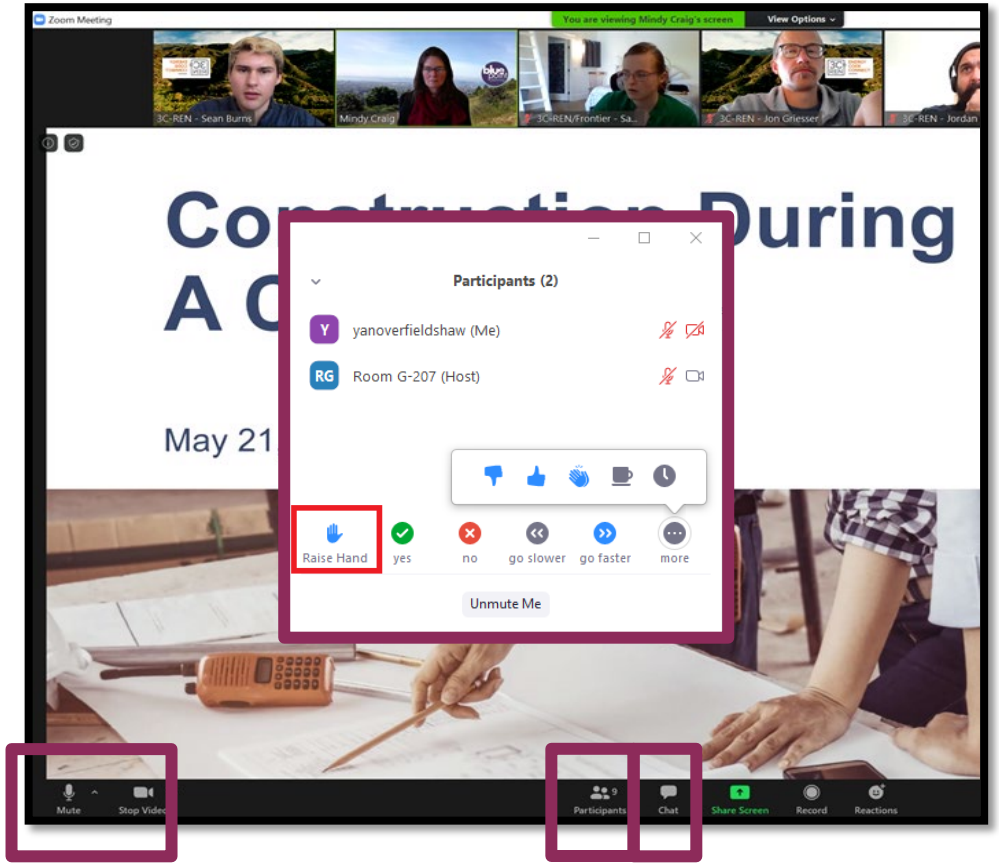
Introduction to Passive House Trades

Steve Mann – The Passive House Network and Home Energy Services

August 27, 2024

Zoom Orientation

- Please be sure your full name is displayed
- Please mute upon joining
- Use "Chat“ box to share questions or comments
- Under "Participant" select "Raise Hand" to share a question or comment verbally
- The session may be recorded and posted to 3C-REN's on-demand page. Feel free to ask questions via the chat and keep video off if you want to remain anonymous in the recording.



3C-REN: Tri-County Regional Energy Network

- Three counties working together to improve energy efficiency in the region
- Services for –
  - **Building Professionals:** industry events, training, and energy code compliance support
  - **Households:** free and discounted home upgrades
- Funded by ratepayer dollars that 3C-REN returns to the region

3C REN ENERGY CODE CONNECT

3C REN BUILDING PERFORMANCE TRAINING

3C REN HOME ENERGY SAVINGS

3C REN ENERGY CODE CONNECT

- Serves all building professionals
- Three services –
  - **Energy Code Coach**
  - **Training and Support**
  - **Regional Forums**
- Makes the Energy Code easy to follow

Energy Code Coach:
3c-ren.org/codes
805.781.1201

Event Registration:
3c-ren.org/events

3C REN BUILDING PERFORMANCE TRAINING

- Serves current and prospective building professionals
- Expert instruction:
  - **Technical skills**
  - **Soft skills**
- Helps workers to thrive in an evolving industry

Event Registration:
3c-ren.org/events

3C REN HOME ENERGY SAVINGS

Multifamily (5+ units)

- No cost technical assistance
- Rebates up to $750/apartment plus additional rebates for specialty measures like heat pumps

Single Family (up to 4 units)

- Sign up to participate!
- Get paid for the metered energy savings of your customers

Enrollment:
3C-REN.org/contractor-participation

Introduction to Passive House Trades

Sendero Verde, Handel Architects

The Network

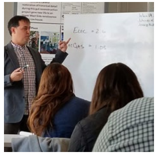
Global Knowledge. Regional Context. Local Applications

The Passive House Network


















Passive House Seattle – The Passive House Network
Passive House Rocky Mountains – The Passive House Network
Passive House Minnesota – The Passive House Network
Passive House Pennsylvania – The Passive House Network
Passive House Washington DC – The Passive House Network
New Jersey Passive House – The Passive House Network
Passive House Empire State – The Passive House Network
Passive House Northeast – The Passive House Network
PHCA Passive House California

North American Certifiers Circle – Passive House Certifier – Passive House Institute accredited
International Passive House Association – iPHA
Passive House Institute
Designer – Certified Passive House Designer
Certified Passive House Tradesperson – Tradesperson
Certified Passive House – Passive House Institute

Training and Resources

The Passive House Network

https://passivehousenetwork.org/designer-training/

DESIGNER
CERTIFIED PASSIVE HOUSE DESIGNER

Pacific Cohort Schedule

Fall 2024 - On-Demand / Live Online CPHD/C Training

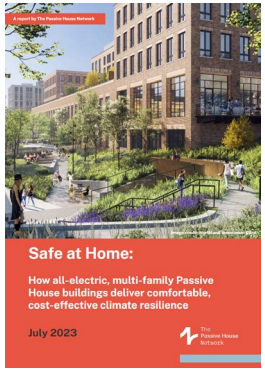
October 10th start

Depending on your learning preferences, **you can tackle this course in three ways**:

1. Focus on the on-demand content and view recordings of live-online content. **(Most flexible)**
2. Stick to the cohort schedule of live online-sessions. **(Best for clear pacing and making connections and community)**
3. Do a mix! Start before or after the cohort registration deadline, focus on the on-demand format at your pace, and also attend the live-online sessions as makes sense for you. **(Most popular)**

On-Demand Activities		Live Online Activities		
Week Starts	**Content**	**Activity Date/Time**	**Activity**	**Led by**
10/7/24	Module 1: **Introduction** Module 2: **Insulation**	10/10/24 | 12-1 PM PT	Kick-Off	PHN
10/21/24	Module 3: **Airtightness** Module 4: **Thermal Bridging** Module 5: **Windows**	10/24/24 | 12-1 PM PT	Q&A Session 1	CPHD Practitioner
10/28/24	Module 6: **Ventilation** Webinar 1: **Building Services & Economics**	10/31/24 | 9-12 PM PT	Webinar 1: Building Envelope	PHN Trainer
11/4/24	Module 7: **Heating & DWH** Module 8: **Cooling** Module 9: **Certification**	11/7/24 | 12-1 PM PT	Q&A Session 2	CPHD Practitioner
11/11/24	Module 10: **Economics** Module 11: **QA/QC** Module 12: **Bidding**	11/14/24 | 12-1 PM PT	Q&A Session 3	CPHD Practitioner
11/18/24	Module 13: **designPH** Webinar 2: **Building Services & Economics**	11/21/24 | 9-12 PM PT	Webinar 2: Building Services & Economics	PHN Trainer
11/25/24	Module 14: **PHPP**			
12/2/24	Module 15: **Exam Prep Course & Wrap-up** Review Exam Prep Modules	12/3/24 | 9-10 AM PT	**Tech Setup (Required)**	PHN with PHA
	Review Exam Prep Modules	12/5/24 | 9-11 AM PT	**Exam Review**	PHN Trainer
12/9/24	Review Exam Prep Modules	12/12/24 | 9-12 PM PT	**PHI CPHD/C Exam**	PHN with PHA

All online sessions - excluding the Tech Setup & Exam - will be recorded and made available for all cohort students for reference.



https://passivehousenetwork.org/safe-at-home/

Agenda

The Passive House Network

1. Intro to Passive House
2. Envelope
3. Mechanical Systems
4. QA/QC & Certification
5. Resources

Waring School, Massachusetts, Opal Architecture

PHN's Introduction to Passive House Trades course is a comprehensive dive into constructing residential and commercial Passive House buildings, specifically at the enclosure and mechanical trades.

There will be a brief introduction to Passive House about the basic principles and the drivers of Passive House performance that most concern builders' work.

The enclosure section will look at typical construction types, windows and installation, air barriers and insulation, and new, innovative PH products. The mechanical will look at the ventilation heating, cooling systems, and domestic hot water.

The work of the trades will be clearly placed in the context of Passive House performance, the role of each aspect of construction, its sequencing - and the importance of the tradesperson's work in achieving the target goals.

2 AIA LUs Credit, #Intro_PH_Trades_LO

Learning Objectives:

1. Describe the five key principles of Passive House projects.
2. Summarize typical materials, methods, and components used in Passive House enclosures and mechanical systems.
3. Outline typical Passive House construction sequencing.
4. Describe the basic approach to quality control, verification and commissioning.

Instructor:

Steve Mann
Principal of Home Energy Services, Steve Mann, is a California HERS, LEED AP+ Homes and Green Rater, and is a certified Passive House Designer, Tradesperson, Trainer, and building Certifier with Passive House Institute. His two most recent design/build residential projects are Net Zero Energy (NZE), and are both LEED Platinum and Passive House certified.

Introductions

The Passive House Network

Please answer questions in the comments:

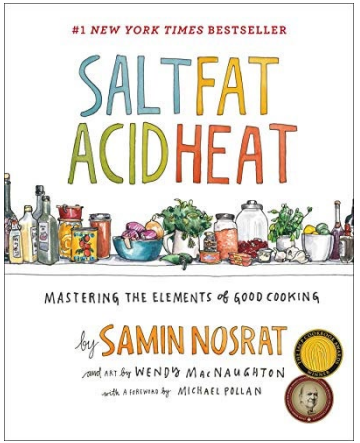
1. Name? (if you'd like)
2. Location?
3. Typical project role?
4. Any previous Passive House knowledge or experience? If so, what?

Intro to Passive House

How we use fundamental elements matters

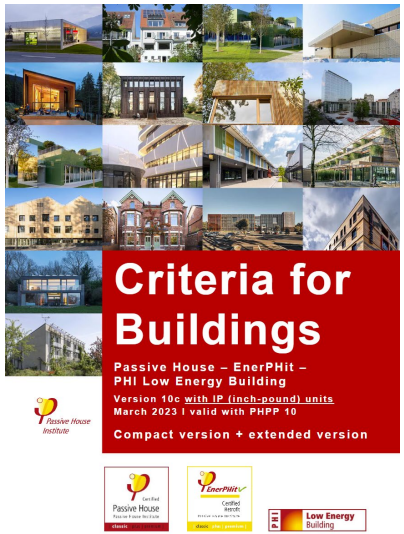
"I was working as a physicist. I read that the construction industry had experimented with adding insulation to new buildings and that energy consumption had failed to reduce. This offended me – it was counter to the basic laws of physics. I knew that they must be doing something wrong. So I made it my mission to find out what, and to establish what was needed to do it right."

- Wolfgang Feist



Passive House masters the elements of high -performance building.

What is Passive House?



- Passive House is a building standard
- Applies to new & existing buildings
- The most rigorous energy efficiency certification available
- Performance -based approach
- Focuses on mastering the drivers of building performance.

Project Types – Not Just Houses!

The House at Cornell Tech

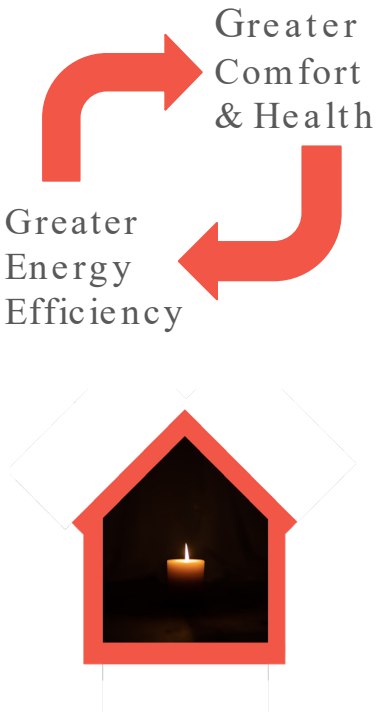
Star Garment Factory

Betances V

Goals of Passive House

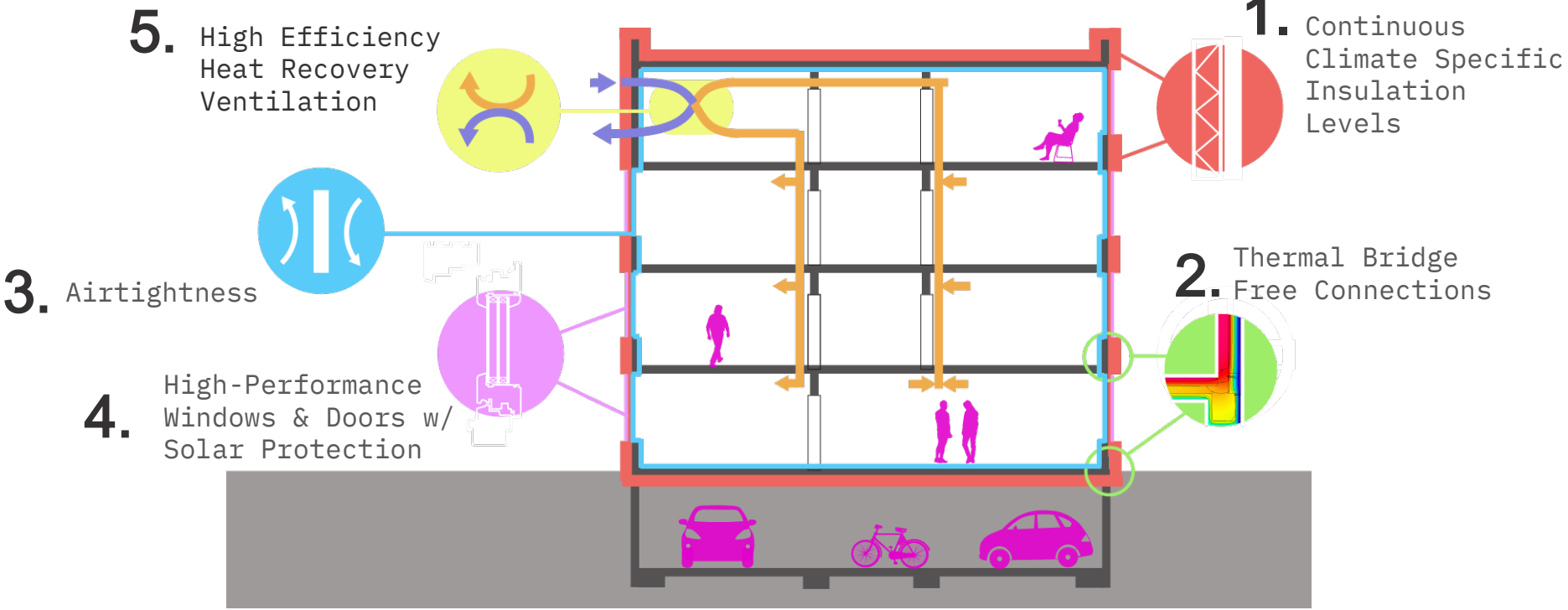
- Thermal Comfort
- Hygienic conditions
  - No mold
  - Healthy indoor air quality
- Energy Efficiency
- Durability

  +
- Affordability



5 Principles of Construction (the drivers)

The Passive House Network



These are the 5 things builders must focus on most intently.

