


High Performance Walls in Pennsylvania

[www.phrc.psu.edu](http://www.phrc.psu.edu)




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Pennsylvania Housing Research Center

- The Pennsylvania Housing Research Center (PHRC) provides and facilitates education, training, innovation, research, and dissemination to the residential construction industry for the purpose of improving the quality and affordability of housing.
- Educational programs and publications by the PHRC address a wide range of topics relevant to the home building industry and are designed to reach a diverse audience: builders, code officials, remodelers, architects, developers, engineers, planners, landscape architects, local government officials, educators, etc. to provide professional development and continuing education.



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PHRC Conference Week | March 4-6, 2020

- Early Bird Registration is open!**  
[-http://bit.ly/2020PHRCHousingConference](http://bit.ly/2020PHRCHousingConference)
- Conference & accommodations at The Penn Stater**
- Session topics include:**
  - Codes
  - Construction
  - Design
  - Land Development



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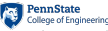
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Description

A primary area where builders can influence the energy performance of a home is through a climate zone-appropriate wall system. This webinar will provide an overview of common high-performance opaque wall systems that can work in Pennsylvania, including walls with continuous exterior insulation and extended plate and beam (EP&B) walls. Following this webinar, builders will have a better understanding of how to scale up current code-level wall systems to be prepared for future code changes or explore above-code performance standards, such as ENERGY STAR, Zero Energy Ready Home, and/or Passive House standards.

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## Learning Objectives

1. Understand the building science principles behind the 'perfect wall' system to avoid moisture risks in wall system choices.
2. Explore benefits and drawbacks of several common climate-zone appropriate wall systems per building science and constructability criteria.
3. Understand applicability of various wall systems for above-code performance standards for enhanced building energy performance.
4. Gain greater insight into environmental impacts of common wall materials to aid in wall system choices.

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## Outline

### • Introductions

- a. Objective Requirements
  - Building science for walls
  - Building Science Advisor
- b. Subjective Considerations
  - Economic
  - Environmental
- c. Above-Code Standards

### • Overview of Select High Performance Walls

- a. Cavity-only high density spray foam
- b. 2x6 advanced framed cellulose with 2" XPS
- c. 2x7.5" Extended Plate & Beam
- d. Double stud wall with cellulose
- e. 2x6 advanced framed cellulose with cellulose-filled wall truss



Photo by S. Klotz/Lens



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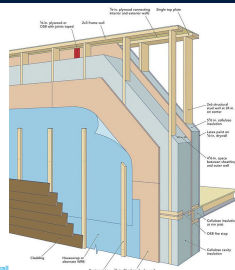
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## Context

1. **New construction** (vs. retrofits)
2. **Opaque walls** (vs. windows)
3. **Handful of common options** (vs. every wall possibility)
4. **Field-built walls** (vs. prefab)
5. **Walls in Isolation** (vs. systems)
6. **Focus on increasing thermal resistance or R-value** (vs. building science detailing)



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<https://www.greenbuilding.com/2015/09/16/technical-deep-double-stud-wall/>

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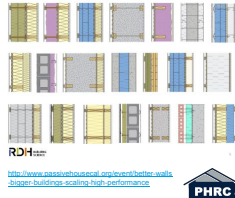
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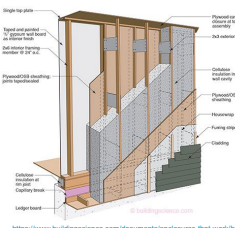
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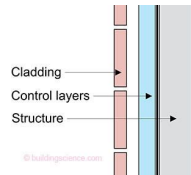
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## Introduction - 'Perfect Wall' System



© buildingperformance.com

### Cladding

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

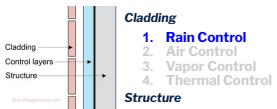
### Structure

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<https://www.buildingperformance.com/documents/insights/001-the-perfect-wall>



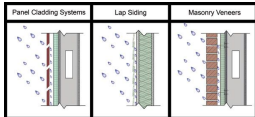
## 1. Rain Control



### Cladding

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2. Air Control
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4. Thermal Control

### Structure

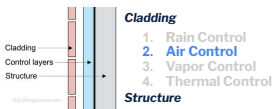


<https://www.buildingperformance.com/documents/insights/002-cladding-choices-how-much-rain-can-the-cladding-keep-it-outside-the-building>



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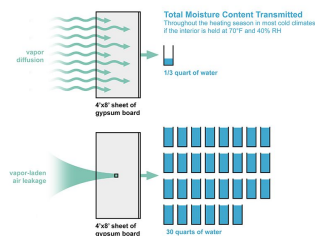
## 2. Air Control



### Cladding

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

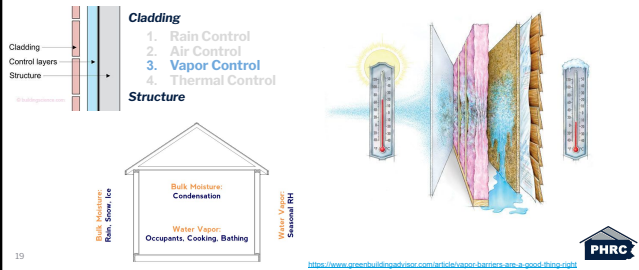
### Structure



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<https://www.wronline.com/articles/20419-the-moisture-threat-of-infiltration-to-the-building-envelope>

### 3. Vapor Control




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### 4. Thermal Control




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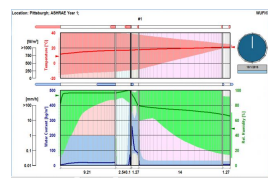
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### Verification - WUFI

- [www.WUFI.de/en](http://www.WUFI.de/en)
- Wärme Und Feuchte Instationär ("Heat and Moisture Transiency")
- Comprehensive tool to evaluate vapor and moisture transport in building materials
- Free versions available for download



<https://www.greenbuildingadvisor.com/article/best-practices-for-producing-a-wu-fi-2.aspx#stc=1>

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## Building Science Advisor - [BSA.ornl.gov](http://BSA.ornl.gov)

