thermal bridging
Air leakage risks
Air barrier!
Cellulose is your friend

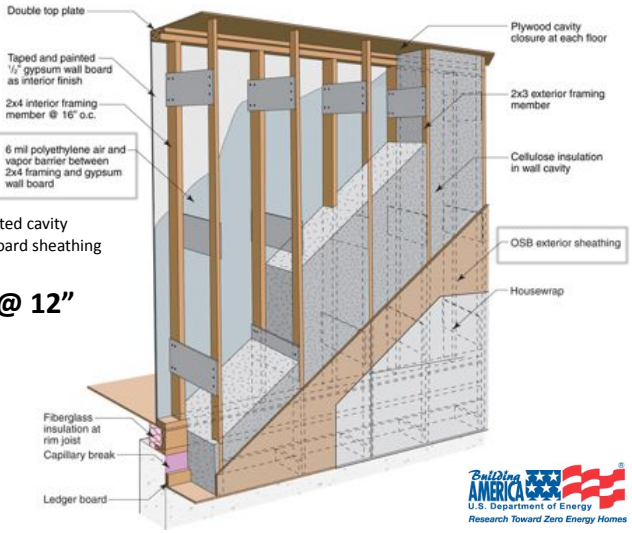
R30 @9.5”
R36 @11.5”

Construction issues



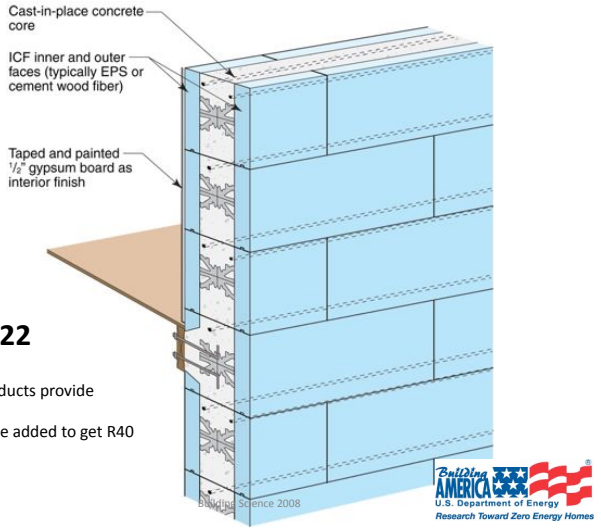
VARIANT
SPF solves air leakage issues

R38 @11.5”



¾" vented cavity
Fibreboard sheathing

R36 @ 12"

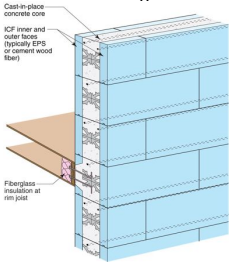


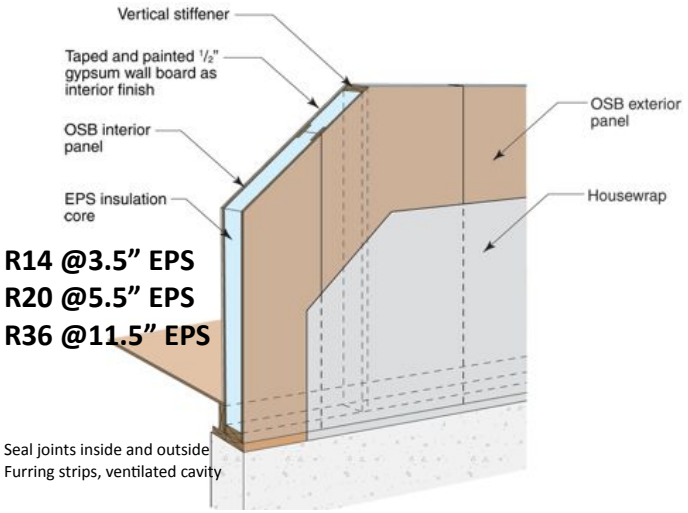
R16-R22

A few products provide
R30-40+
EIFS can be added to get R40

Insulated Concrete Forms

- If you afford it, use them –
  - cap break,
  - insulation,
  - vapor retarder,
  - above grade