Energy Modeling: Calculating Predictable Performance

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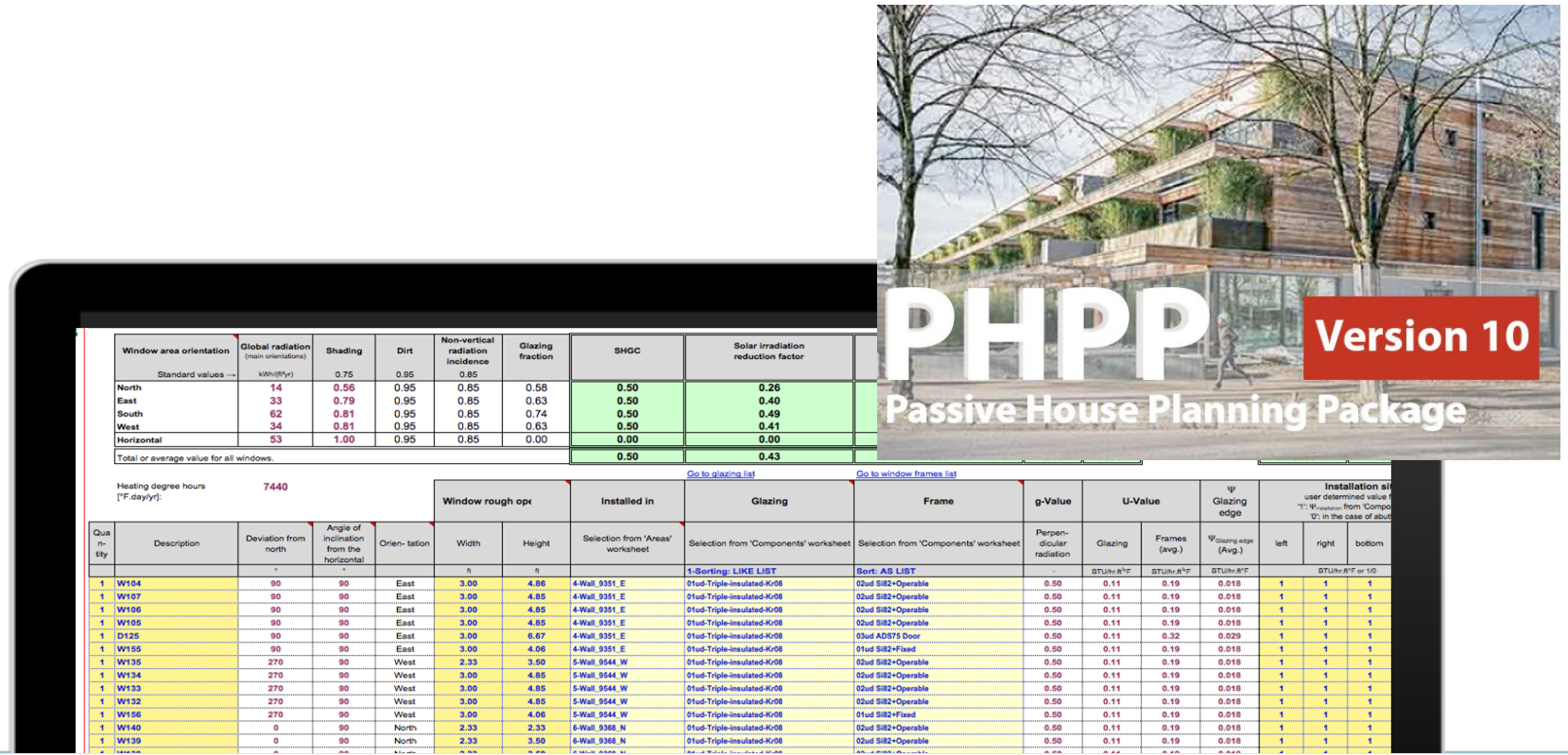
https://passivehouse.com/04_phpp/04_phpp.htm



Window area orientation	Global radiation (main orientations)	Shading	Dirt	Non-vertical radiation incidence	Glazing fraction	SHGC	Solar irradiation reduction factor
Standard values →	kWh/(ft²yr)	0.75	0.95	0.85			
North	14	0.56	0.95	0.85	0.58	0.50	0.26
East	33	0.79	0.95	0.85	0.63	0.50	0.40
South	62	0.81	0.95	0.85	0.74	0.50	0.49
West	34	0.81	0.95	0.85	0.63	0.50	0.41
Horizontal	53	1.00	0.95	0.85	0.00	0.00	0.00
Total or average value for all windows.						0.50	0.43

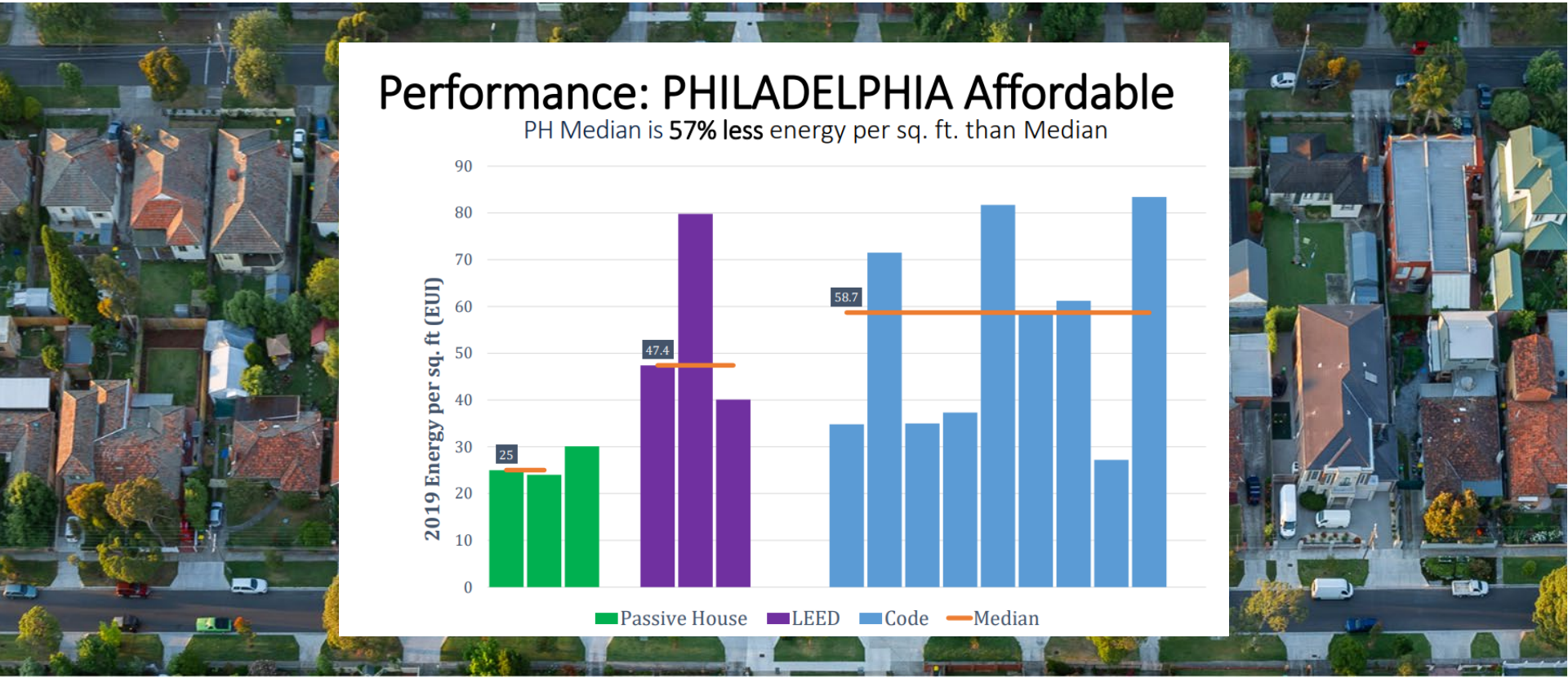
Heating degree hours [°F.day/yr]: 7440

Go to glazing list | Go to window frames list

Qua n-tity	Description	Deviation from north	Angle of inclination from the horizontal	Orien- tation	Window rough ope Width	Window rough ope Height	Installed in	Glazing	Frame	g-Value	U-Value Glazing	U-Value Frames (avg.)	Ψ Glazing edge	Installation si left	Installation si right	Installation si bottom
		°	°		ft	ft		1-Sorting: LIKE LIST	Sort: AS LIST	-	BTU/hr.ft².F	BTU/hr.ft².F	BTU/hr.ft².F			
1	W104	90	90	East	3.00	4.86	4-Wall_9351_E	01ud-Triple-insulated-Kr08	02ud Sil82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W107	90	90	East	3.00	4.85	4-Wall_9351_E	01ud-Triple-insulated-Kr08	02ud Sil82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W106	90	90	East	3.00	4.85	4-Wall_9351_E	01ud-Triple-insulated-Kr08	02ud Sil82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W105	90	90	East	3.00	4.85	4-Wall_9351_E	01ud-Triple-insulated-Kr08	02ud Sil82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	D125	90	90	East	3.00	6.67	4-Wall_9351_E	01ud-Triple-insulated-Kr08	03ud ADS75 Door	0.50	0.11	0.32	0.029	1	1	1
1	W155	90	90	East	3.00	4.06	4-Wall_9351_E	01ud-Triple-insulated-Kr08	01ud Sil82+Fixed	0.50	0.11	0.19	0.018	1	1	1
1	W135	270	90	West	2.33	3.50	5-Wall_9544_W	01ud-Triple-insulated-Kr08	02ud Sil82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W134	270	90	West	3.00	4.85	5-Wall_9544_W	01ud-Triple-insulated-Kr08	02ud Sil82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W133	270	90	West	3.00	4.85	5-Wall_9544_W	01ud-Triple-insulated-Kr08	02ud Sil82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W132	270	90	West	3.00	4.85	5-Wall_9544_W	01ud-Triple-insulated-Kr08	02ud Sil82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W156	270	90	West	3.00	4.06	5-Wall_9544_W	01ud-Triple-insulated-Kr08	01ud Sil82+Fixed	0.50	0.11	0.19	0.018	1	1	1
1	W140	0	90	North	2.33	2.33	6-Wall_9368_N	01ud-Triple-insulated-Kr08	02ud Sil82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W139	0	90	North	2.33	3.50	6-Wall_9368_N	01ud-Triple-insulated-Kr08	02ud Sil82+Operable	0.50	0.11	0.19	0.018	1	1	1

Predictable Performance is THE thing.

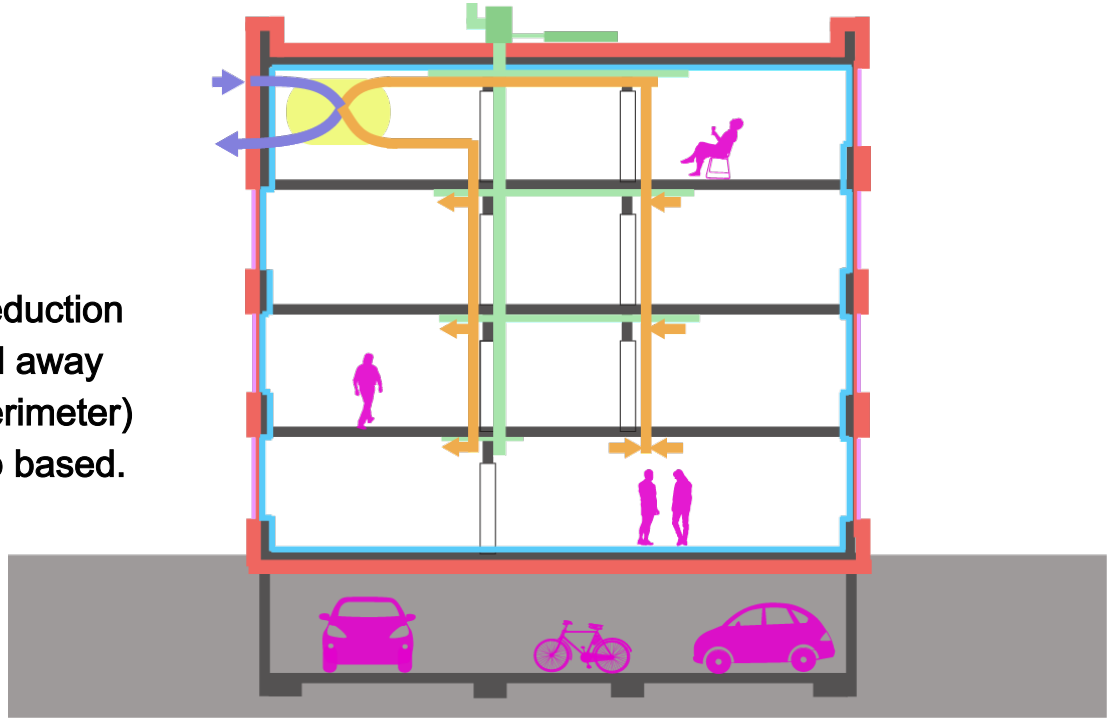
The Passive House Network



Right size Heating & Cooling Systems

The Passive House Network

75% equip sizing reduction
Efficient distribution (Pulled away from perimeter)
Often all -electric, heat pump based.



Construction is complicated!

So many demands:

- Structural
- MEP
- Life safety
- Environmental
- Worker safety
- Framing
- Finishes
- Sequencing
- Budgets
- Other certifications!
- etc…

Passive House Focus: Hygiene, Comfort and Efficiency

What Trades to Focus on

- Carpentry
- Masonry
- Steel
- Foundation work
- Heating, Cooling & Ventilation
- Plumbing
- Electrical
- Verification, Testing & Commissioning

Each should have a general understanding of Passive House & specific knowledge of their works impact. Connect the work to final performance results.

Logic of Passive House

The Passive House Network

Principles (the drivers)

1. Continuous Climate Specific Insulation
2. Thermal Bridge Free Connections
3. Airtight Enclosure
4. High Performance Windows & Doors
5. Mechanical Ventilation with Heat Recovery

Goals

1. Health
2. Comfort
3. Efficient
4. Durable
+ Affordable

Logic of Passive House

Building industry is disconnected from the drivers of building performance.

Passive House connects the dots and transforms industry expectations & capacity

Passive House empowers builders and designers to consistently deliver high-performance core solutions.

Focus makes high quality affordable

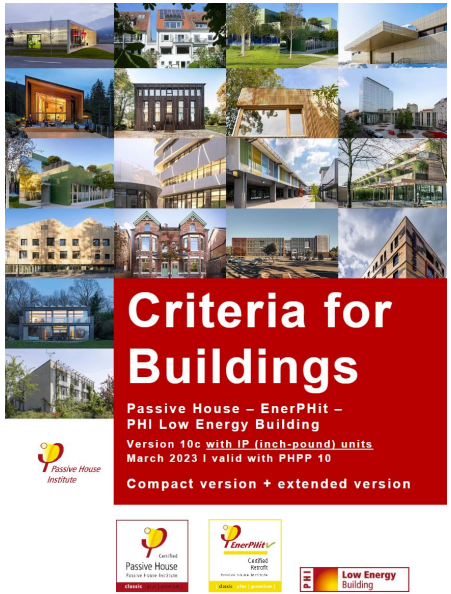
The Passive House Network

Anyone can build Passive House with modest but specific training.

It’s more about building intentionally and simply.

The Passive House Criteria

Criteria: Goals



1. Occupant Health
2. Thermal Comfort
3. Energy Efficient
4. Durable

Criteria: Enclosure Quality

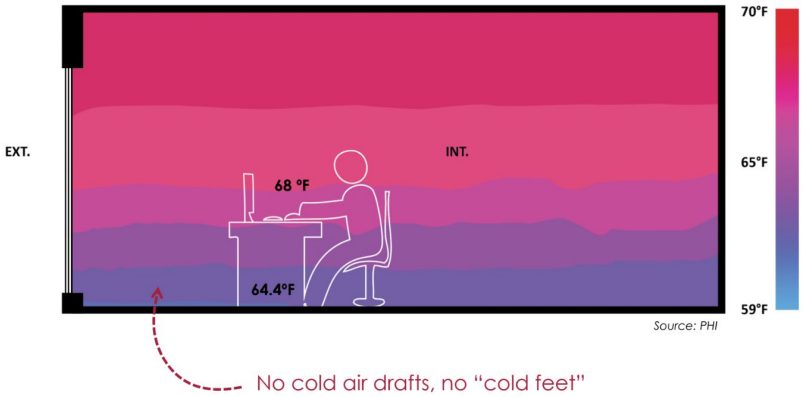
The Passive House Network

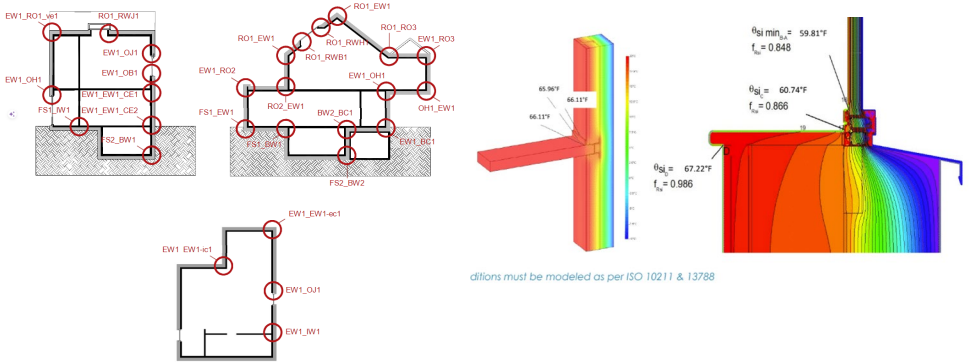
Thermal Protection (COMFORT)

- Interior Surface Temperatures: not more than 7.6 F below the operative indoor temperature.
- Floors: not below 66.2 F, Checked against 71.6 F in PHPP

Moisture Protection (HYGIENE/HEALTH)

fRsi defines the coldest point which can occur on the interior surface of a construction system. For example, if the temperature factor is 0.7, then 70% of the temperature difference between the inside and outside air is still present at the interior surface. If the temperature factor is achieved, then mould and condensation formation can be safely prevented at normal outdoor temperatures, indoor temperatures and indoor air humidity levels.





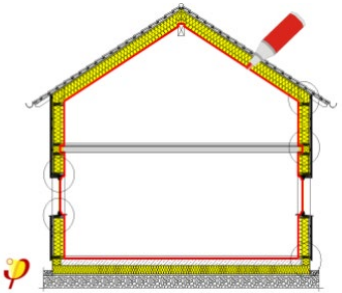
Even internal surface temperatures - Details matter a lot!

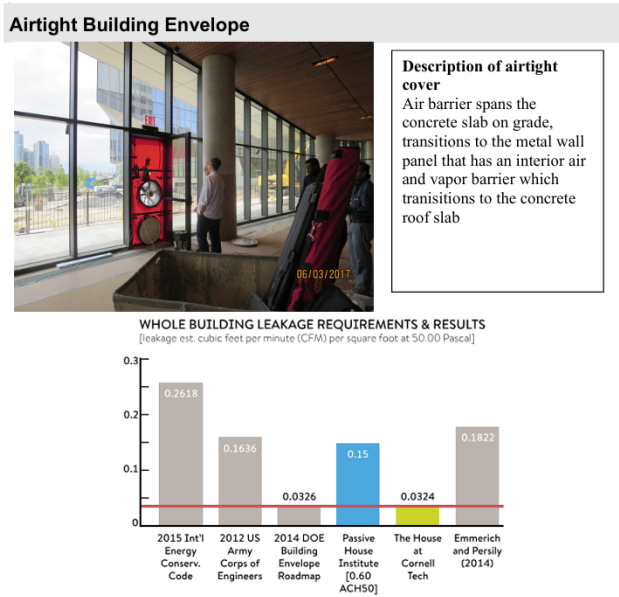
Criteria: Enclosure Quality

The Passive House Network

Airtightness (Health, Comfort & Durability)

- Whole building test result of equal or less than **0.60 ACH50** .
- Average of depressurization & pressurization.