- [BSA.ornl.gov](http://BSA.ornl.gov)
- Free & user-friendly alternative to WUFI modeling
- Evaluate wall moisture durability risk

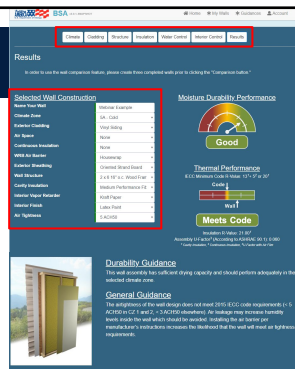


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[www.thesprawl.gov/building-science-advisor](http://www.thesprawl.gov/building-science-advisor)

## Building Science Advisor [BSA.ornl.gov](http://BSA.ornl.gov)

- Select your climate and assembly details
- Visual feedback on:
  - Moisture durability performance
  - Meeting 2015 IECC prescriptive requirements
- Guidance to improve durability of assembly

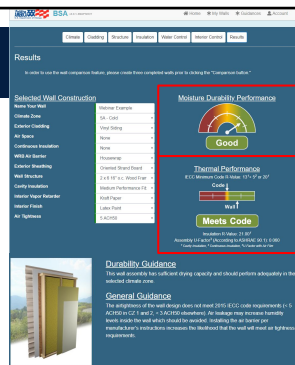


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[BSA.ornl.gov](http://BSA.ornl.gov)

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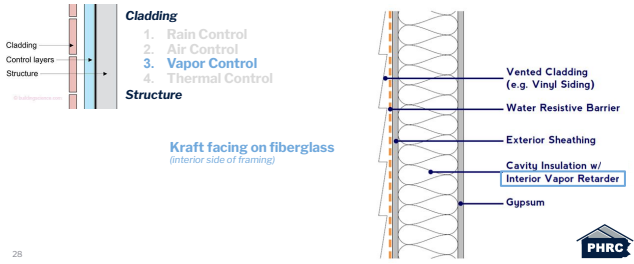
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## CZ5 Code-Minimum Wall Control Layers




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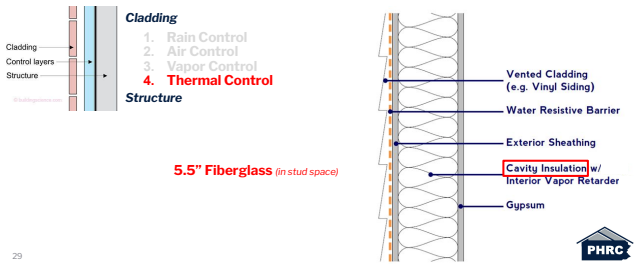
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## CZ5 Code-Minimum Wall Control Layers




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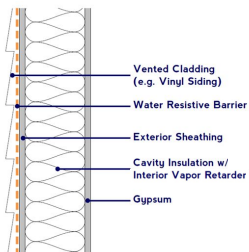
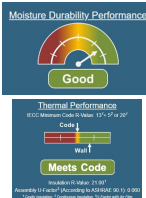
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## CZ5 Code-Minimum Wall - BSA

### Building Science Advisor 5A Climate Zone

Selected Wall Construction	
Roofing Type	Roofing Example
Climate Data	5A - Cold
Exterior Cladding	Vinyl Siding
Air Space	Exterior Insulated Air Sp.
Continuous Insulation	None
Wind Air Barrier	Insulating
Exterior Sheathing	Exterior Sheathing
Wall Structure	2 x 6 @ 16" o.c. Wood Fram.
Cavity Insulation	Medium Performance Ins.
Interior Vapor Retarder	Wall Paper
Interior Finish	Plaster
Air Tightness	5 ACH50




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## Economic Considerations

### Batt/Blown Insulation

- R-2.2 to R-3.4 per inch
- \$0.03-\$0.04 per square foot

### Rigid Board/Expanding Spray Foam

- R-3.6 to R-6.25 per inch
- \$0.10-\$0.14 per square foot

Insulation Type	Units	Details	Cost/ft <sup>2</sup> value	Practice
<b>Batt/Blown</b>				
fiberglass batt	1.0	fiberglass batts, typical batts 23" x 48"	\$0.03	standard
fiberglass batt	2.2	fiberglass batts	\$0.04	standard
fiberglass blown	2.2	no significant concerns	\$0.04	standard
cellulose blown	2.4	cellulose blown, no significant concerns, but may require additional air sealing	\$0.03	standard
<b>Rigid Board</b>				
extruded polystyrene (XPS)	2.0	1" high density board, standard 23" x 48"	\$0.10	standard
extruded polystyrene (XPS)	5	no significant concerns, standard 23" x 48"	\$0.14	standard
polyisocyanurate	5.0	flexible, standard 23" x 48"	\$0.10	standard
<b>Expanding Spray Foam</b>				
closed cell spray foam (CCF)	6.25	flexible, standard 23" x 48"	\$0.14	standard
open cell spray foam (OCF)	3.6	flexible, standard 23" x 48"	\$0.10	standard

Cost data based on 2015 McGraw-Hill Construction Cost Data. All values are in dollars per square foot. The quality and the design of the wall assembly significantly affect cost. Values are for standard wall types. Values are subject to change.