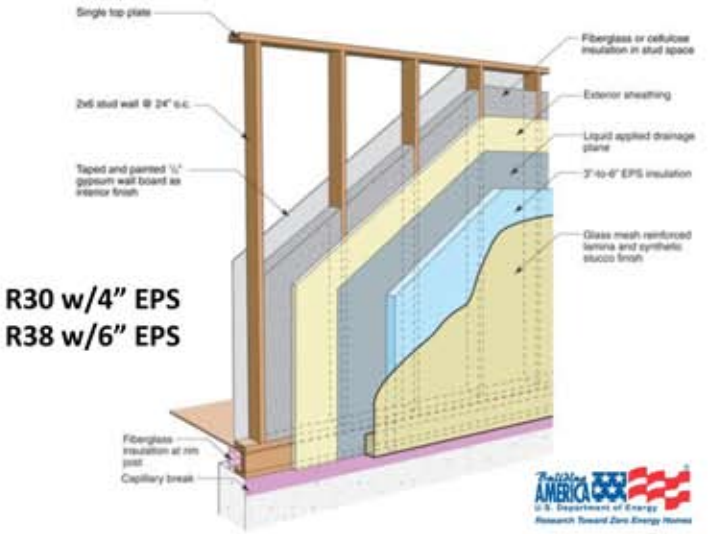


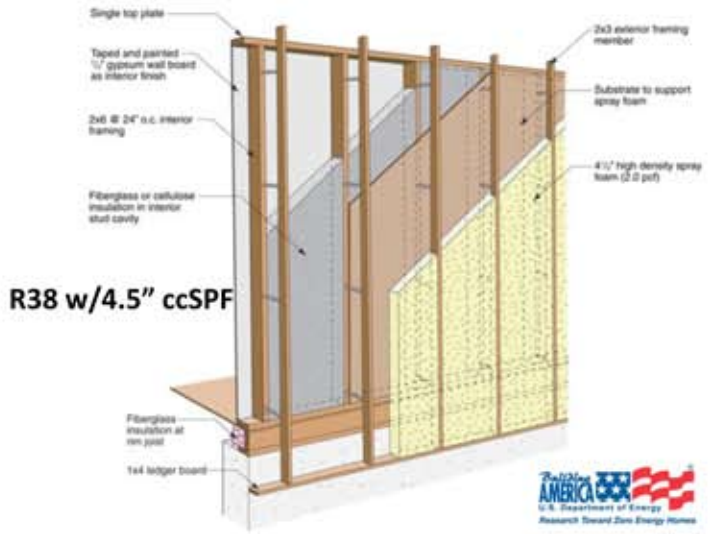
R14 @3.5" EPS
R20 @5.5" EPS
R36 @11.5" EPS

Seal joints inside and outside
Furring strips, ventilated cavity

Structural Insulated Panels

- Advantages
  - Superior blanket of insulation
  - if no voids then no convection or windwashing
- Must seal OSB joints for air barrier system
- Therefore, done right = excellent
- Small air leaks at joints in roofs can cause problems
- Don't get them too wet from rain
  - Low perm layers means limited drying: strapped cavity





Small changes are easy

	Case	Description	Whole Wall R-value	Rim Joist	Clear Wall R-value	Top Plate
Ugly	1bi	2x4, 16"oc, R13FG + OSB (25%ff)	10.0	9.8	10.1	9.8
	1b	2x4 AF, 24"oc, R13FG + OSB	11.1	9.8	11.5	9.8
	1ai	2x6, 16"oc, R19FG + OSB (25%ff)	13.7	12.3	14.1	12.5
	6a	SIPs (3.5" EPS)	14.1	12.3	14.5	10.6
Bad	1a	2x6 AF, 24"oc, R19FG + OSB	15.2	12.3	16.1	12.5
	7a	ICF - 8" foam ICF (4" EPS)	16.4		16.4	
	8b	2x6 AF, 24" o.c., 5.5" R21 0.5 pcf SPF, OSB	16.5	13.1	17.2	16.6
	7c	ICF - 14" cement woodfiber ICF with Rockwool	17.4		17.4	
	9	2x6 AF, 24"oc, 2" SPF and 3.5" cellulose	17.5	13.2	18.4	17.7
	8a	2x6 AF, 24" o.c., 5" 2 pcf R29 SPF, OSB	19.1	13.6	20.3	19.5
	2a	2x6 AF, 24"oc R19FG + 1" R5 XPS	20.2	16.5	20.6	20.3
	7b	ICF - 15" foam ICF (5" EPS)	20.6		20.6	
	3	2x6 AF, 24"oc, 2x3 R19+R8 FG	21.5	13.4	23.5	18.4
Good	4	Double stud wall 9.5" R34 cellulose	30.1	14.4	33.5	28.8
	12	2x6 AF, 24"oc, EIFS - 4" EPS	30.1	23.8	31.4	31.1
	10	Double stud with 2" 2.0 pcf foam, 7.5" cell.	32.4	15.9	36.2	28.5
	2b	2x6 AF, 24"oc R19FG + 4" R20 XPS	34.5	29.0	35.6	35.4
	6b	SIPs (11.25" EPS)	36.2	14	41.6	28.2
	5	Truss wall 12" R43 cellulose	36.5	18.6	40.5	34.4
	11	Offset frame wall with ext. spray foam	37.1	18.8	40.6	41.9