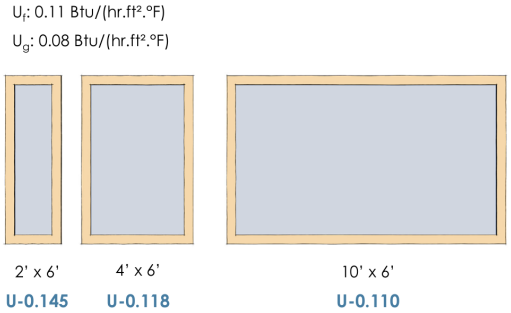


0.13 ACH50 final test = 0.15 CFM/SF

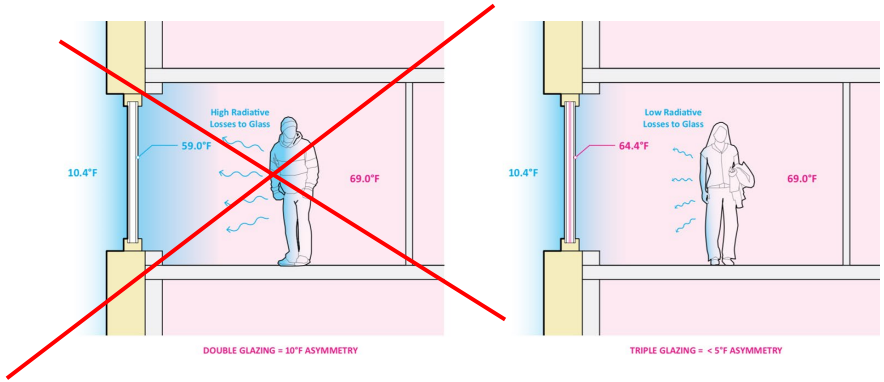
Criteria: High -Performance Windows & Doors

The Passive House Network

- Airtight
- Excellent thermal performance
- Interior Surface Temperatures: not more than 7.6 F below the operative indoor temperature.



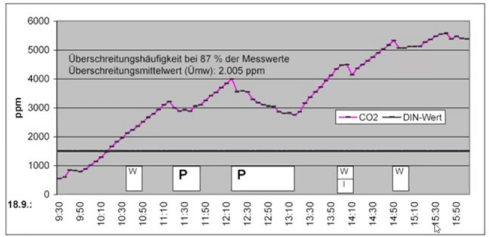
Less Frame = Better Performance

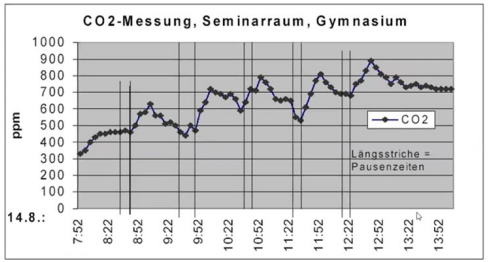


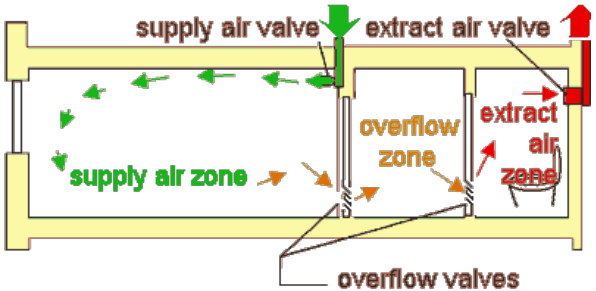
Criteria: Ventilation

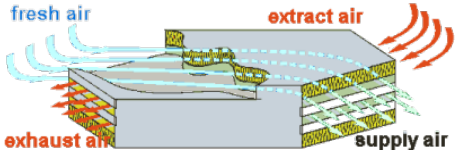
The Passive House Network

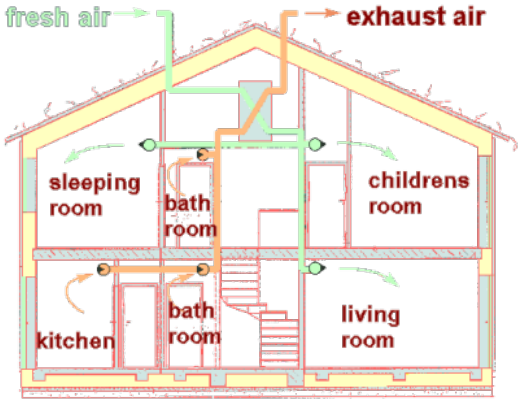
1. Sufficient filtered fresh air to all occupied spaces
2. User control and boost
3. 75% min system heat recovery efficiency
4. Fan power efficiency <0.765 W/CFM
5. Balanced Flow: <10% disbalance between fresh air supply and exhaust air.











Criteria: Other MEP

The Passive House Network

Heating & Cooling:

1. No hard rules but must be efficient.
2. While heat pumps are now common any type of system is possible.
3. Typical successful approaches.
    a. Keep it simple and small (right sized):
    b. Combined heat/cooling systems
    c. Minimize refrigerant lines.

Domestic Hot Water:

1. Efficient piping layout - minimizing circulation.
2. Well insulated hot water piping & accessories.
3. Efficient heater: Heat pump encouraged.
4. Efficient pumps.
5. Bath waste water heat recovery encouraged.

Appliances & Lighting:

1. Efficient appliances and lighting.
2. All -electric encouraged.

“Do no harm”: Minimize “accidental” heating & cooling. Only use what you need.

Criteria: Energy

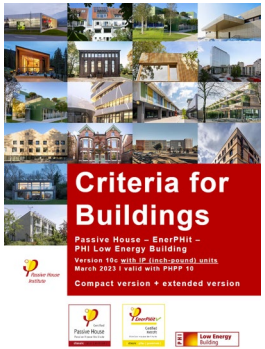


Table 1 Passive House criteria

			Criteria[1]			Alternative Criteria[2]
Heating						
Heating demand	[kBTU/(ft²yr)]	≤	4.75			-
Heating load[3]	[BTU/(hr.ft²)]	≤	-			3.17
Cooling						
Cooling + dehumidification demand	[kBTU/(ft²yr)]	≤	4.75 + variable allowance[4]			
Airtightness						
Pressurization test result n_{50}	[1/hr]	≤	0.6			
Renewable Primary Energy (PER)[5]			Classic	Plus	Premium	
PER demand[6]	[kBTU/(ft²yr)]	≤	19.02	14.26	9.51	±4.75 kBTU/(ft²yr) deviation from criteria…
Renewable energy generation[7] (with reference to projected building footprint)	[kBTU/(ft²yr)]	≥	-	19.02	38.04	…with compensation of the above deviation by different amount of generation[8]

Table 5 PHI Low Energy Building criteria

			Criteria[1]	Alternative Criteria[2]
Heating				
Heating demand	[kBTU/(ft²yr)]	≤	9.51	
Cooling				
Cooling + dehumidification demand	[kBTU/(ft²yr)]	≤	Passive House requirement[3] + 4.75	
Airtightness				
Pressurization test result n_{50}	[1/hr]	≤	1.0	
Renewable Primary Energy (PER)[4]				
PER demand[5]	[kBTU/(ft²yr)]	≤	23.77	Exceeding the criteria up to +4.75 kBTU/(ft²yr) is permitted…
Renewable energy generation[6] (with reference to projected building footprint)	[kBTU/(ft²yr)]	≥	-	…with compensation of the above deviation by additional generation

PHI Low Energy Building

Renovation Energy Criteria: EnerPHit

The Passive House Network

Table 3 EnerPHit energy demand criteria (as an alternative to Table 2)

Climate zone according to PHPP	Heating	Cooling
	Max. heating demand	Max. cooling + dehumidification demand
	[kBTU/(ft²yr)]	[kBTU/(ft²yr)]
Arctic	11.09	equal to Passive House requirement[1]
Cold	9.51	
Cool-temperate	7.92	
Warm-temperate	6.34	
Warm	4.75	
Hot	-	
Very hot	-	

or

Table 2 EnerPHit component criteria

Climate zone according to PHPP	Opaque envelope[1] against...				Windows (including exterior doors)					Ventilation	
	...ground	...ambient air			Overall[4]		Glazing[5]	Solar load[6]			
	Insu-lation	Exterior insulation	Interior in-sulation[2]	Exterior paint[3]	Max. heat transfer coefficient ($U_{D/W,installed}$)		Solar heat gain coefficient (SHGC)	Max. specific solar load during cooling period		Min. heat reco-very rate[7]	Min. hu-midity re-covery rate[8]
	Min. thermal resistance (R-value)			Cool colours							
	[hr.ft².°F/BTU]			-	[BTU/hr.ft².°F]		-	[kBTU/(ft²yr)]		%	
					C						
Arctic	Deter-mined in PHPP from project specific heating and cooling degree days against ground.	63.09	22.71	-	0.08	0.09	0.11	U_g - SHGC*0.7 ≤ 0	32	80%	-
Cold		47.32	18.93	-	0.11	0.12	0.14	U_g - SHGC*1.0 ≤ 0		80%	-
Cool-temperate		37.86	16.22	-	0.15	0.18	0.19	U_g - SHGC*1.6 ≤ 0		75%	-
Warm-temperate		18.93	11.36	-	0.18	0.19	0.21	U_g - SHGC*3.2 ≤ -0.6		75%	-
Warm		11.36	7.57	-	0.22	0.23	0.25	-		-	-
Hot		11.36	7.57	Yes	0.22	0.23	0.25	-		-	60 % (humid climate)
Very hot		22.71	12.62	Yes	0.18	0.19	0.21	-		-	60 % (humid climate)

plus

Table 4 General EnerPHit criteria (always applicable irrespective of the chosen method)

			Criteria[1]			Alternative Criteria[2]
Airtightness						
Pressurization test result n_{50}	[1/hr]	≤	1.0			
Renewable Primary Energy (PER)[3]			Classic	Plus	Premium	
PER demand[4]	[kBTU/(ft²yr)]	≤	19.02	14.26	9.51	±4.75 kBTU/(ft²yr) deviation from criteria...
			+ allowance for larger heating/cooling demand (compared to Passive House)			
Renewable energy generation[5] (with reference to projected building footprint)	[kBTU/(ft²yr)]	≥	-	19.02	38.04	...with compensation of the above deviation by different amount of generation

30+ Certifiers Working in the US

The Passive House Network

Active Certifiers in the US include:

1. CertiPHIers Cooperative
2. Emu Passive
3. Herz & Lang
4. Home Energy Services
5. Passive House Academy
6. Passive House Institute
7. Peel Passive House
8. RDH Building Science
9. Steven Winter Assoc

https://passivehousenetwork.org/certification/

The North American Certifiers Circle

A group of independent organizations that certify buildings in North America which meet Passive House Institute performance standards.

Benefits of Certification

The North American Certifiers Circle (NACC) certification provides many benefits to the developer, designer, consultant, builder, owner, and others.

Independent Review

Review services provided by a certifier are separate and distinct from those of a Passive House consultant or designer. This ensures an independent and objective assessment as well as additional quality assurance that benefits all parties involved.

Avoid False Starts

By working with a certifier from the start of the project the project can benefit from the experience and institutional knowledge of the certifier, avoiding rookie mistakes that need to be later undone.

Professional Development for Project Teams

The review of energy calculations and design and construction documentation through the lens of experts in high-performance building allows other members of the project team to gain a new perspective.

Assurance for the Project Team

Consultants, designers, and builders alike can breathe easier knowing their energy calculations and related details have been double-checked before construction begins.

Cost Control

We have established that the biggest driver of additional costs for Passive House is the experience or inexperience of the project team. No one has more experience than the building certifiers. Consequently the four reasons above work together to help you contain costs and meet your budget.

An initiative of Passive House Canada, The Passive House Network and the NACC members.

PASSIVEHOUSE CANADA

The Passive House Network

NACC MEMBERS

Find a NACC member for your next building project:

US Based Members

CertiPHIers Cooperative
www.certiphiers.com

Emu
www.emu.systems

Home Energy Services
green-mann.com

Steven Winter Associates
www.swinter.com

Canada Based Members

Mizu Passive House Consulting
www.mizupassivehouse.com

Peel Passive House Consulting
www.peelpassivehouse.ca

RDH Building Science Inc.
www.rdh.com

Stich Consulting & Design
stichpassivedesign.com

Europe Based Members

Herz & Lang
www.herz-lang.de

Mead LTD
www.meadconsulting.co.uk

Passive House Academy
www.passivehouseacademy.com

Passive House Institute
passivehouse.com

Praxis
praxis-rb.com

Zephir Passivhaus Italia
passivhausitalia.com

https://passivehousenetwork.org/wp-content/uploads/2023/01/NACC-Brochure-Jan-2023.pdf

Other accredited Passive House certifiers

PASSIVE HOUSE CERTIFIER

Passive House Institute accredited

The following experts* have been internationally accredited by the Passive House Institute to certify Passive House buildings, EnerPHit retrofits and Low Energy Buildings anywhere in the world on behalf of the Passive House Institute and in accordance with their criteria

How to become a Passive House certifier

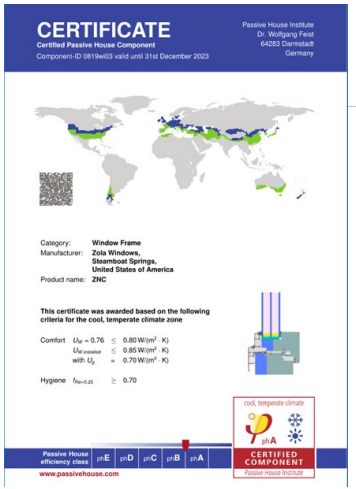
* Unless otherwise stated, building certification contracts are always concluded between the Passive House Institute and an individual person and not with their companies/organisations.

Organisation	Country	Website	Building Certifier
CertiPHIers Cooperative, Inc.	United States of America	http://www.certiphiers.com	• Matthew Bowers, Languages: en • Tad Everhart, Languages: en • Rolf Jacobson, Languages: en • Chris Petit, Languages: en • Christina Snyder, Languages: en
Emu Building Science LLC	United States of America	https://emu.systems/	• Enrico Bonilauri, Languages: en | it
Home Energy Services	United States of America	http://www.green-mann.com	• Steve Mann, Languages: en
Steven Winter Associates, Inc	United States of America	http://www.swinter.com	• Lois Arena, Languages: en
Etude Consulting Ltd.	United Kingdom/ Britain	http://passivhaus.etude.uk | passivhaus.certification@etude.uk	• Naomi Grint, Languages: en • Will South, Languages: en • Chris Worboys, Languages: en
Mead Energy & Architectural Design LTD	United Kingdom/ Britain	http://www.meadconsulting.co.uk	• Kym Mead, Languages: en
WARM - Low Energy Building Practice	United Kingdom/ Britain	http://www.peterwarm.co.uk	• Sally Godber, Languages: en • Liam McDonagh-Greaves, Languages: en • Mike Roe, Languages: en • Peter Warm, Languages: en
ZE Passivhaus Services Ltd	United Kingdom/ Britain	https://www.passiv.org	• Jesus Menendez Amigo, Languages: es | en
Passivhusbyrån Ingo Theoboldt	Sweden	http://www.passivhusbyran.se	• Ingo Theoboldt, Languages: de | en | sv

https://passivehouse.com/03_certification/02_certification_buildings/03_certifiers/01_accredited/01_accredited.html

Certified Passive House Components

The Passive House Network



Climate icon legend

- Arctic
- Cold
- Cool, temperate
- Warm, temperate
- Warm
- Hot
- Very hot

Opaque building envelope

- Construction systems
- Floor slabs
- Wall and column connections
- Balcony connections
- Façade anchors
- ICF for roof parapets
- Attic staircases
- Flue systems
- Airtightness systems

Transparent building envelope

- Windows
- Roof windows
- Skylights
- Curtain wall systems
- Glass roofs
- Openable elements in glass roof
- Shutters
- Entry doors
- Sliding doors
- Glazing
- Glazing edge bonds
- Fall protections

Building services

- Heat pumps
- Ventilation systems (capacity < 600 m^3/h)
- Decentralised ventilation system (single room only / with second room connection)
- Decentralised ventilation system (school room)
- Ventilation systems (capacity > 600 m^3/h)
- Drain water heat recovery
- Exhaust air wall system

CERTIFIED COMPONENT
Passive House Institute

https://database.passivehouse.com/en/components/

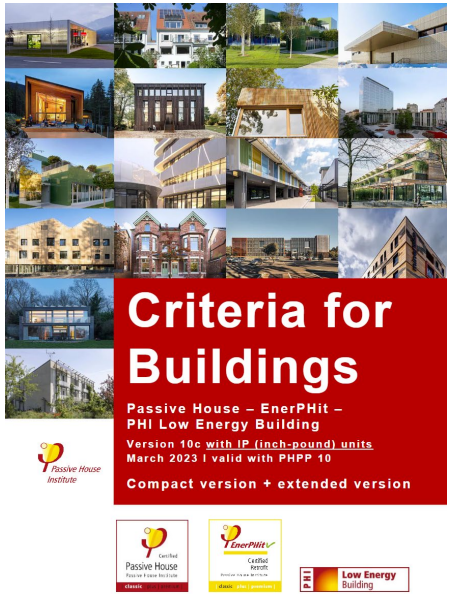
Certified Professionals

The on-demand and hybrid formats allow students to leverage the benefits of on-demand & live online training to best meet their learning preferences.
35 AIA LU/HSW credits

https://passivehousenetwork.org/designer-training/

https://passivehousenetwork.org/tradesperson-training/

Criteria Goals in Summary



1. Occupant Health
2. Thermal Comfort
3. Energy Efficient
4. Durable

1. Interior Surface Temperatures
2. Airtightness
3. Ventilation
4. Efficient MEP

Team & Process Overview

Assemble the team to deliver a Passive House

The Passive House Network

- Architects
- Engineers
- Consultants
- Passive House Consultant
- Verifier
- Inspectors
- Ventilation Commissioning
- Blower door testers
- Builder & Trades

What a team needs:

1. common language
2. common goal: Passive House
3. good attitudes
4. enough training
5. willingness to work as a team and connect the dots

+

Owner, Owner's Rep and Certifier

Certification Process Overview

The Passive House Network

Initial Check Planning/Pre - Design

The basic programming complete, engage a Certifier, and have the Certifier conduct an **initial check** of programmatic assumptions and certification criteria - to **clarify how aspects will be assessed in the certification** .