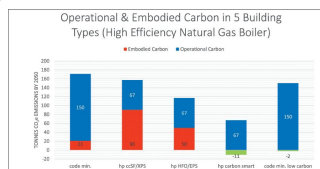
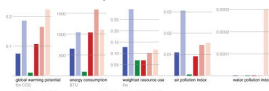
<http://www.mhfi.umn.edu/fb/foaminsulation.html>

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## Environmental Considerations

### Numerous metrics for environmental considerations, including:

- Embodied Energy
- Embodied Carbon
- Global Warming Potential
- Ozone Depletion Potential
- Air pollution
- Water pollution



<https://www.buildingscienceonline.com/article/1422002/embodied-carbon-in-five-building-types>



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<http://www.mhfi.umn.edu/fb/foaminsulation.html>

## Environmental Considerations

- **2007 - Study of blowing agents' impact on climate by L.D. Danny Harvey at University of Toronto**
- **2010 - "Avoiding the Global Warming Impact of Insulation" study by Alex Wilson at BuildingGreen**
- **2016 - "Calculating the Global Warming Impact of Insulation" by Dr. Allison Bailes at Energy Vanguard**

[http://faculty.geog.utoronto.ca/Harvey/Harvey/papers/Harvey%20\(2007c,%20BAE,%20Climatic%20Impact%20of%20Insulation\).pdf](http://faculty.geog.utoronto.ca/Harvey/Harvey/papers/Harvey%20(2007c,%20BAE,%20Climatic%20Impact%20of%20Insulation).pdf)



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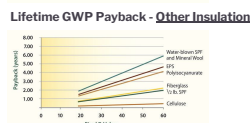
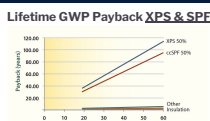
Isolation Material	Refractive Index	Density (g/cm <sup>3</sup> )	Ind. n <sub>D</sub> 20°C	Ind. n <sub>D</sub> 25°C	Ind. n <sub>D</sub> 30°C	Refractive Index	RI at 20°C	Refractive Index at 25°C	Refractive Index at 30°C
Calcium (hard pulp)	3.7	3.0	2.1	0.056	0.0033	None	0	N/A	0.0033
Fluorapatite	3.3	3.0	1.28	1.44	0.0165	None	0	N/A	0.0165
Hard enamel	4.0	4.0	17	1.2	0.0455	None	0	N/A	0.0455
Polycarbonate	6.0	1.5	72	3.0	0.0284	None	0.002	0.0217	0.002
Sorte polymerized UPE - closed cell	6.0	2.0	3.0	0.0379	None	MC245 (MC245-133)	0.01	0.68	1.48
SP - closed cell (water-borne)	3.0	2.0	3.0	0.0455	Water [CO]	None	0	0	0.0455
SP - open cell (water-borne)	3.7	0.5	73	3.0	0.0154	Water [CO]	0	0	0.0154
Expanded polystyrene (EPS)	3.9	1.0	89	3.5	0.0027	None	0.006	0.02	0.006
Expanded polystyrene (EPS)	5.0	2.0	89	3.5	0.0379	MC245 (MC245-133)	0.08	0.67	1.77

1. XPS manufacturers have not divulged their post-HCFC blowing agent, and MSDS data have not been updated. The blowing agent is assumed here to be HFC-134a.

<https://www.buildingscience.com/features/building-global-warming-impact-insulation>

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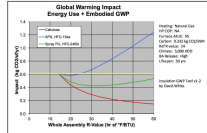


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### Closed Cell SPF

- ccSPF can have much lower GW impact
- Blowing agents: water or next generation



<https://www.dynopave.com/updates/GlobalWarmingImpact16GlobalWarmingImpact.html>  
<https://www.energyvanguard.com/blog/insulation-and-global-warming-passive-house-conference>  
<https://www.energyvanguard.com/blog/calculating-global-warming-impact-insulation>

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Type of Insulation	Blowing Agent	Global Warming Potential (GWP)	CO <sub>2</sub> e	GWP
Original	HCFC-141b	1	1	1,470
2nd Generation	HFC-141b	93	0.11	723
3rd Generation	HFC-141b	0	0	0
Original	HCFC-141b	1	1	1,470
2nd Generation	HFC-141b	93	0.11	723
3rd Generation	HFC-141b	0	0	0
Original	HCFC-141b	1	1	1,470
2nd Generation	HFC-141b	93	0.11	723
3rd Generation	HFC-141b	0	0	0
Original	HCFC-141b	1	1	1,470
2nd Generation	HFC-141b	93	0.11	723
3rd Generation	HFC-141b	0	0	0

1. Source: adaptation potential (GWP) values from U.S. EPA using Intergovernmental Panel on Climate Change (IPCC) values. GWP values are relative to CO<sub>2</sub>, which is defined as having a value of 1.0.  
 2. Global warming potential (GWP) values from EPA using IPCC Fourth Assessment Report values. 100-year time horizon assumed. GWP values are relative to CO<sub>2</sub>, which is defined as having a value of 1.0.  
 3. From L.D. Danny Harvey, "The Global Impact of Insulation Materials Produced and Transported to the U.S. for Blowing Agents in Polyurethane and Polyisocyanurate Foam." BuildingGreen, 2010.  
 4. Detailed technical analysis. GWP manufacturers declared to say what their product's blowing agent, and GWP calculation for all have updated the blowing agent is assumed here to be HFC-141b, though it may be less or more of HFC and hydrocarbons.

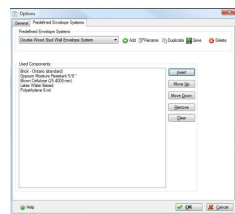


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## Environmental Considerations - Life-Cycle Assessment Tools

### Athena Impact Estimator

- Life-cycle assessment (LCA) methodology of whole buildings & assemblies (vs. just one material)
- Free to download
- [www.athenasmi.org/our-software-data/overview/](http://www.athenasmi.org/our-software-data/overview/)



<https://lca.athenasmi.org/our-software-data/overview/>  
<https://www.athenasmi.org/our-software-data/overview/>

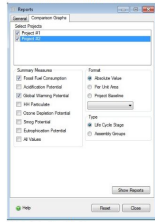


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<http://www.athenasmi.org/our-software-data/overview/>  
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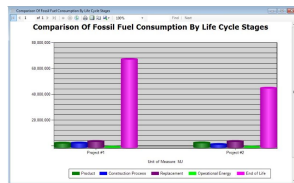
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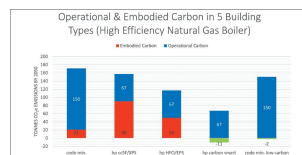
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## Environmental Considerations

- Number of environmental factors to consider
- Ongoing conversation in high performance building design
- For purposes of today's webinar, will make generalizations about relative environmental impact of foam vs. non-foam products
- Many other insulation materials (mineral wool, wood fiber, etc.) that we won't address today
- Evolving industry improvements
- Tools like Athena Impact Calculator can help with assembly decision making