*AF - Advanced Framing

Other Components

- R40 Walls are just one component!
  - Basements, airtightness
- Windows often weak link
  - Triple-glazed becoming justified
- Basement
  - Slabs R5-10 is worth it for comfort alone
  - Basement walls should be R15-30
- Easy and cheap to upgrade vented attics R60+
- Airtightness: aim for 1.5 ACH@50

Questions?

- BuildingScience.com
  "High-R Walls"

Building America Special Research Project: High-R Walls Case Study Analysis

Research Report - 0903

March 11, 2009 (rev. 8/7/09)

John Straube and Jonathan Smegal

Abstract

Many concerns, including the rising cost of energy, climate change concerns, and demands for increased comfort, have lead to the desire for increased insulation levels in many new and existing buildings. More building codes are being modified to require higher levels of thermal control than ever before. This report considers a number of promising wall systems that can meet the requirement for better thermal control. Unlike previous studies, this one considers performance in a more realistic manner, including some true three dimensional heat flow and the relative risk of moisture damage.

Building America
U.S. Department of Energy
Research Toward Zero Energy Homes

Summary Comparison

Case	Description	Whole Wall R-value	Rim Joist	Clear Wall R-value	Top Plate	Framing Factor
1a	2x6 OVE, 24"oc, R19FG + OSB	**15.2**	12.3	16.1	12.5	16%
1aii	2x8, 16"oc, R19FG + OSB (25%ff)	**13.7**	12.3	14.1	12.5	25%
1b	2x4 OVE, 24"oc, R13FG + OSB	**11.1**	9.8	11.5	9.8	16%
1bii	2x4, 16"oc, R13FG + OSB (25%ff)	**10.0**	9.8	10.1	9.8	25%
2a	2x6 OVE, 24"oc R19FG + 1" R5 XPS	**20.2**	18.5	20.6	20.3	16%
2b	2x6 OVE, 24"oc R19FG + 4" R20 XPS	**34.5**	29.0	35.6	35.4	16%
3	2x6 OVE, 24"oc, 2x3 R19+R8 FG	**21.5**	13.4	23.5	18.4	16%
4	Double stud wall 9.5" R34 cellulose	**30.1**	14.4	33.5	28.8	
5	Larsen Truss 12" R43 cellulose	**36.5**	18.6	40.5	34.4	
6a	SIPs (3.5" EPS)	**14.1**	12.3	14.5	10.6	
6b	SIPs (11.25" EPS)	**36.2**	14	41.6	28.2	
7a	ICF - 8" foam ICF (4" EPS)	**16.4**		16.4		
7b	ICF - 15" foam ICF (5" EPS)	**20.6**		20.6		
7c	ICF - 14" cement woodfiber ICF with Rockwool	**17.4**		17.4		
8a	2x6 OVE, 24" o.c., 5" 2 pcf R29 SPF, OSB	**19.1**	13.6	20.3	19.5	16%
8b	2x6 OVE, 24" o.c., 5.5" R21 0.5 pcf SPF, OSB	**16.5**	13.1	17.2	16.6	16%
9	2x6 OVE, 24"oc, 2" SPF and 3.5" fibrous fill	**17.5**	13.2	18.4	17.7	16%
10	Double stud with 2" 2.0 pcf foam, 10" FG	**32.4**	15.9	36.2	28.5	
11	modified Larsen Truss with ext. spray foam	**37.1**	18.8	40.6	41.9	16%
12	2x6 OVE, 24"oc, EIFS - 4" EPS	**30.1**	23.8	31.4	31.1	16%