Preliminary Review SD/DD Phase(s)

1. Assessment of the concepts for the design, insulation and building services, and of the **preliminary version of the PHPP** calculation for **consistency with the certification criteria** .
2. The PH consultant **assembles key information** .
3. The Certifier will provide **feedback and suggestions** so you can optimize your design and specifications and update the PHPP energy model.

Design Stage Review Construction Document Phase

1. The PH consultant will prepare the detailed **certification submittal package** (PHPP, plans, specifications, and required supporting documentation) **according to your Certifier's guidance** .
2. Make corrections to your Certifier requests and **re-submit until your Certifier can conditionally assure** certification when construction is completed.
3. Your Certifier will **issue a design stage assurance letter** that, as designed, the building can be certified.

Final Review Construction Completion

1. Upon completion, **complete submissions** for Certifier's final review.
- As-built PHPP energy model and plans per PHI certification protocols
- Executed Builder Assurance Certificate that building has been constructed to the as-built plans and energy model per PHI certification protocols.
- Photo documentation per PHI certification protocols.
- Blower door test results per PHI certification protocols.
- Ventilation system commissioning report per PHI certification protocols.

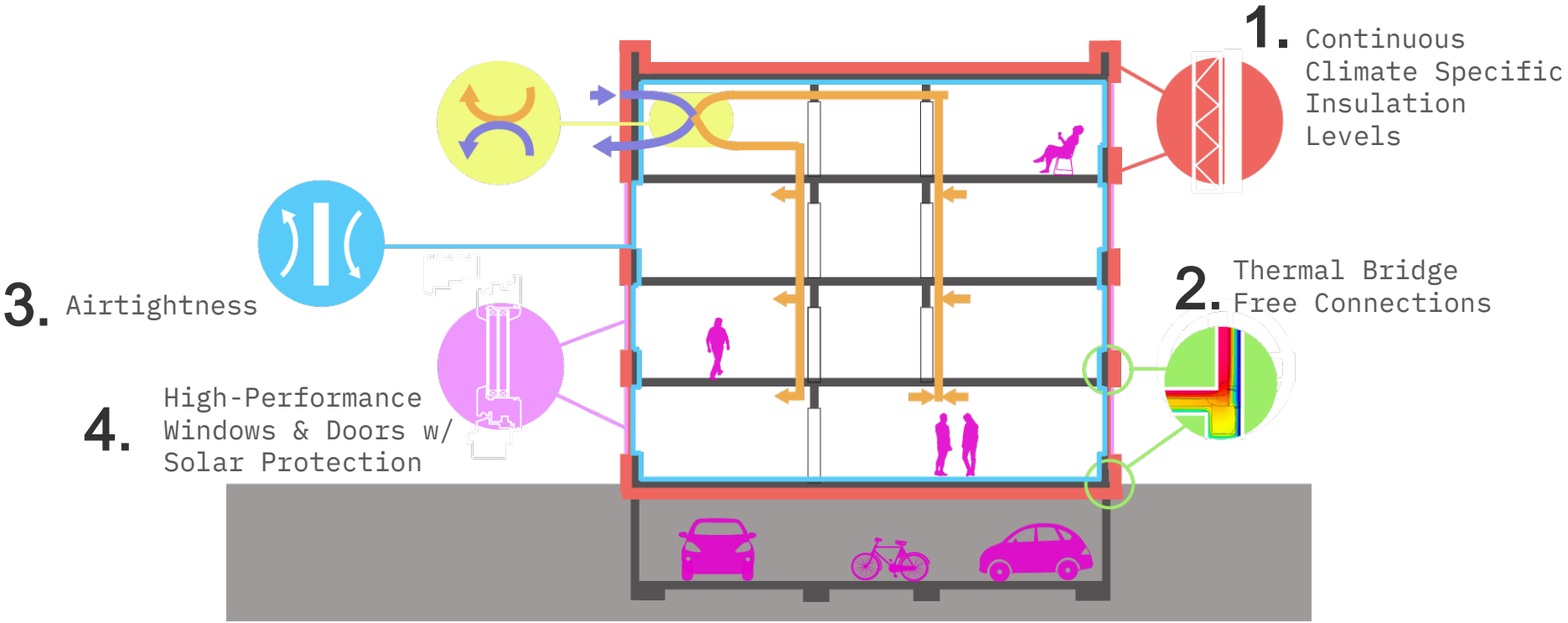
2. If your building meets all certification criteria, you will receive the building certificate.
3. Post the certificate on your website and attach the plaque to your new Passive House building.
4. List your newly certified building in PHI's online international project directory.

Enclosure

Principles 1 -4

First 4 Principles are about the enclosure

The Passive House Network



https://passipedia.org/basics/what_is_a_passive_house

Continuous Climate Specific Insulation

Principle #1

Any Insulation is possible too - just be continuous!

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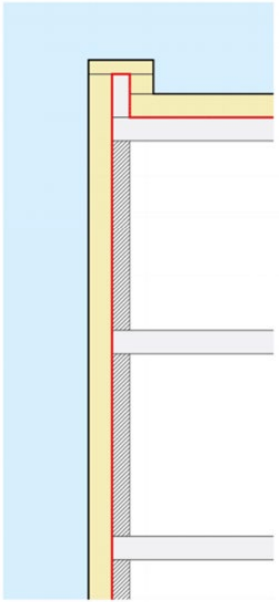
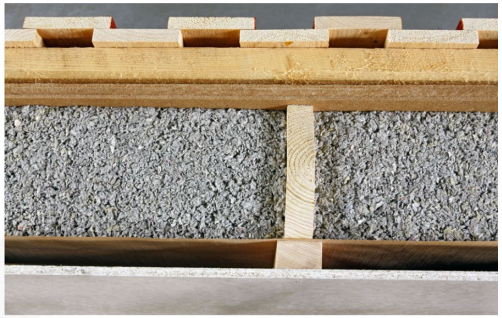


Boards: Mineral Wool, Foam, Wood Fiber

Spray Insulation: Dense Pack Cellulose is a Favorite



Dense-pack:
Pump to 3.5 lbs per ft³ in walls to prevent settling

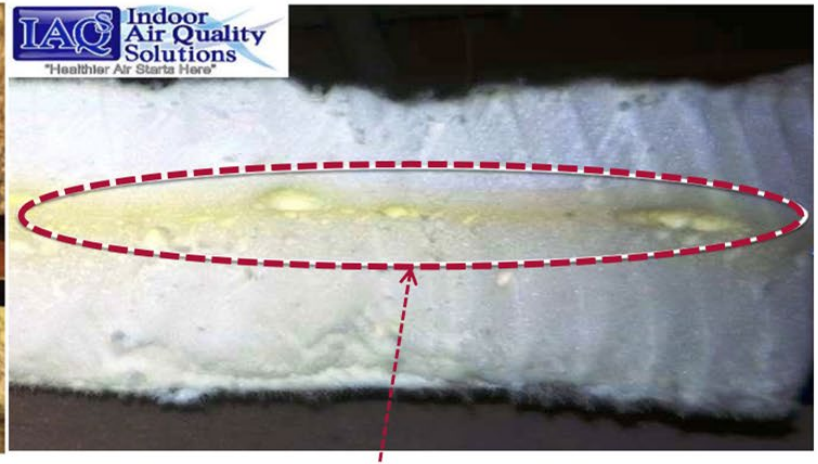
Batt Insulation (not continuous) Can play a part.

Quality Control of Batt Insulation is a Concern

Bad Installations Samples of Rigid Insulation

Problems with Spray Foam

Shrinking over time



Incorrectly mixed

SOURCE: John Lapotaire

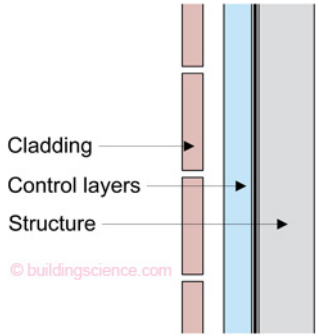
Assembly Characteristics

Fundamental Characteristics of Enclosures

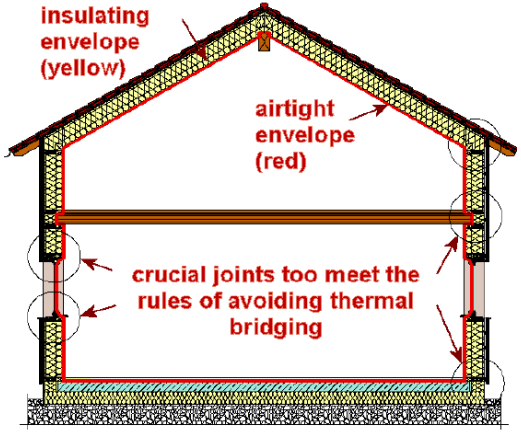
The Passive House Network

Control Layers:

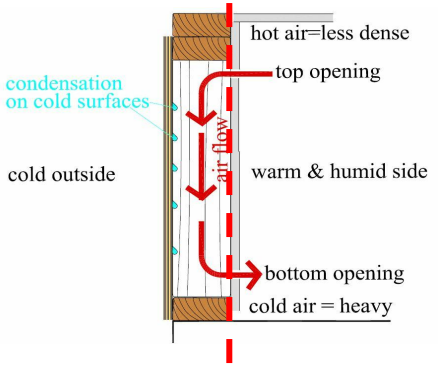
1. Shed Bulk Water (rain coat)
2. Vapor Control (prevent wetting and allow drying)
3. Air Control (airtightness)
4. Thermal Control (insulation)



"Perfect Wall" - The control layers wrap the structure and are protected by exterior cladding.



Ref http://passipedia.passiv.de/passipedia_en/



Primary air barrier at interior side of insulation - in a heating dominated climate this keeps warm moist air from condensing in the wall assembly.

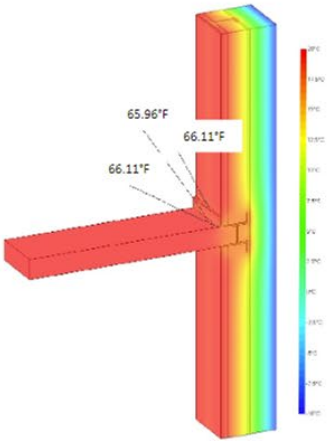
fRsi helps guide insulation levels at weak points.

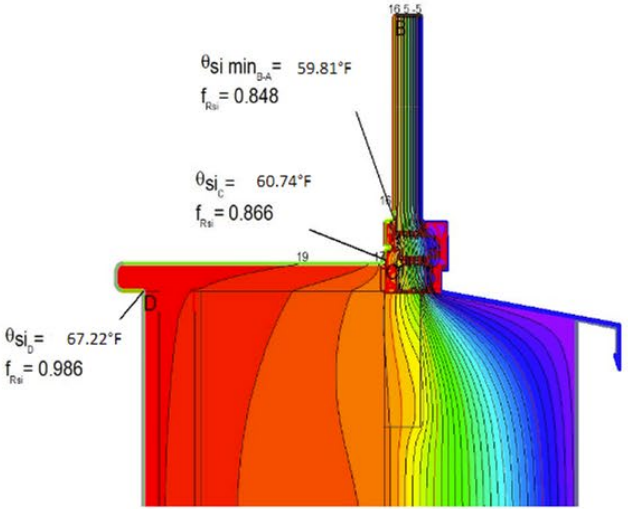
The Passive House Network

$$f_{Rsi} = (t_{si} - t_e) \div (t_i - t_e)$$

With:

- f_{Rsi} Temperature factor at the internal surface
- t_{si} Interior Surface Temp
- t_e Exterior Design Temp
- t_i Interior Design Temp



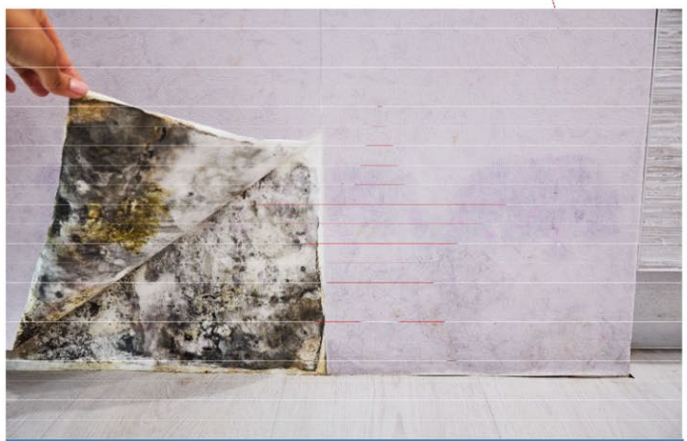


Note: For f_{Rsi} calculation, surface temps and exterior conditions must be modeled as per ISO 10211 & 13788

Avoid Vapor Barriers in Walls & Roofs

The Passive House Network

Vinyl and plastic are vapor 'barriers' which will never let the moisture in these assemblies dry out



Vinyl Wallcovering – Mold due to inwardly driven moisture trapped by the vapor impermeability of the vinyl wallcovering

Interior Polyethylene Vapor Barrier – Condensation from inwardly driven moisture

Building Science Corp.

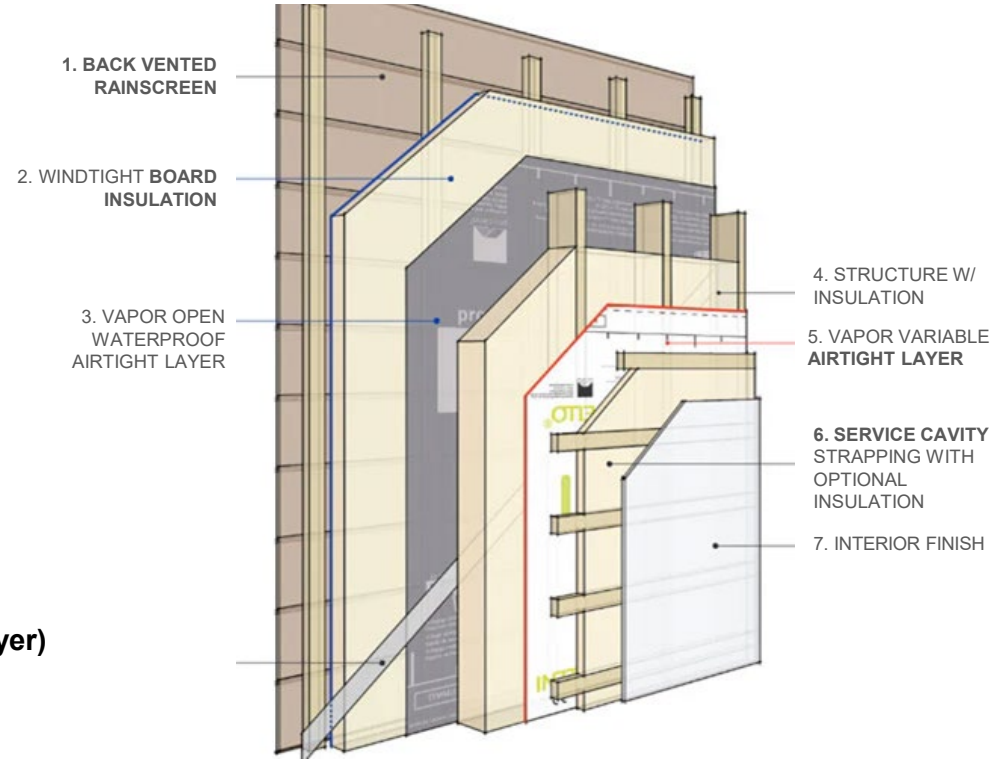
#1: Try to keep water out, BUT…
#2: When* it gets in, let the water dry out.