<https://www.buildingscienceonline.com/energy/2018/08/2018-MobilePageArticle.action?articleId=1422002&articleId=1422002>




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## Zero Energy Ready Home Standard

1. National = Rev. 07
2. Must meet ALL of the following:
  - a. **ENERGY STAR for Homes Baseline**
    - i. Reduced Thermal Bridging
  - b. **2015 IECC levels**
    - i. CZ4 & CZ5: R-20 or 13+10
    - ii. CZ6: R-20+5, 13+10, or 18+6.5
  - c. **Air sealing performance**
    - i. CZ4: 2.5 ACH50
    - ii. CZ5 & CZ6: 2.0 ACH50

Exhibit 1: DOE Zero Energy Ready Home Mandatory Requirements for All Labeled Homes

Area of Improvement	Mandatory Requirements
1. ENERGY STAR for Homes Baseline	<input type="checkbox"/> Labeled must achieve ENERGY STAR Qualified Homes Program Version 3.1.1 or 3.2 (depending on date) or under ENERGY STAR Multifamily New Construction program Version 1.0 or 1.1 (depending on date) 1, 2
2. Envelope	<input type="checkbox"/> Fenestration shall meet or exceed ENERGY STAR requirements. See End Note for specific to SHGC values and exceptions 1, 2
3. Duct System	<input type="checkbox"/> Ceiling, wall, floor, and slab insulation shall meet or exceed 2015 IECC levels 1, 2
4. Water Efficiency	<input type="checkbox"/> Hot water distribution systems located within the home's thermal and air barrier boundary at an optimized location to achieve comparable performance 1, 2
5. Lighting & Appliances	<input type="checkbox"/> Hot water delivery systems (distributed and central) shall meet efficient design requirements 1, 2
6. Indoor Air Quality	<input type="checkbox"/> Water heaters and boilers shall meet efficiency criteria 1, 2
7. Renewable Ready	<input type="checkbox"/> All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified 1, 2
	<input type="checkbox"/> 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 90% of fixtures
	<input type="checkbox"/> All installed bathroom ventilators and ceiling fans are ENERGY STAR qualified
	<input type="checkbox"/> Certified under EPA Indoor airPLUS 1, 2
	<input type="checkbox"/> Provisions of the DOE Zero Energy Ready Home Pilot Ready Checklist are completed 1, 2

<https://www.energy.gov/sites/default/files/2015/04/f52/DOE%20ZERH%20Spec%20Rev07.pdf>



## PHIUS+ 2018

1. National = PHIUS+ 2018, V.2.1
2. Performance vs. Prescriptive Standard
  - a. **Walls = ~R-31 - R-51**
  - b. **Thermal Bridge Mold Risk Assessment**
  - c. **Air sealing performance**
    - i. 0.06 CFM/ft2 envelope @ 50Pa

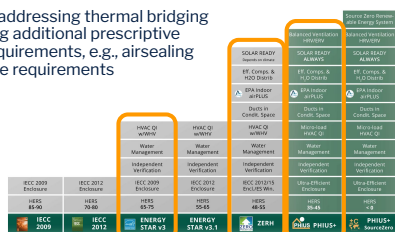
### Sample R-Value Guidelines

Sample R-Value Guidelines	Zone	Wall	Ceiling	Slab
Miami, FL; Honolulu, HI	1	19-27	44-52	25 R-0 vertical joints
Atlanta, GA; Phoenix, AZ	2	19-27	44-52	uninsulated
Chattanooga, TN; Sacramento, CA	3	19-27	44-52	uninsulated or 20 R-0 vertical joints
San Francisco, CA	Home 3	19-23	38-38	40 R-0.02 vertical joints
Baltimore, MD; Annapolis, VA	4	31-43	44-52	2-40 R-0.02 vertical joints
Spokane, OR; Seattle, WA	Home 4	31-43	44-52	40 R-0.02 vertical joints or minimum R-0.02
Providence, RI; Fayetteville, AR	5	31-43	44-52	40 R-0.02 vertical joints or minimum R-0.02
Burlington, VT; Billings, MT	6	31-43	44-52	40 R-0.02 vertical joints or minimum R-0.02
Durham, NH; Edmonton, AB	7	40-40	44-52	40 R-0.02 vertical joints or minimum R-0.02
Portland, ME	8	40-40	44-52	40 R-0.02 vertical joints or minimum R-0.02

Generated from PHIUS+ 2018 studies  
Values may vary with climate  
Actual R-values may vary by project  
<https://www.phius.org/what-is-passive-building/passive-house-plus>

## Above Code Standards

- All three require addressing thermal bridging
- Each have varying additional prescriptive and/or design requirements, e.g., airsealing and non-envelope requirements



<https://www.phius.org/what-is-passive-building/passive-house-plus>



## Outline

### • Introductions

- a. Objective Requirements
  - Building science for walls
  - Building Science Advisor
- b. Subjective Considerations
  - Economic
  - Environmental
- c. Above-Code Standards

### • Overview of Select High Performance Walls

- a. Cavity-only high density spray foam
- b. 2x6 advanced framed cellulose with 2" XPS
- c. 2x7.5" Extended Plate & Beam
- d. Double stud wall with cellulose
- e. 2x6 advanced framed cellulose with cellulose-filled wall truss



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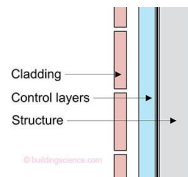
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## Why These Walls?

- Examples build from 5.5" cavity-only options to 17" assemblies
- Can work for PA climate zones
- Careful attention to the control layers & building science details is critical



<https://www.buildingscience.com/documents/insights/ins-001-the-perfected-wall>



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## Cavity-Only High Density Spray Foam

### General Advantages

- High R-value per inch of insulation (~R-6/inch)
- High density foam serves as air barrier & vapor control
- Avoids added labor of continuous exterior insulation

### Specifications

Framed Thickness = 5.5"

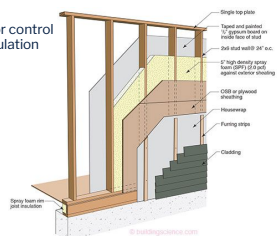
Installed Insulation R-Value = R-30

Address Thermal Bridging? NO

### Works for Above Code Standards

ENERGY STAR for Homes  
Zero Energy Ready Home Standard  
PHIUS+ 2018

<https://www.buildingscience.com/documents/enclosures-that-work/high-density-wall-assembly-high-density-study-wall-assembly>



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# Cavity-Only High Density Spray Foam

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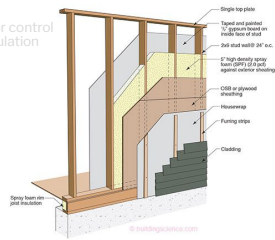
Installed Insulation R-Value = R-30

Address Thermal Bridging? NO

## Works for Above Code Standards

- ENERGY STAR for Homes
- Zero Energy Ready Home Standard
- PHIUS+ 2018

<https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assemblies/high-r-wall-spray-foam-wall-construction>



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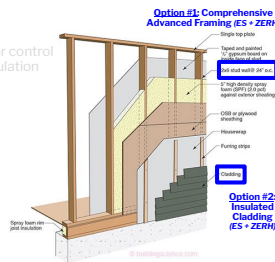
Installed Insulation R-Value = R-30

Address Thermal Bridging? NO

## Works for Above Code Standards

- ENERGY STAR for Homes
- Zero Energy Ready Home Standard
- ✗ PHIUS+ 2018

<https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assemblies/high-r-wall-spray-foam-wall-construction>



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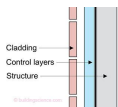
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# Cavity-Only High Density Spray Foam

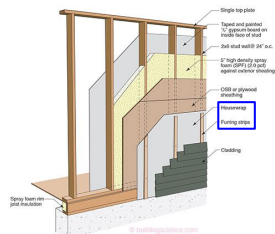


## Cladding

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

## Structure

1. Furring strips (min. 3/4\" drainage gap)
2. Housewrap or alternate WRB



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## Cavity-Only High Density Spray Foam



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## Cavity-Only High Density Spray Foam



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## Cavity-Only High Density Spray Foam



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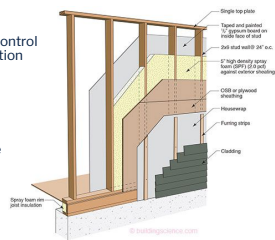
## Cavity-Only High Density Spray Foam

### General Advantages

- High R-value per inch of insulation (~R-6/inch)
- High density foam serves as air barrier & vapor control
- Avoids added labor of continuous exterior insulation

### Drawbacks

- Higher thermal losses from thermal bridging
- Higher environmental impact of foam products
- For Climate Zone 6, must use the PA Alternative Energy compliance path to allow a cavity-only insulation wall assembly



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<https://www.buildingscience.com/documents/enclosures-that-work/high-density-wall-assembly/cavity-only-high-density-foam-wall-construction>

## 2x6 A.F. cavity cellulose with 2" XPS

### General Advantages

- Reduces thermal bridging from framing members
- XPS serves double duty as the exterior sheathing
- Can increase XPS for higher R-value (R-5/inch, up to 4")

### Specifications

Framed Thickness = 7.5"

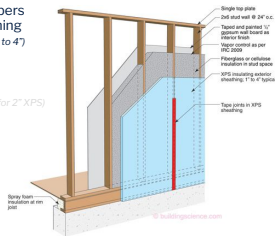
Installed Insulation R-Value = R-30 (R-20 cavity + R-10 for 2" XPS)

Address Thermal Bridging? YES

### Works for Above Code Standards

ENERGY STAR for Homes  
Zero Energy Ready Home Standard  
PHIUS+ 2018

<https://www.buildingscience.com/documents/enclosures-that-work/high-density-wall-assembly/cavity-cellulose-wall-construction>



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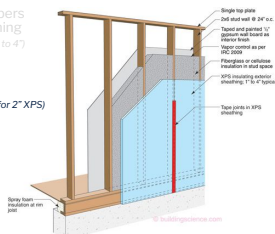
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Address Thermal Bridging? YES

### Works for Above Code Standards

ENERGY STAR for Homes  
Zero Energy Ready Home Standard  
PHIUS+ 2018

<https://www.buildingscience.com/documents/enclosures-that-work/high-density-wall-assembly/cavity-cellulose-wall-construction>



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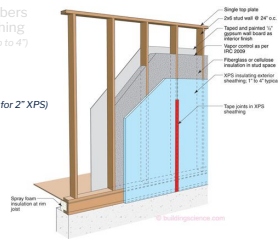
Installed Insulation R-Value = R-30 (R-20 cavity + R-10 for 2" XPS)

Address Thermal Bridging? YES

### Works for Above Code Standards

- ✓ ENERGY STAR for Homes
- ✓ Zero Energy Ready Home Standard
- ✓ PHIUS+ 2018

[https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assembly/copy\\_of\\_advanced-frame-wall-construction](https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assembly/copy_of_advanced-frame-wall-construction)



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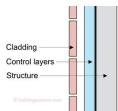
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## 2x6 A.F. cavity cellulose with 2" XPS

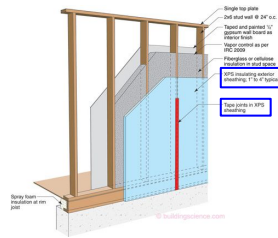


### Cladding

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

### Structure

2" of XPS with taped joints



[https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assembly/copy\\_of\\_advanced-frame-wall-construction](https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assembly/copy_of_advanced-frame-wall-construction)

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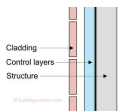
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## 2x6 A.F. cavity cellulose with 2" XPS