Variations on Layering below is typical

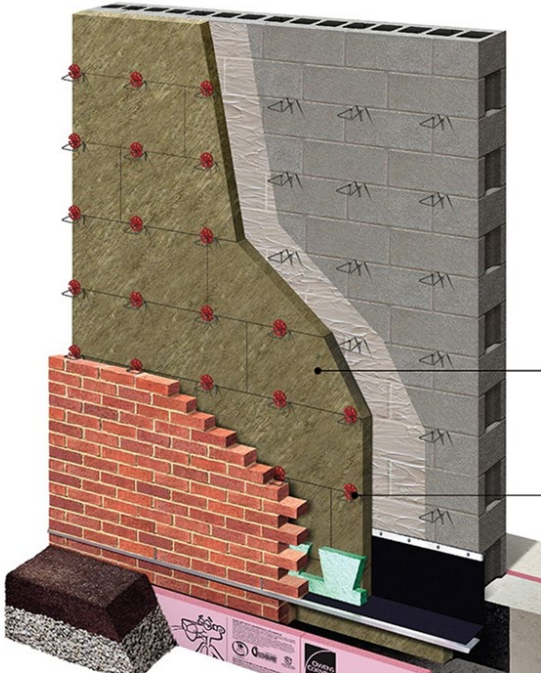
The Passive House Network

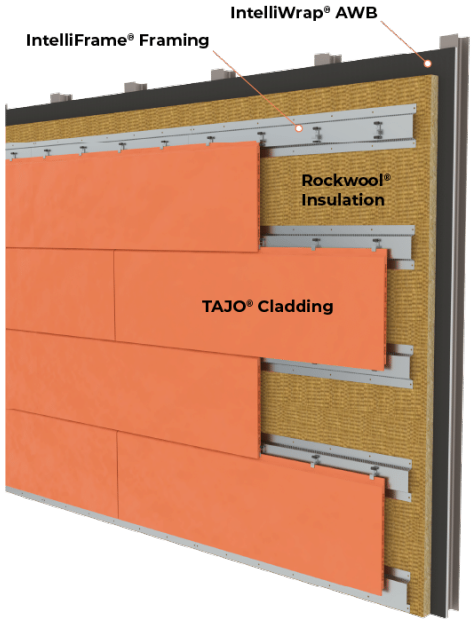
Shed Water
Vapor Control
Air Control
Thermal Control

1. **Back Vented Rainscreen**
2. **Continuous Insulation**
3. **Waterproofing**
4. **Structure (w/ insulation)**
5. **Airtightness**
6. **Service Cavity** **(to protect the airtight layer)**
7. **Interior Finish**

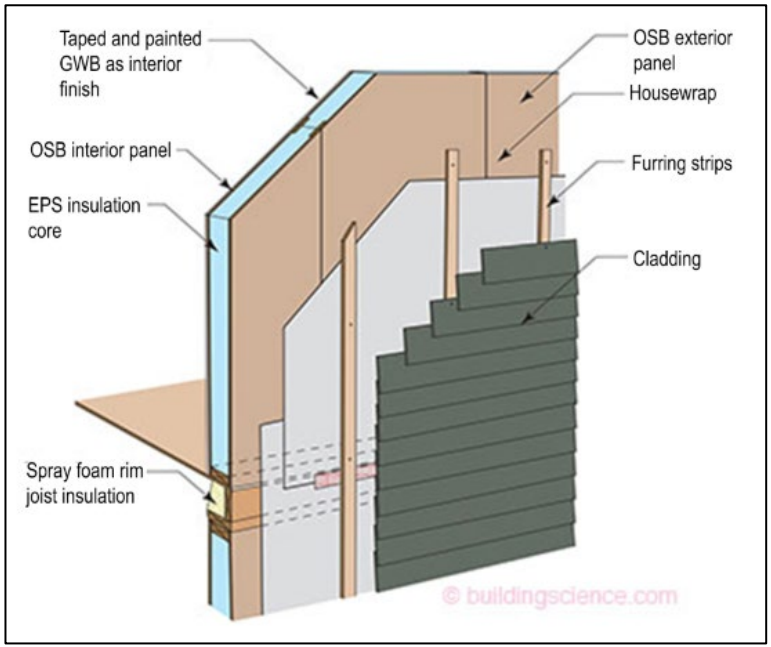


Brick, Panels & Siding on Masonry & Framing Walls

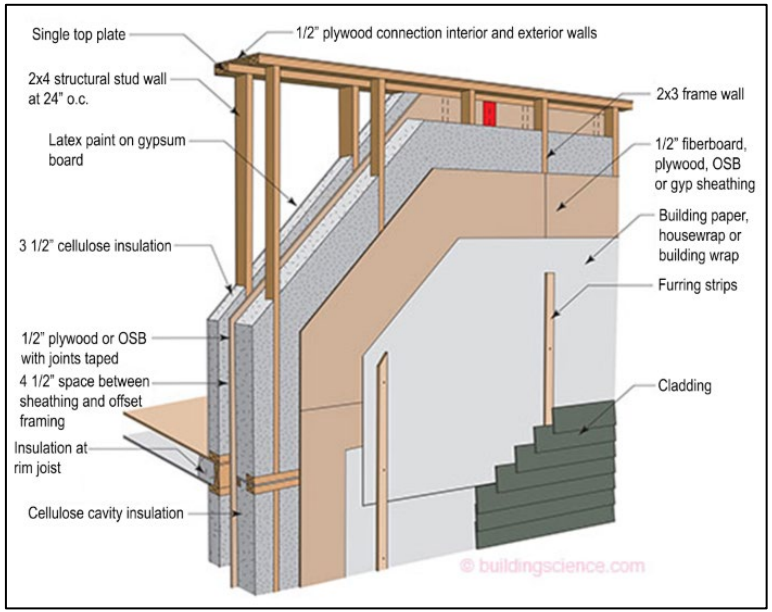




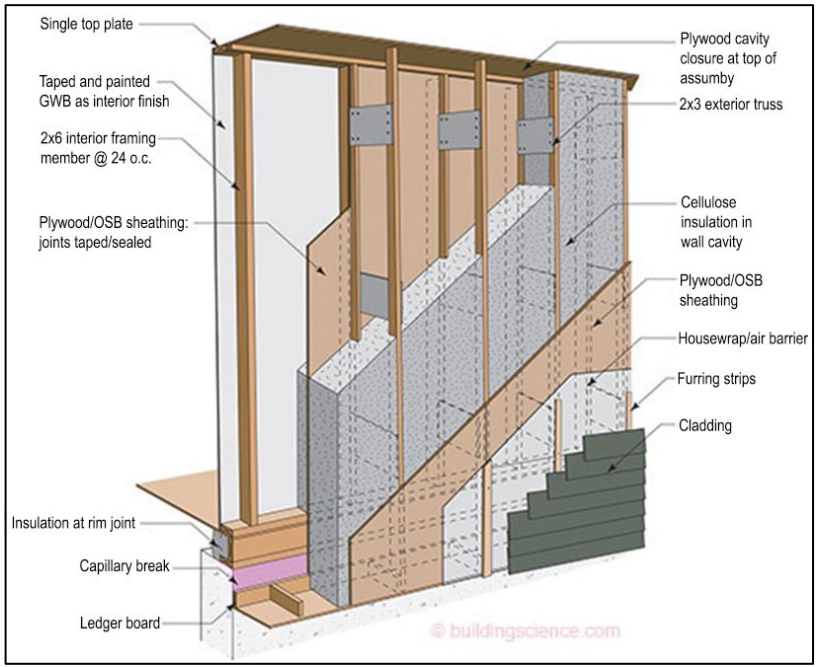
STRUCTURAL INSULATED PANELS (SIPS)



Double Stud Walls

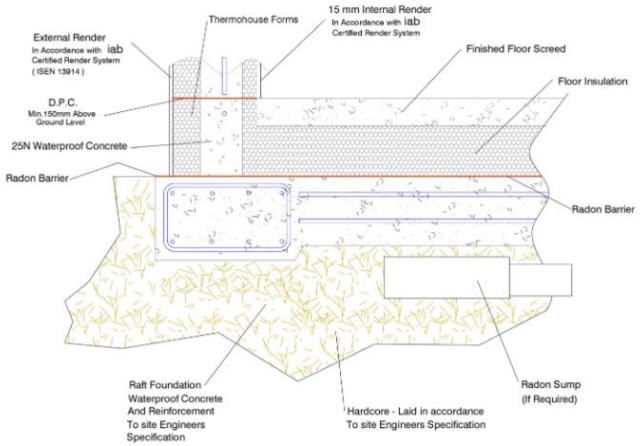


Larsen Truss or I -Joist Outrigger on Stud Wall



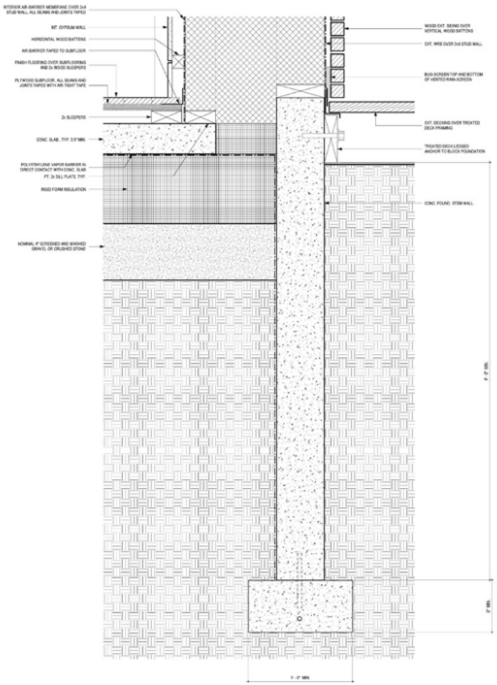
For a thick parka!

Insulated Concrete Form



SOURCE: Thermohouse ICF

Insulation under the entire slab on grade.



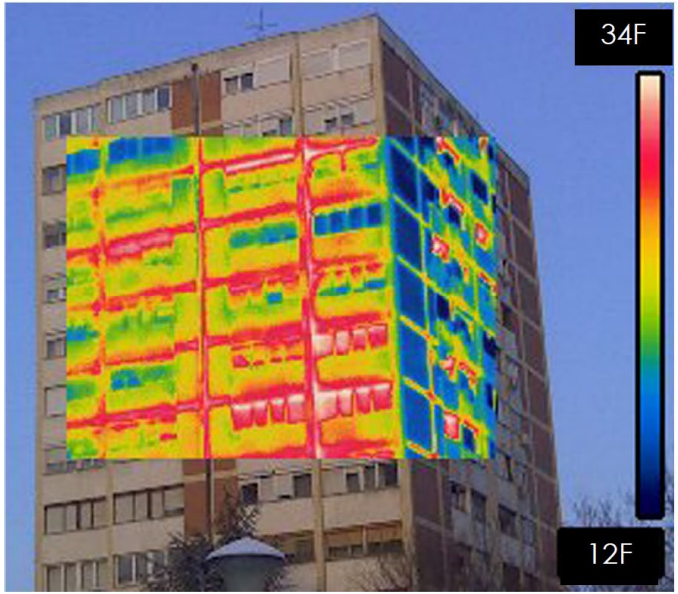
Foam

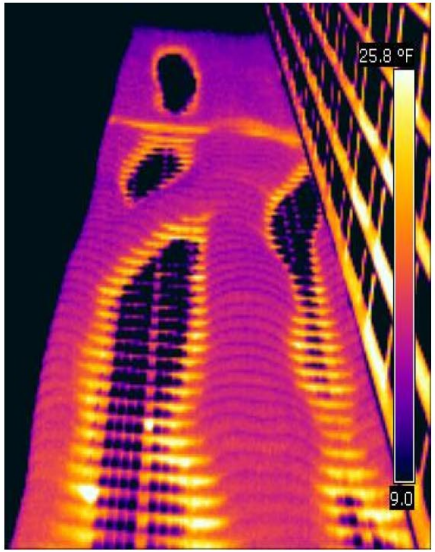
Mineral Wool

Thermal Bridge Free

Principle #2

Thermal ‘Shortcuts’ Through the Envelope Insulation





What's a Thermal Bridge?

The Passive House Network

Part of the building envelope where the otherwise uniform thermal resistance is significantly reduced by:

full or partial penetration of the insulating layers by materials with a different thermal conductivity

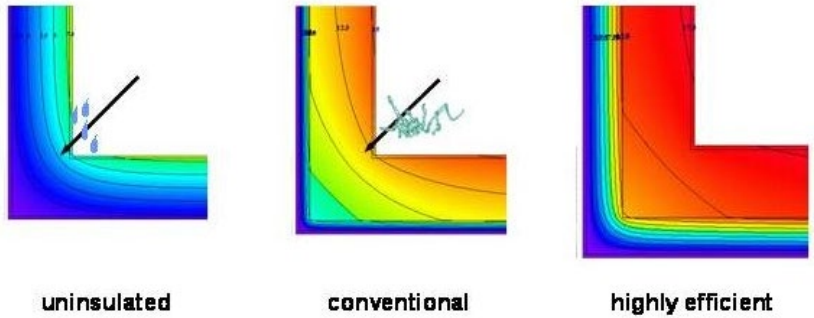
and/or

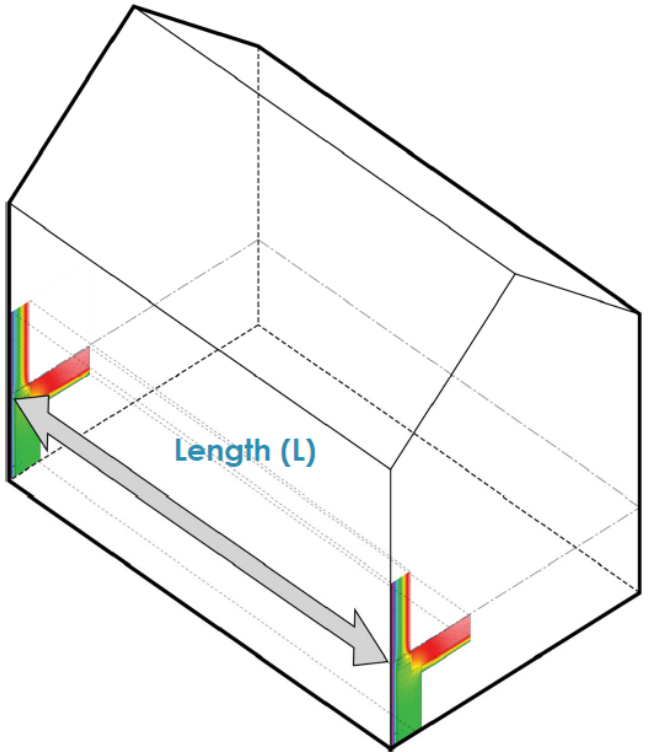
a change in thickness of the insulating layers

and/or

a difference between internal and external areas, such as occurs at wall/floor/ceiling junctions.

The Quality & Lengths of Joints Add Up!



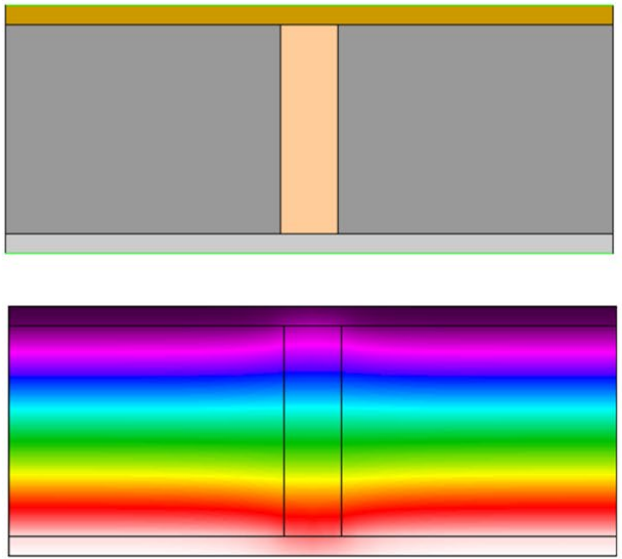


Repeating Thermal Bridges (clear field)

Wood stud wall, insulated cavity:

Nominal R-value (through cavity): 22.3

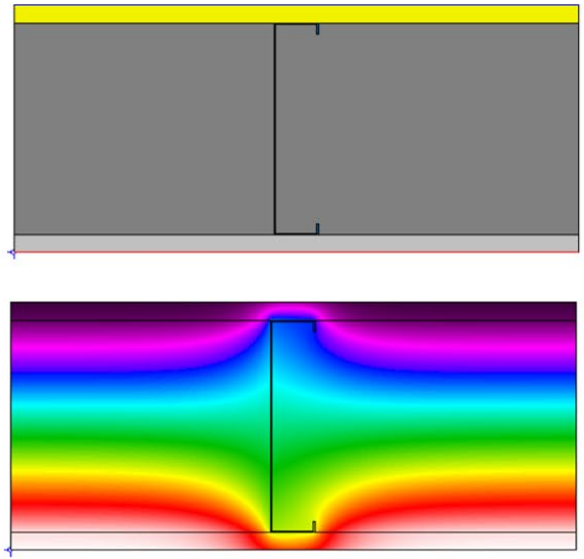
Actual R-value (incl. framing): 19.0



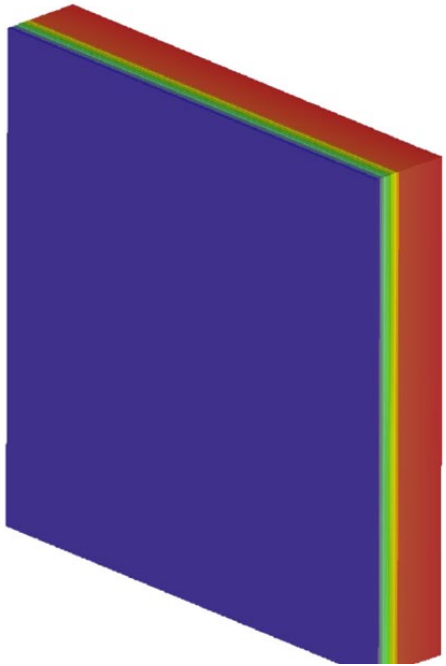
Steel stud wall, insulated cavity:

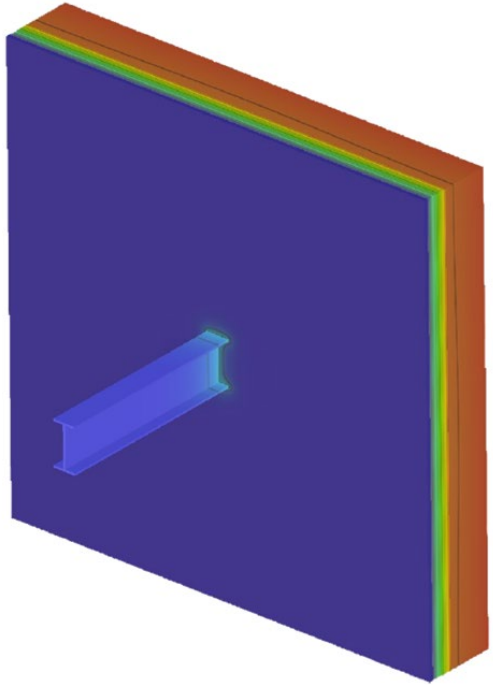
Nominal R-value (through cavity): 22.3

Actual R-value (incl. framing): 11.6

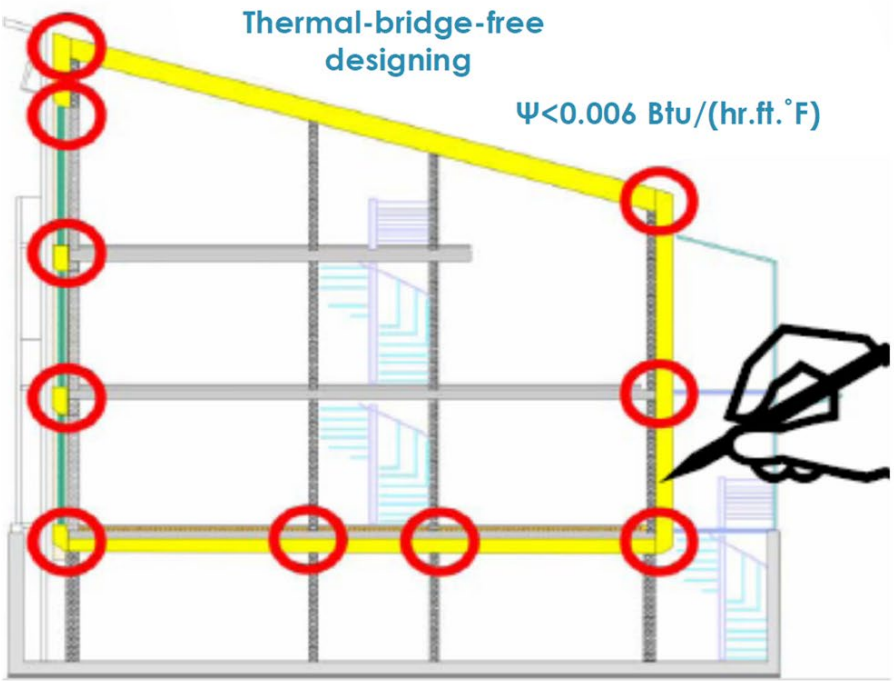


Point Thermal Bridges at Structure & Attachments



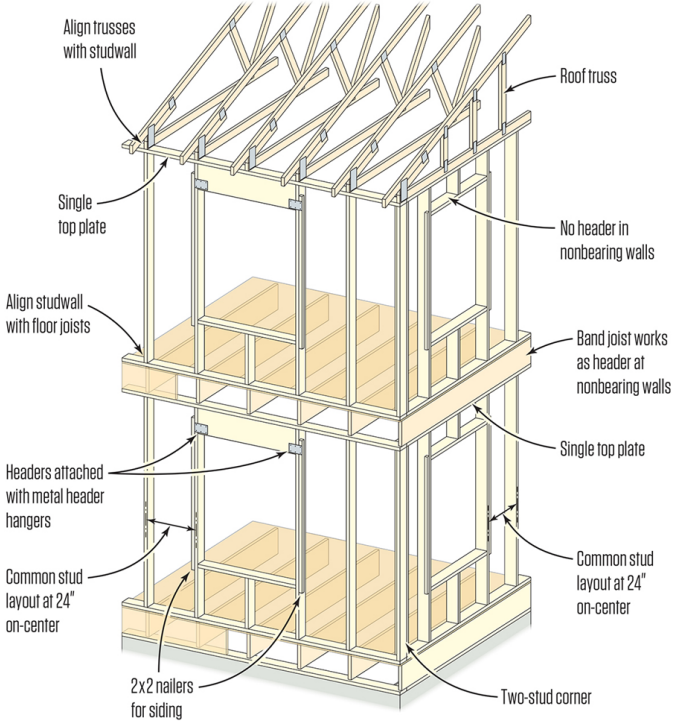


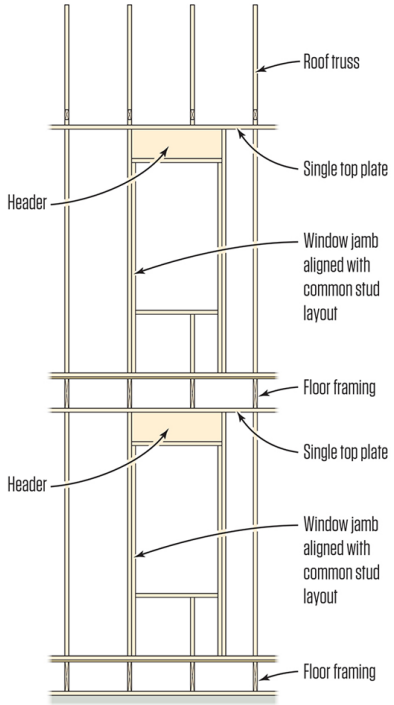
Identify all the locations of possible thermal bridges

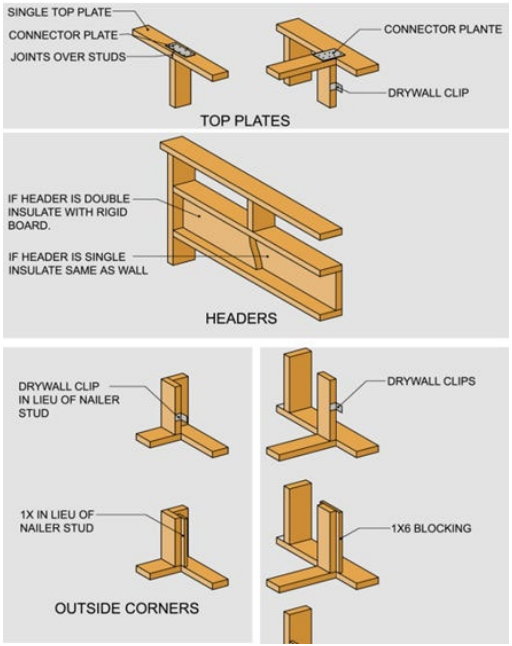


Source: PHI, Author: JS

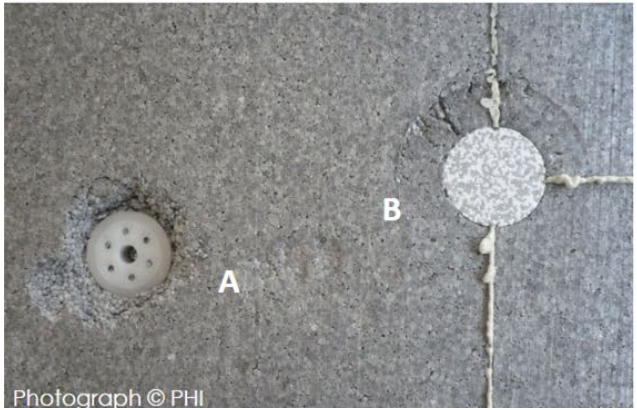
Advanced Framing







Thermal Bridge Free Attachments

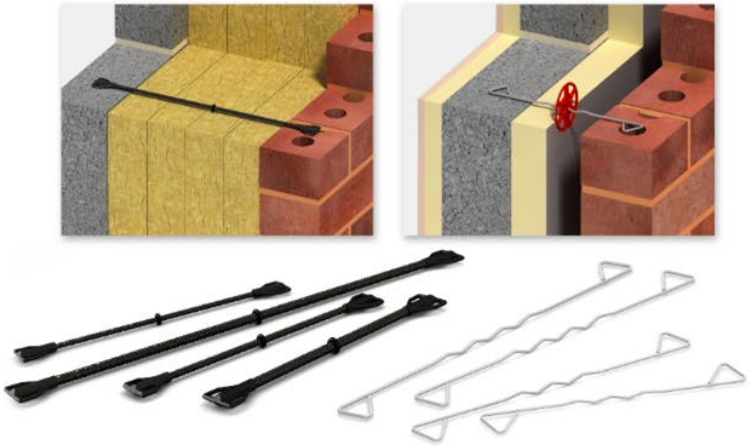


Brick Ties

The Passive House Network

Basalt Wall Ties

Thermal Conductivity (k): 0.4 Btu/hr.ft.°F

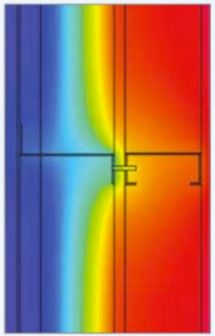


Stainless steel Wall Ties

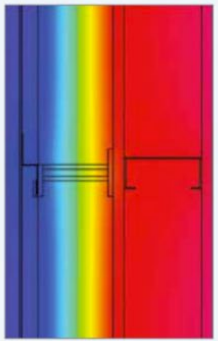
Thermal Conductivity (k): 9.8 Btu/hr.ft.°F

25 times more heat loss!

Facade Clips

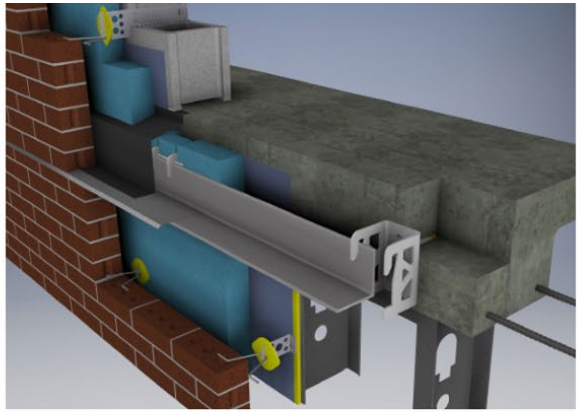


Typical Z-girt system

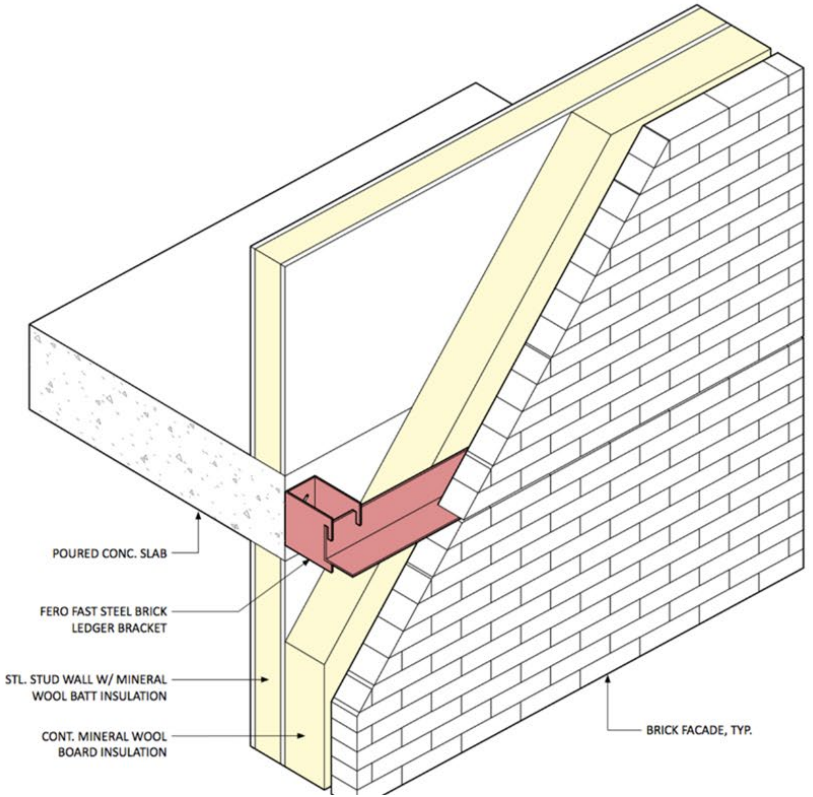


Cascadia Clip® system

Brick Shelf



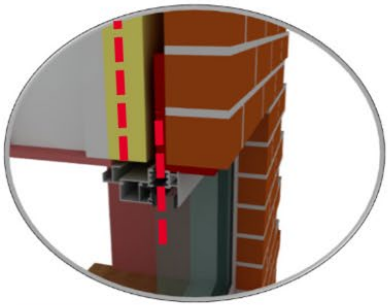
SOURCE: Ferro Fast



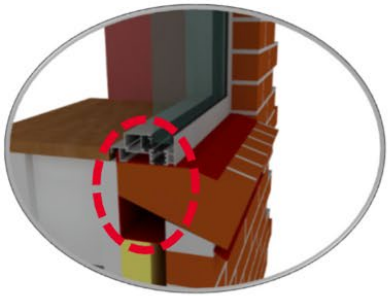
Window Installation

The Passive House Network

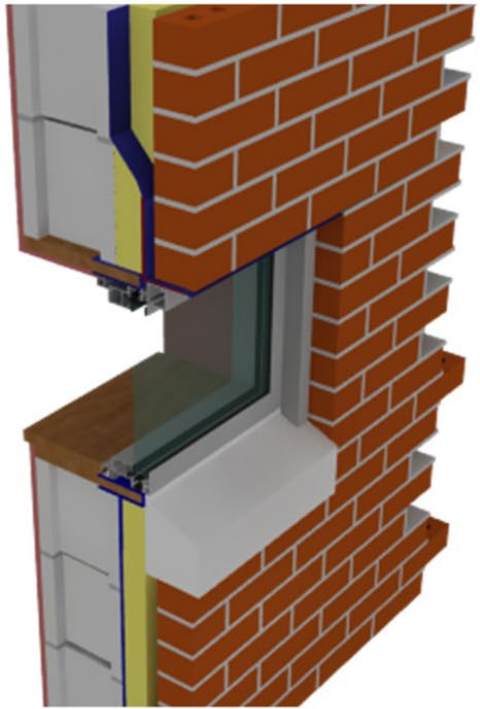
Typical Detail



0.068 BTU/hr.ft.ºF

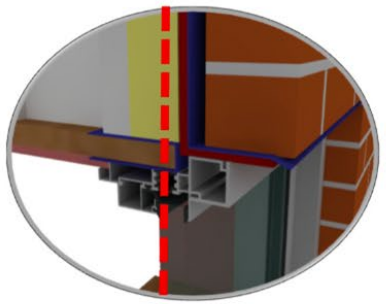


0.445 BTU/hr.ft.ºF

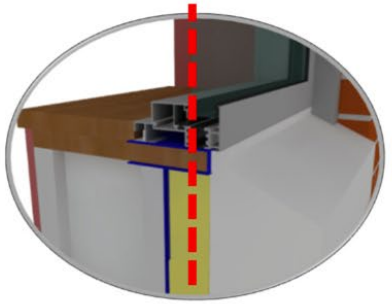


Note: Not Passive House insulation thickness

New Construction



0.042 BTU/hr.ft.ºF

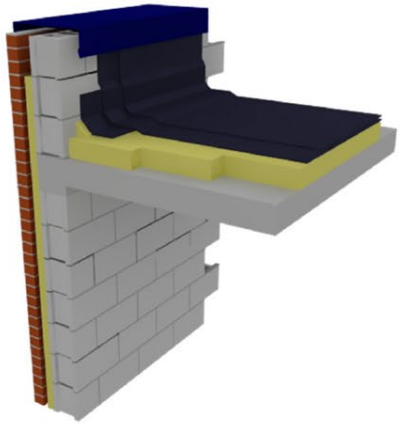


0.042 BTU/hr.ft.ºF

Parapet Improvement

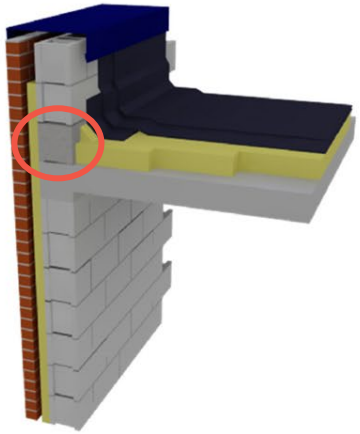
The Passive House Network

Typical detail – poor thermal bridge



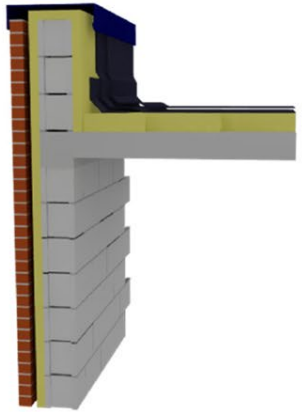
0.247 BTU/hr.ft.°F

Option 1: Insert thermal break



0.010 BTU/hr.ft.°F

Option 2: Wrap the parapet



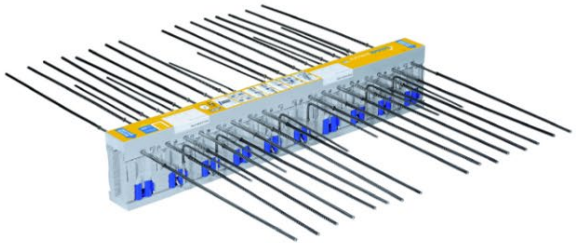
0.039 BTU/hr.ft.°F

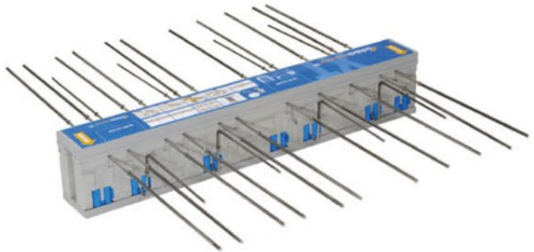
AAC Block

Autoclaved Aerated Concrete Block (AAC)

- Increased thermal insulation (roughly R-1)
- Structural thermal break material
- Lightweight, workable with hand tools
- Fireproof
- Less Portland cement
- Noise reduction
- Moisture regulation

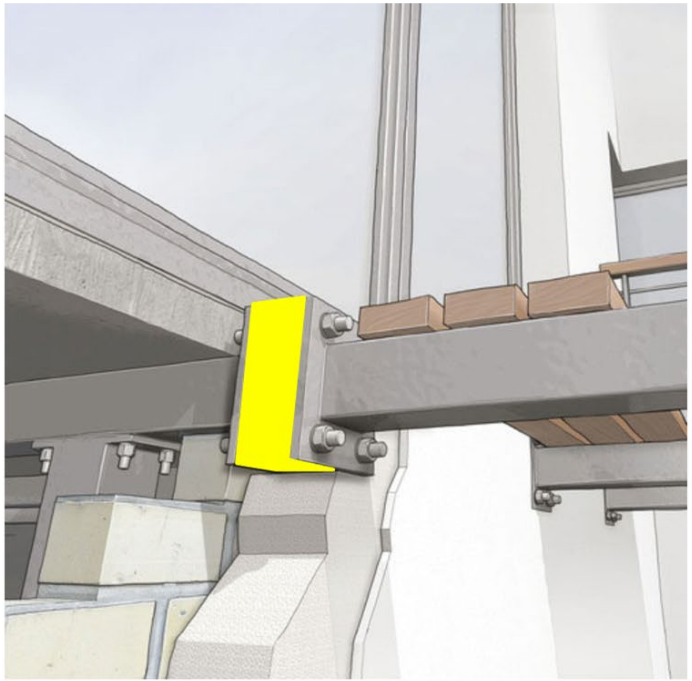
Balconies





Source: Contech Accessories and Schock

Structural Breaks

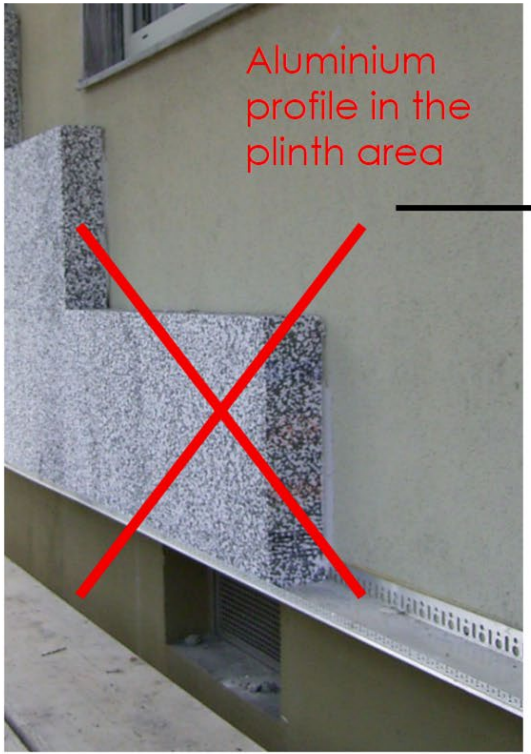


Steel to Steel Connections: Balcony Attachments (images courtesy of Contech Accessories and Shock)