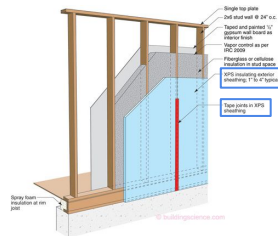


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[https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assembly/copy\\_of\\_advanced-frame-wall-construction](https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assembly/copy_of_advanced-frame-wall-construction)

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## 2x6 A.F. cavity cellulose with 2" XPS

**Cladding**

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

**Structure**

**Code-Specified Vapor Control**

- CZ4: none required
- CZ5: Class III Vapor Retarder
- CZ6: Class I or II Vapor Retarder

[https://www.buildingscience.com/documents/enclosures-that-work/high-value-wall-assembly/copy\\_of\\_advanced-frame-wall-construction](https://www.buildingscience.com/documents/enclosures-that-work/high-value-wall-assembly/copy_of_advanced-frame-wall-construction)

## 2015 IRC Section R702.7.1 Class III Vapor Retarders

- **Class III vapor retarders shall be permitted where any one of the conditions in Table R702.7.1 is met.**

*By adding insulated sheathing, drying potential to exterior is reduced  
– Must maximize interior drying potential*

- **Table R702.7.1 (modified)**

Climate Zone	Class III Vapor Retarders Permitted For:
5	Continuous insulation with R-value $\geq 5$ over 2 x 4 wall Continuous insulation with R-value $\geq 7.5$ over 2 x 6 wall
6	Continuous insulation with R-value $\geq 7.5$ over 2 x 4 wall Continuous insulation with R-value $\geq 11.25$ over 2 x 6 wall



Source: International Code Council (ICC), (2014). 2015 International Residential Code, Country Club PHC III.

## 2x6 A.F. cavity cellulose with 2" XPS

**Cladding**

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

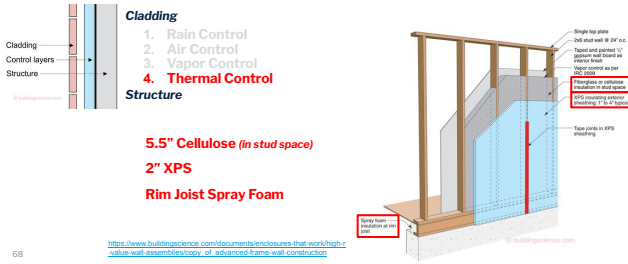
**Structure**

**Code-Specified Vapor Control**

- CZ4: none required
- CZ5: Class III Vapor Retarder
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[https://www.buildingscience.com/documents/enclosures-that-work/high-value-wall-assembly/copy\\_of\\_advanced-frame-wall-construction](https://www.buildingscience.com/documents/enclosures-that-work/high-value-wall-assembly/copy_of_advanced-frame-wall-construction)

## 2x6 A.F. cavity cellulose with 2" XPS



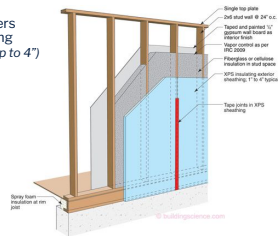
## 2x6 A.F. cavity cellulose with 2" XPS

### General Advantages

- Reduces thermal bridging from framing members
- XPS serves double duty as the exterior sheathing
- Can increase XPS for higher R-value (R-5/inch, up to 4")

### Drawbacks

- Constructability with foam
  - Wall bracing, fastening, trim details, etc.
- Using XPS as a WRB can be challenging



## 2x7.5" Extended Plate & Beam Wall

### General Advantages

- Integrated cavity + XPS insulation assembly
- Reduce cavity thermal bridging
- Quicker panel installation

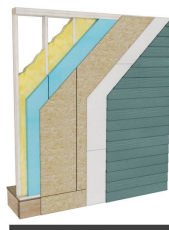


Figure 8. Exterior View of EP&B System

## 2x7.5" Extended Plate & Beam Wall

### General Advantages

- Integrated cavity + XPS insulation assembly
- Reduce cavity thermal bridging
- Quicker panel installation

### Specifications

**Framed Thickness = 7.5"**

**Installed Insulation R-Value = R-29**

(R-19 for 5.5" fiberglass + R-10 of 2" XPS)

**Address Thermal Bridging? YES and NO**

### Works for Above Code Standards

ENERGY STAR for Homes

Zero Energy Ready Home Standard

PHIUS+ 2018



Figure 5. Interior View of EP&B System



Figure 6. Exterior View of EP&B System

[https://www1.eere.energy.gov/buildings/publications/pdfs/building\\_america/1439541.pdf](https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/1439541.pdf)  
<https://www.homesinnovation.com/-media/Files/Reports/W%20B%20older%20Guide%20to%20Energy%20Star%20and%20Zero%20Energy%20Ready%20Systems.pdf>

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### Specifications

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ENERGY STAR for Homes

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PHIUS+ 2018



Figure 5. Interior View of EP&B System



Figure 6. Exterior View of EP&B System

[https://www1.eere.energy.gov/buildings/publications/pdfs/building\\_america/1439541.pdf](https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/1439541.pdf)  
<https://www.homesinnovation.com/-media/Files/Reports/W%20B%20older%20Guide%20to%20Energy%20Star%20and%20Zero%20Energy%20Ready%20Systems.pdf>

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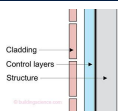
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## 2x7.5" Extended Plate & Beam Wall



### Cladding

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

### Structure

Housewrap or alternate WRB  
Taped foam panel joints

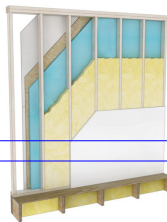


Figure 7. Interior View of EP&B System

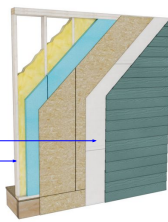


Figure 8. Exterior View of EP&B System

[https://www1.eere.energy.gov/buildings/publications/pdfs/building\\_america/1439541.pdf](https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/1439541.pdf)  
<https://www.homesinnovation.com/-media/Files/Reports/W%20B%20older%20Guide%20to%20Energy%20Star%20and%20Zero%20Energy%20Ready%20Systems.pdf>

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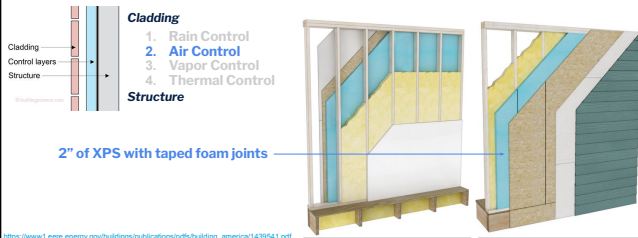
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## 2x7.5" Extended Plate & Beam Wall



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## 2x7.5" Extended Plate & Beam Wall



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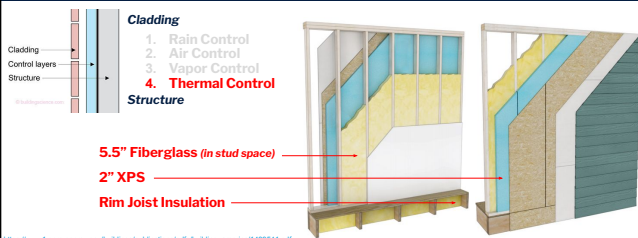
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## 2x7.5" Extended Plate & Beam Wall



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Figure 8. Exterior View of EP&B System

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78 <https://www.finehomebuilding.com/2015/09/16/stibureks-ideal-double-stud-wall>

79 [https://www.finehomebuilding.com/2015/09/16/stibureks-ideal-double-stud-wall](https://www.finehomebuilding.com/2015/09/16/stibureks-ideal-double-stud-wall-assemblies/high-r-value-double-stud-wall-construction)

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## Double Stud Wall with Cellulose

### General Advantages

- Utilize existing framing crews
- Avoids thermal bridging from framing members
- Utilize lower embodied energy insulation materials

### Specifications

**Framed Thickness = 10.5"**

**Installed Insulation R-Value = R-35** (R-3.7/inch @ 9.5" ins.)

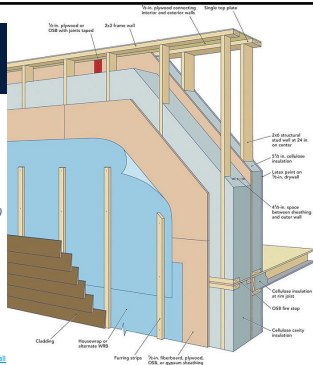
**Address Thermal Bridging? YES**

### Works for Above Code Standards

- ✓ ENERGY STAR for Homes
- ✓ Zero Energy Ready Home Standard
- ✓ PHIUS+ 2018

<https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assemblies/high-r-value-double-stud-wall-construction>

<https://www.frsthomebuilding.com/2015/09/16/fstbuilds-ideal-double-stud-wall/>



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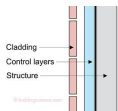
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## Double Stud Wall with Cellulose



### Cladding

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

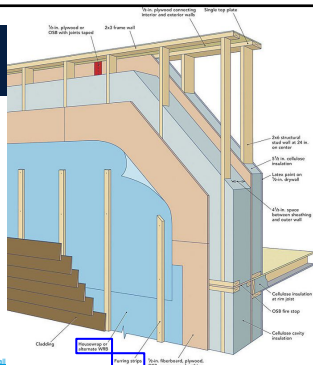
### Structure

**Furring strips (min. 3/8" drainage gap)**

**Housewrap or alternate WRB**

<https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assemblies/high-r-value-double-stud-wall-construction>

<https://www.frsthomebuilding.com/2015/09/16/fstbuilds-ideal-double-stud-wall/>



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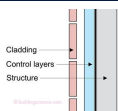
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## Double Stud Wall with Cellulose



### Cladding

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

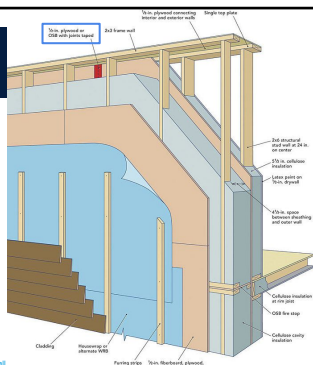
### Structure

**1/2" plywood or OSB with**

**joints taped**  
(exterior of the interior frame wall)

<https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assemblies/high-r-value-double-stud-wall-construction>

<https://www.frsthomebuilding.com/2015/09/16/fstbuilds-ideal-double-stud-wall/>



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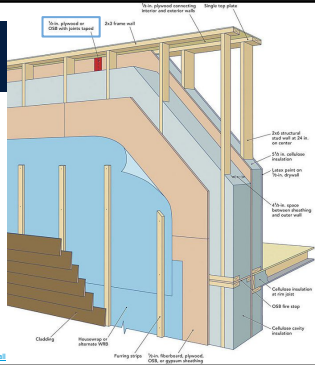
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## Double Stud Wall with Cellulose



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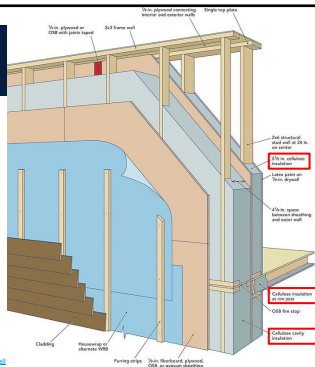
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## Double Stud Wall with Cellulose



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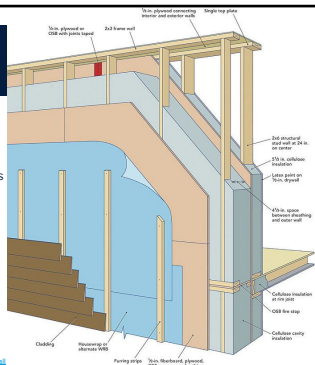
## Double Stud Wall with Cellulose

### General Advantages

- Utilize existing framing crews
- Avoids thermal bridging from framing members
- Utilize lower embodied energy insulation materials

### Drawbacks

- Complicated detailing (framing, trim, etc.)