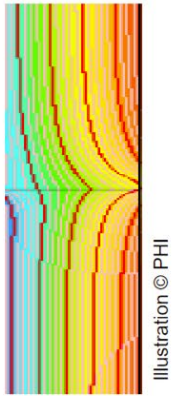
Thermal Bridge Free Eaves

The Passive House Network

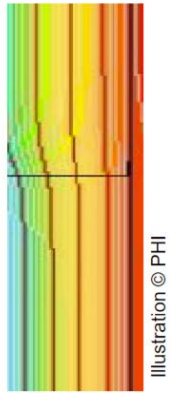
Don’t undermine insulation w/ metal parts



Higher heat losses



Plastic profile in the plinth area



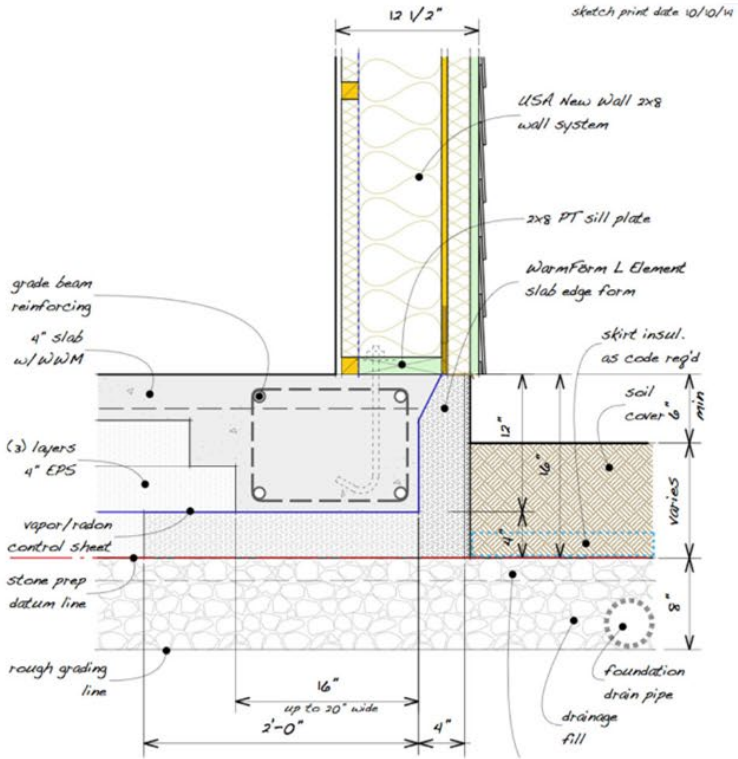
Hardly any heat losses

Aluminum starter track very commonly used

Creates a significant thermal bridge

Better to use a plastic version, or if using metal don’t run completely to the exterior.

Foundation Edge: Slab on Grade



Source: WarmForm

Thermal Break Materials: Armatherm

Airtightness

Principle #3

0.60 ACH 50: There will be a test!

The Passive House Network

- Care toward details and workmanship make the difference.
- Experienced teams can rely on a good result with final test.
- Teams new to passive house will want to plan for preliminary tests while air barrier remains exposed and repairable.
- Teams must recognize the air barrier, protect it, and report any damages.
- The building can never be too airtight.

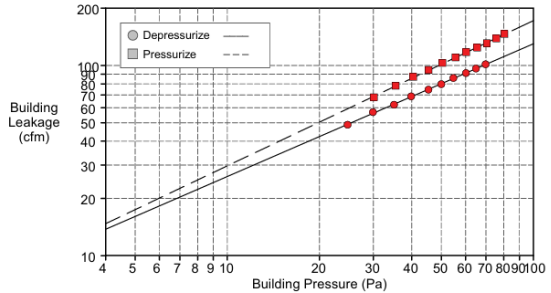
Date of Test: 1/11/2013 Test File: 15 Park Place Test
Technician: Nicholas Abreu Signature:
Project Number: 15 Park Place

Customer: Placetailor
67 Dudley Street
Roxbury, MA 02119
Phone: 617-639-0633
Fax:

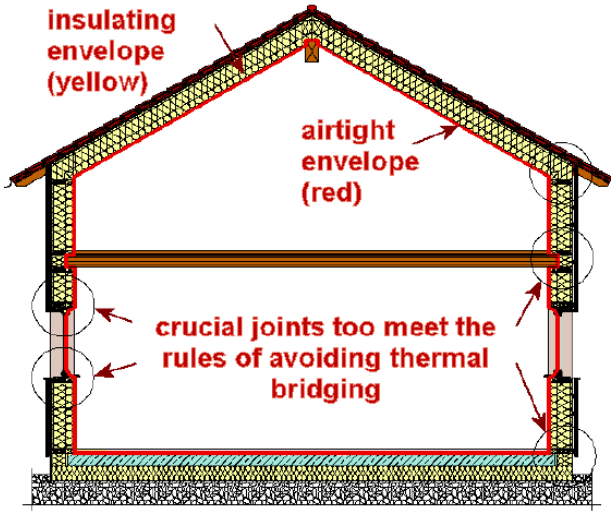
Building Address: 15 Park Place
Somerville, MA 02144

Test Results at 50 Pascals:	Depressurization	Pressurization	Average
cfm (Airflow)	80 (+/- 0.6 %)	101 (+/- 0.5 %)	91 (+/- 0.4 %)
ACH50	0.38	0.48	0.43
cfm/ft² (Floor Area)	0.0609	0.0770	0.0689
cfm/ft² (Surface Area)	0.0154	0.0194	0.0174
Leakage Areas:			
Canadian EqLA @ 10 Pa (in²)	7.7 (+/- 2.5 %)	8.7 (+/- 2.6 %)	8.2 (+/- 1.8 %)
in²/ft² Surface Area	0.0015	0.0017	0.0016
LBL ELA @ 4 Pa (in²)	3.9 (+/- 4.0 %)	4.2 (+/- 4.0 %)	4.0 (+/- 2.8 %)
in²/ft² Surface Area	0.0008	0.0008	0.0008
Building Leakage Curve:			
Flow Coefficient (C)	5.2 (+/- 6.2 %)	5.1 (+/- 6.1 %)	5.2 (+/- 4.3 %)
Exponent (n)	0.698 (+/- 0.016)	0.763 (+/- 0.015)	0.730 (+/- 0.011)
Correlation Coefficient	0.99959	0.99965	

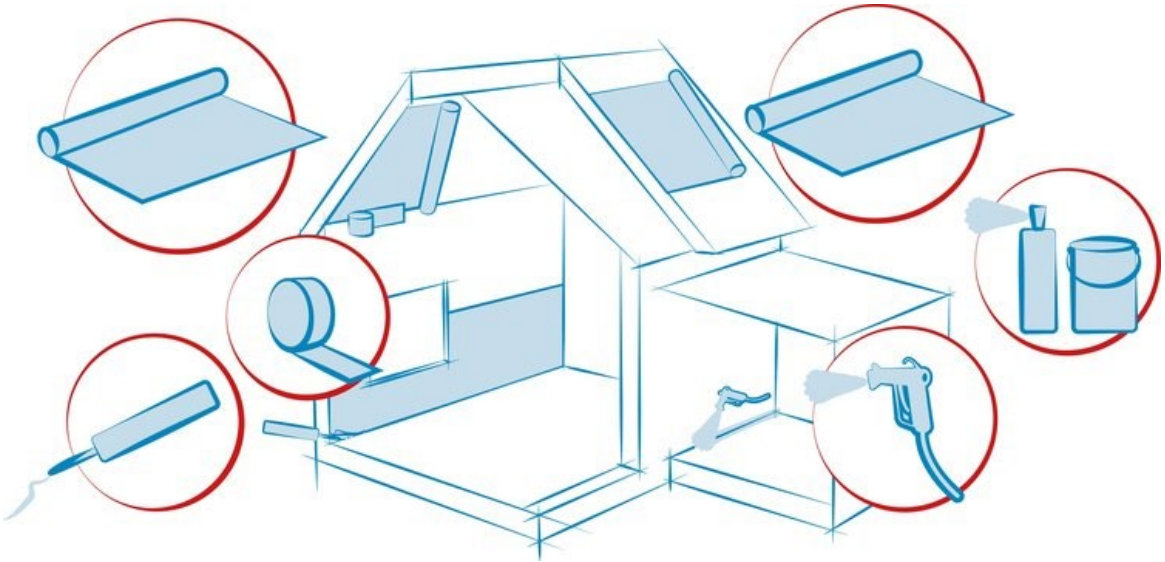
Test Standard: E779-10
Test Mode: Depressurization and Pressurization



Airtightness is a SYSTEM

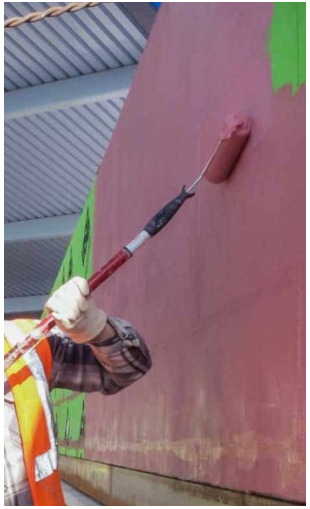


Ref http://passipedia.passiv.de/passipedia_en/



Membranes, tapes, caulks and sprays.

Air Barrier: Fluid Applied



Air Barrier Materials: Membranes

Inboard, Outboard / Reinforced, Self-Adhered / Vapor Control

Airtightness: Sheathing, Plaster and Concrete

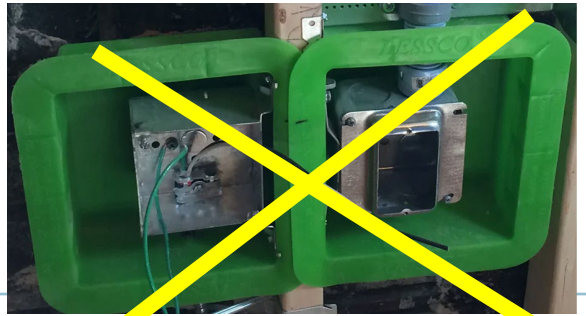
Air Barriers?

??????????????????

Don’t Use Sacrificial layers as air barrier.

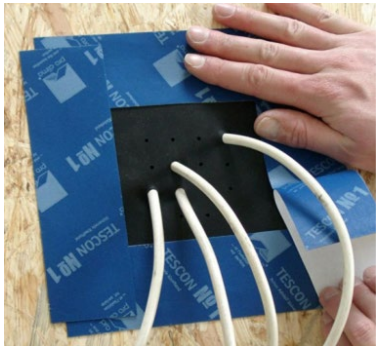
Protect Airtight Layer & Minimize Penetrations!

The Passive House Network

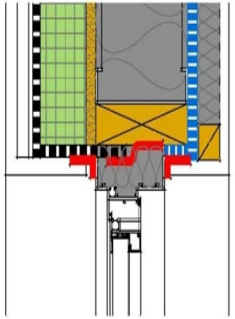


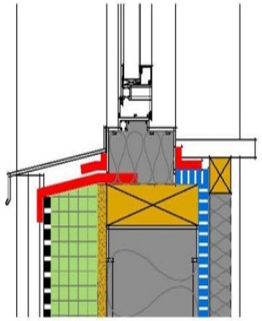
Ducts, Pipes, Wires: Flexible & Long Lasting

The Passive House Network



Connections: Use flexible materials/connections





Directions and Help

- Always consult and follow the manufacturer's data sheet and directions.
- Involve product reps as often as needed for assistance.

AIR & VAPOR BARRIER

FIRE RESIST **Barrithane VP**

Substrate Inspection

Concrete

Shall be cured in place 3 days minimum. It shall be smooth, with sharp protrusions such as cold joints ground flush. Honeycomb and holes/cracks shall be filled with grout or mortar.

Concrete Masonry Unit (CMU)

Mortar joints shall be struck flush or tooled and shall be free of voids. Mortar droppings shall be removed from brick ties and all other surfaces accepting Barrithane VP and CCW accessories.

Gypsum Sheathing

Sheathing boards shall be flush at joints, with gap between boards according to building code and sheathing manufacturer's requirements. Sheathing boards shall also be securely fastened to the structure with proper fastener type, technique and spacing according to building code and sheathing manufacturer's requirements. Sheathing boards shall be repaired or replaced if inspection reveals moisture damage, mechanical damage or if sheathing boards have exceeded the exposure duration or exposure conditions as required by the sheathing manufacturer.

OSB, Plywood, Lumber, Pressure-Treated Wood

Wood sheathing inspection carries the same protocol given for gypsum sheathing. Also, moisture content, measured with a wood moisture meter in the core of the substrate, shall be below 20%. Do not cover any wooden materials with Barrithane VP or CCW accessories if moisture content is 20% or above. Do not encapsulate wood (such as nailers) with membrane, as this will cause premature rot. In most cases fire-treated and pressure-treated wood must be kiln dried to accommodate the less than 20% moisture content requirement.

Installation

Before application, obtain full, safe access to the area and mask adjacent surfaces to protect from splashes or drips. Verify that the product is within shelf life, as indicated on the product label.

The following conditions shall be detailed in accordance with Barrithane VP standard details:

- Sheathing joints: cover with 2" width tooled ribbon of Barribond or cover with embedded 4" width strip of DCH Reinforcing Fabric
- Rough openings, pipe/duct penetrations, sheathing inside/outside corners shall be treated with one of these methods: 1) 705 FR-A/705 FR-A XLT strip; 2) Trowel application 40 mils wet thickness of Barribond or; 3) Single or multiple coats of Barrithane VP to build minimum 40 mils total wet thickness. If method 2 or 3 is used, fill all cracks and holes with Barribond and coat raw edges of gypsum sheathing with CCW contact adhesive.
- Expansion joints, control joints, termination at head/foot of wall, transitions of dissimilar materials: 705 FR-A/705 FR-A XLT strip bearing 3" onto each side of joint.

Prepare wall substrates accepting CCW self-adhered flashings with CCW-702, CCW-702 LV, CCW-702 WB, CAV-GRIP or Travel-Tack™ contact adhesive. Prepare cured Barrithane VP membrane accepting CCW self-adhered flashings with CAV-GRIP or Travel-Tack contact adhesive.

Corner treatments shall cover the transition and extend at least 3 inches on each side. Rough opening treatment shall extend 3 inches minimum onto the wall and shall return into the rough opening deep enough to provide continuous seal of the fenestration to the air barrier. Consult Barrithane VP details for more information. All terminating edges of CCW self-adhered flashing shall be covered with a 1" width tooled ribbon of Barribond.