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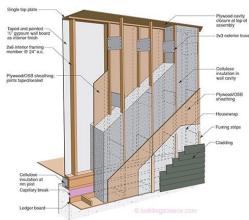
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## 2x6 cellulose + cellulose-filled wall truss

### General Advantages

- Significantly higher R-value
- Utilize lower embodied energy insulation materials
- Lower cost exterior insulation material than XPS for ultra high performance design



66 <https://www.greenbuildingadvisor.com/article/all-about-timber-trusses> <https://www.buildingscience.com/documents/techdocs/2016-03-01-2x6-high-r-value-wall-assemblies-high-r-value-wall-construction>

## 2x6 cellulose + cellulose-filled wall truss

### General Advantages

- Significantly higher R-value
- Utilize lower embodied energy insulation materials
- Lower cost exterior insulation material than XPS for ultra high performance design

### Specifications

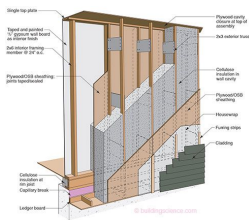
Thickness = varies (~13"-17")

Installed Insulation R-Value = ~R-48 to ~R-63 (R-3.7/inch)

Address Thermal Bridging? YES

### Works for Above Code Standards

ENERGY STAR for Homes  
Zero Energy Ready Home Standard  
PHIUS+ 2018



67 <https://www.greenbuildingadvisor.com/article/all-about-timber-trusses> <https://www.buildingscience.com/documents/techdocs/2016-03-01-2x6-high-r-value-wall-assemblies-high-r-value-wall-construction>

## 2x6 cellulose + cellulose-filled wall truss

### General Advantages

- Significantly higher R-value
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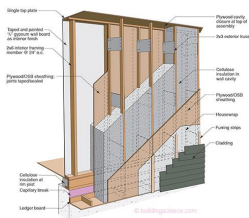
Thickness = varies (~13"-17")

Installed Insulation R-Value = ~R-48 to ~R-63 (R-3.7/inch)

Address Thermal Bridging? YES

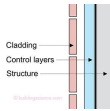
### Works for Above Code Standards

✓ ENERGY STAR for Homes  
✓ Zero Energy Ready Home Standard  
✓ PHIUS+ 2018



68 <https://www.greenbuildingadvisor.com/article/all-about-timber-trusses> <https://www.buildingscience.com/documents/techdocs/2016-03-01-2x6-high-r-value-wall-assemblies-high-r-value-wall-construction>

## 2x6 cellulose + cellulose-filled wall truss

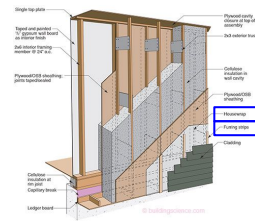


### Cladding

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

### Structure

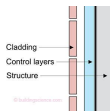
1. Furring strips (min. 3/4" drainage gap)
2. Housewrap or alternate WRB



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<https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assemblies/high-r-value-house-wall-construction>

## 2x6 cellulose + cellulose-filled wall truss

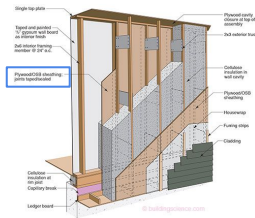


### Cladding

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

### Structure

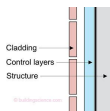
Interior Plywood/OSB sheathing on 2x6 wall (joints taped/sealed)



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<https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assemblies/high-r-value-house-wall-construction>

## 2x6 cellulose + cellulose-filled wall truss



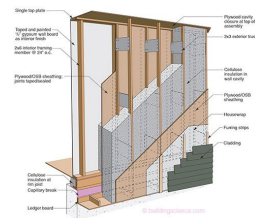
### Cladding

1. Rain Control
2. Air Control
3. Vapor Control
4. Thermal Control

### Structure

#### Code-Specified Vapor Control

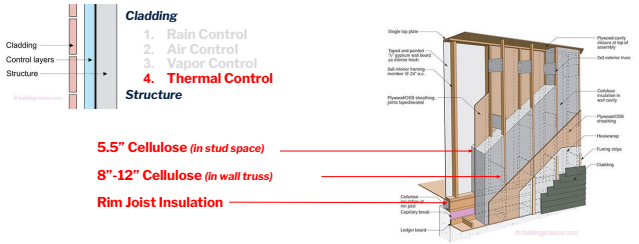
- CZ4: none additional required
- CZ5: [Class I or II](#) Vapor Retarder
- CZ6: [Class I or II](#) Vapor Retarder



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<https://www.buildingscience.com/documents/enclosures-that-work/high-r-value-wall-assemblies/high-r-value-house-wall-construction>

## 2x6 cellulose + cellulose-filled wall truss




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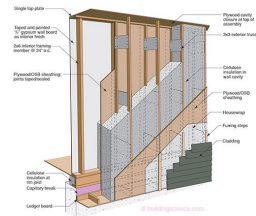
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## 2x6 cellulose + cellulose-filled wall truss

### Building Science Corporation




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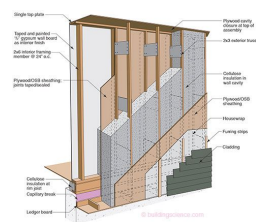
## 2x6 cellulose + cellulose-filled wall truss

### General Advantages

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- Lower cost exterior insulation material than XPS for ultra high performance design

### Drawbacks

- Complicated detailing (framing, trim, etc.)




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## Conclusions

- Showed only a handful of high performance wall options in today's webinar
- Building science details are of critical importance with all high performance walls
- Confirm durability & climate suitability with Building Science Advisor, WUFI, and/or resources like Building Science Corporation
- Consider environmental impacts when choosing insulation materials
- PHRC is a continued resource for building envelope and moisture management detailing



Photo by S. Klotz/Lens

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## Questions?

[www.phrc.psu.edu](http://www.phrc.psu.edu)

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## High Performance Walls in PA

[www.phrc.psu.edu](http://www.phrc.psu.edu)



PENNSYLVANIA HOUSING  
RESEARCH CENTER



NARI  
CEU Approved



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