Open pail and apply Barrithane VP using a paint roller or brush. Do glass

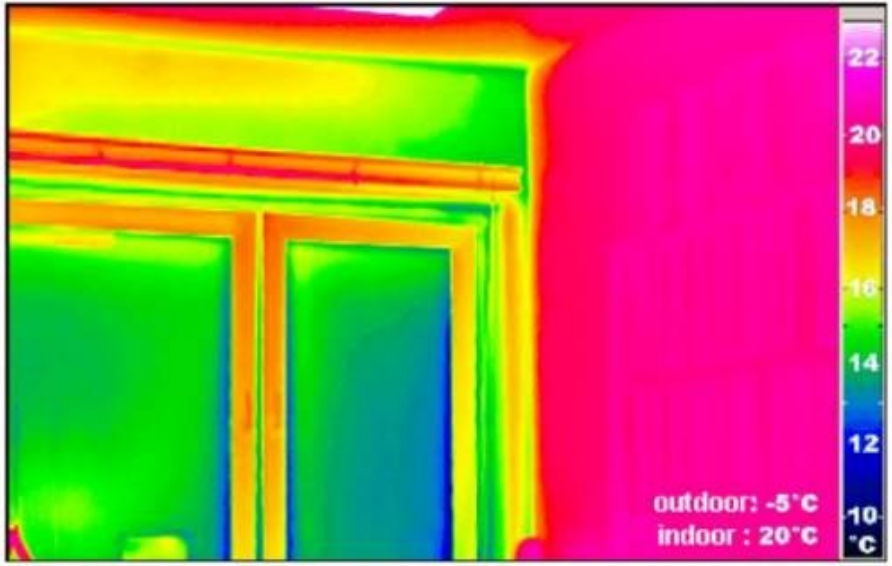
High Performance Windows & Doors

Principle #4

Extensions of Insulation & Airtightness

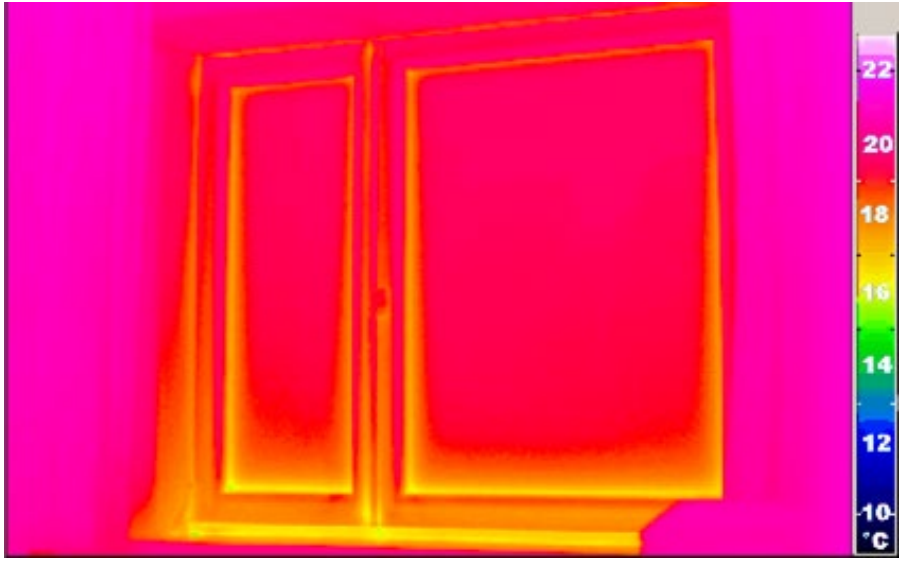
The Passive House Network

Typical Windows



°F
72
68
64
60
58
54
50

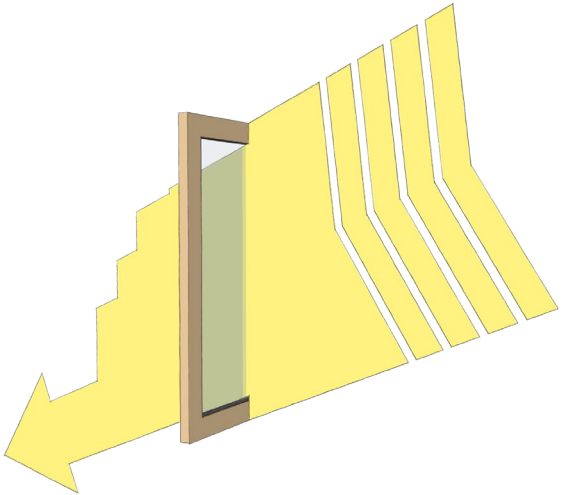
PH Windows



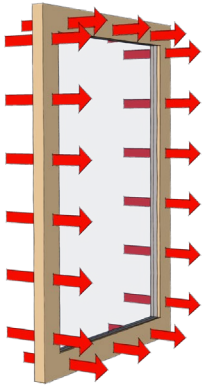
Interior 68 °F Exterior 23 °F

With high performance glass frames are the weakest part of the window assembly

PH Window Performance

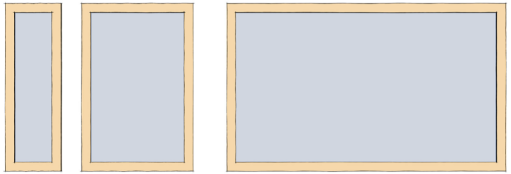


Solar Heat gain through the glass
SHGC



Heat Loss through the glass, frame, and spacer/installation thermal bridges **U-Value**

U_f: 0.11 Btu/(hr.ft².°F)
U_g: 0.08 Btu/(hr.ft².°F)



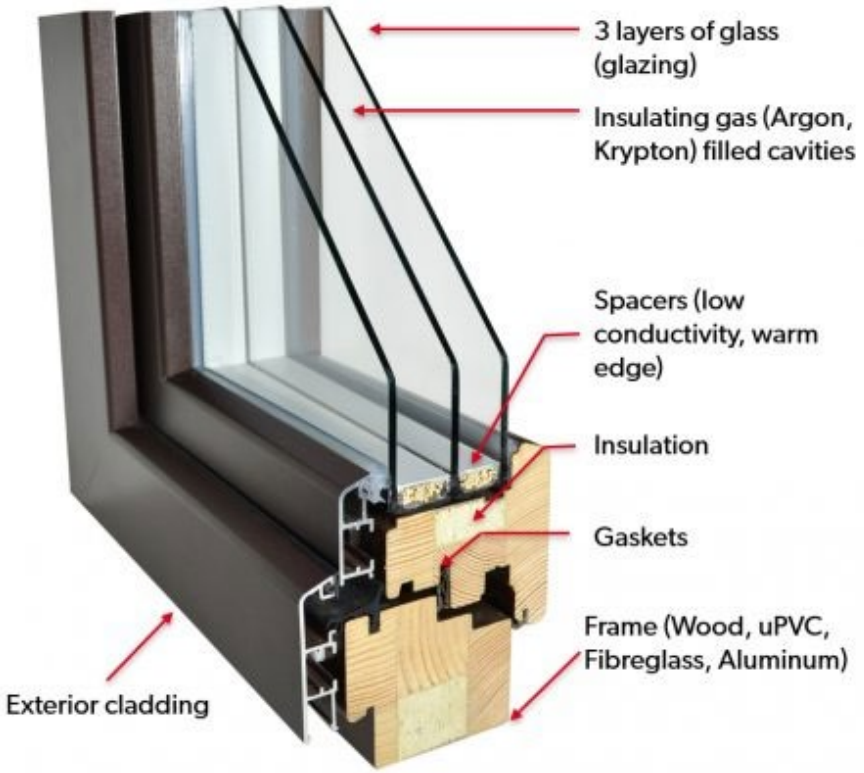
2' x 6' **U-0.145**

4' x 6' **U-0.118**

10' x 6' **U-0.110**

Less Frame = Better Performance

PH Windows



cool, temperate climate

phA

CERTIFIED COMPONENT

Passive House Institute

Certified Window Example Certificate

CERTIFICATE

Certified Passive House Component

Component ID 1270ws03 valid until 31st December 2024

Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

Category: Window system
Manufacturer: Wescon Cedar Products Ltd., Duncan, Canada
Product name: 106mm Wood-Alu Window

This certificate was awarded based on the following criteria for the cool, temperate climate zone

Comfort $U_W = 0.80$ W/(m² · K) ≤ 0.80 W/(m² · K)
$U_{W,installed}$ ≤ 0.85 W/(m² · K)
with U_g = 0.70 W/(m² · K)

Hygiene $f_{Rsi,0.25}$ ≥ 0.70
Airtightness Q_{100} = 0.22 ≤ 0.25 m³/(h · m)

cool, temperate climate
phB
CERTIFIED COMPONENT
Passive House Institute

Passive House efficiency class: phE | phD | phC | phB | phA

www.passivehouse.com

Wescon Cedar Products Ltd.
5120 Polkey Road, V9L 6W3 Duncan, Canada
☎ +1-250-748-5234 | ✉ braden@forsturwindows.com | 🖱 http://www.forsturwindows.com |

Calculation model | Isothermal

Description

Timber-aluminium frame with cork insulation (0,045 W/(mK)). The required temperature factor is not met at the threshold. The airtightness testing was undertaken for a window with two sidelights and toplight (3660mm x 2900mm), as well as for a balcony door (1200mm x 2430mm); the required air tightness standard is not met for the balcony door. Glazing 4/18/4/18/4; glass intersection: 16mm; spacer: Superspacer Premium; secondary seal: butyl.

Explanation

The window U-values were calculated for the test window size of 2.46m x 1.48m with (U_g = 0.70 W/(m² · K)). If a higher quality glazing is used, the window U-values will improve as follows:

Glazing	U_g =	0.70	0.64	0.58	0.52 W/(m² · K)
		↓	↓	↓	↓
Window	U_W =	0.80	0.75	0.71	0.66 W/(m² · K)

Transparent building components are classified into efficiency classes depending on the heat losses through the opaque part. The frame U-Values, frame widths, thermal bridges at the glazing edge, and the glazing edge lengths are included in these heat losses. A more detailed report of the calculations performed in the context of certification is available from the manufacturer.
The Passive House Institute has defined international component criteria for seven climate zones. In principle, components which have been certified for climate zones with higher requirements may also be used in climates with less stringent requirements. In a particular climate zone it may make sense to use a component of a higher thermal quality which has been certified for a climate zone with more stringent requirements.

Further information relating to certification can be found on www.passivehouse.com and passipedia.org.

Component-ID: 1270ws03 2/8
www.passivehouse.com

Frame values		Frame width b_f mm	U-value frame U_f W/(m² · K)	Ψ-glazing edge Ψ_g W/(m · K)	Temp. Factor $f_{Rsi,0.25}$ [-]
Mullion fixed	(MF)	84	0.87	0.019	0.74
Transom fixed	(TF)	84	0.87	0.019	0.74
Mullion 1 casement	(MC)	135	0.89	0.020	0.71
Transom 1 casement	(TC)	135	0.89	0.020	0.71
Bottom fixed	(FBo)	82	0.87	0.020	0.71
Top fixed	(FTo)	82	0.85	0.020	0.71
Lateral fixed	(FLa)	82	0.85	0.020	0.71
Flying Mullion	(FMu)	126	0.92	0.020	0.72
Bottom	(OBo)	102	0.89	0.020	0.71
Top	(OTo)	102	0.86	0.020	0.71
Lateral	(OLa)	102	0.86	0.020	0.71
Threshold	(OTh)	158	1.30	0.021	0.55

Spacer: Super Spacer Premium | Secondary seal: Butyl

Mullion fixed: b_f = 84 mm; U_f = 0.87 W/(m² · K); Ψ_g = 0.019 W/(m · K); f_{Rsi} = 0.74

Transom fixed: b_f = 84 mm; U_f = 0.87 W/(m² · K); Ψ_g = 0.019 W/(m · K); f_{Rsi} = 0.74

3/8 106mm Wood-Alu Window
www.passivehouse.com

Mullion 1 casement: b_f = 135 mm; U_f = 0.89 W/(m² · K); Ψ_g = 0.020 W/(m · K); f_{Rsi} = 0.71

Transom 1 casement: b_f = 135 mm; U_f = 0.89 W/(m² · K); Ψ_g = 0.020 W/(m · K); f_{Rsi} = 0.71

Bottom fixed: b_f = 82 mm; U_f = 0.87 W/(m² · K); Ψ_g = 0.020 W/(m · K); f_{Rsi} = 0.71

Top fixed: b_f = 82 mm; U_f = 0.85 W/(m² · K); Ψ_g = 0.020 W/(m · K); f_{Rsi} = 0.71

Lateral fixed: b_f = 82 mm; U_f = 0.85 W/(m² · K); Ψ_g = 0.020 W/(m · K); f_{Rsi} = 0.71

Component-ID: 1270ws03 4/8
www.passivehouse.com

Validated installations

Formwork blocks (fixed) U_{Wmat} = 0.15 W/(m² · K)

$\Psi_{install}$	W/(m · K)
Top	0.002
Left	0.002
Right	0.002
Bottom	0.016

$U_{W,installed}$ = 0.81 W/(m² · K)

Formwork blocks (operable) U_{Wmat} = 0.15 W/(m² · K)

$\Psi_{install}$	W/(m · K)
Top	0.003
Left	0.003
Right	0.003
Bottom	0.016

$U_{W,installed}$ = 0.81 W/(m² · K)

Lightweight timber (fixed glazed) U_{Wmat} = 0.13 W/(m² · K)

$\Psi_{install}$	W/(m · K)
Top	0.014
Left	0.014
Right	0.014
Bottom	0.029

$U_{W,installed}$ = 0.94 W/(m² · K)

Lightweight timber (operable) U_{Wmat} = 0.13 W/(m² · K)

$\Psi_{install}$	W/(m · K)
Top	0.015
Left	0.015
Right	0.015
Bottom	0.029

$U_{W,installed}$ = 0.84 W/(m² · K)

Exterior insulation and finishing system (EIFS) (fixed) U_{Wmat} = 0.13 W/(m² · K)

$\Psi_{install}$	W/(m · K)
Top	0.000
Left	0.000
Right	0.000
Bottom	0.013

$U_{W,installed}$ = 0.81 W/(m² · K)

Exterior insulation and finishing system (EIFS) U_{Wmat} = 0.13 W/(m² · K)

$\Psi_{install}$	W/(m · K)
Top	0.011
Left	0.011
Right	0.011
Bottom	0.032

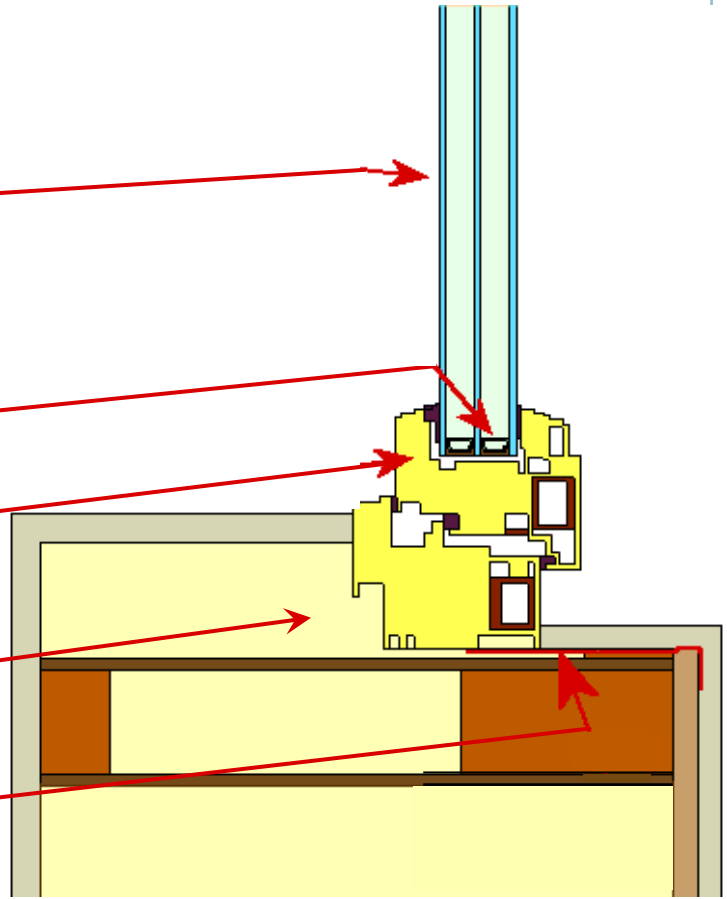
$U_{W,installed}$ = 0.83 W/(m² · K)

Component-ID: 1270ws03 6/8
www.passivehouse.com

https://database.passivehouse.com/en/components/list/group_4?

Window Components

1. Glass
   a. U-value
   b. Glazing Coatings
2. Spacer
3. Frame
4. Installation
5. Airtightness



Traditional vs Passive Windows

Traditional Double Hung

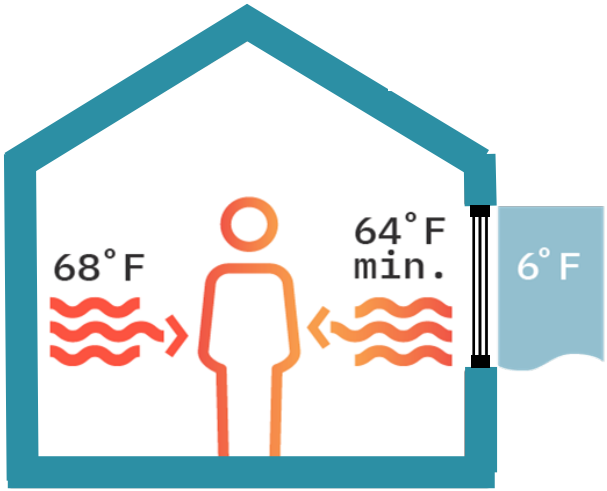
Tilt and Turn

PH Comfort and Hygiene Criteria

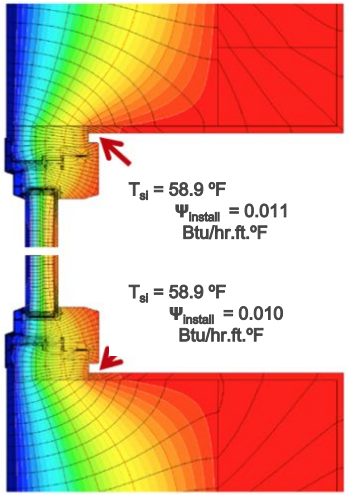
The Passive House Network

1. Comfort Criterion - The minimum average window surface temperature can be no lower than 3.5°C than the average interior surface temperature. Based on the installed U value of a window.

1. Hygiene Criterion - sets limits that restrict the minimum interior surface temperature at the coldest point of the interior surface per climate zone, eliminating the potential for condensation avoiding mold growth. Measured by climate specific temperature factors (f_{Rsi}).

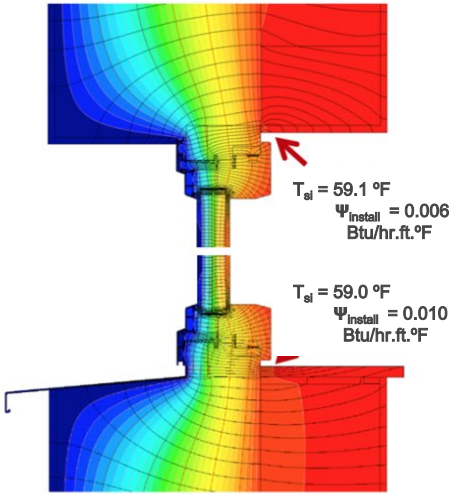


Install Conditions



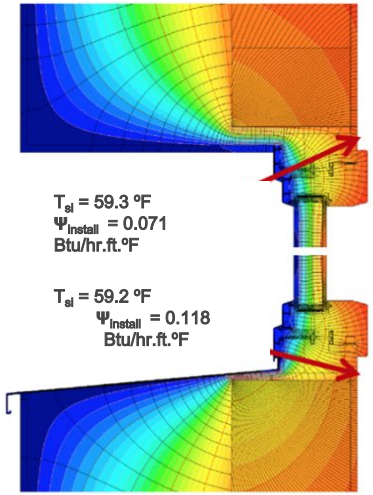
$U_{w\text{-installed}}$ = 0.151 Btu/hr.ft ^{2}.°F
($R_{w\text{-installed}}$ = 6.62 hr.ft ^{2}.°F/Btu)

Poor Installation



$U_{w\text{-installed}}$ = 0.148 Btu/hr.ft ^{2}.°F
($R_{w\text{-installed}}$ = 6.76 hr.ft ^{2}.°F/Btu)

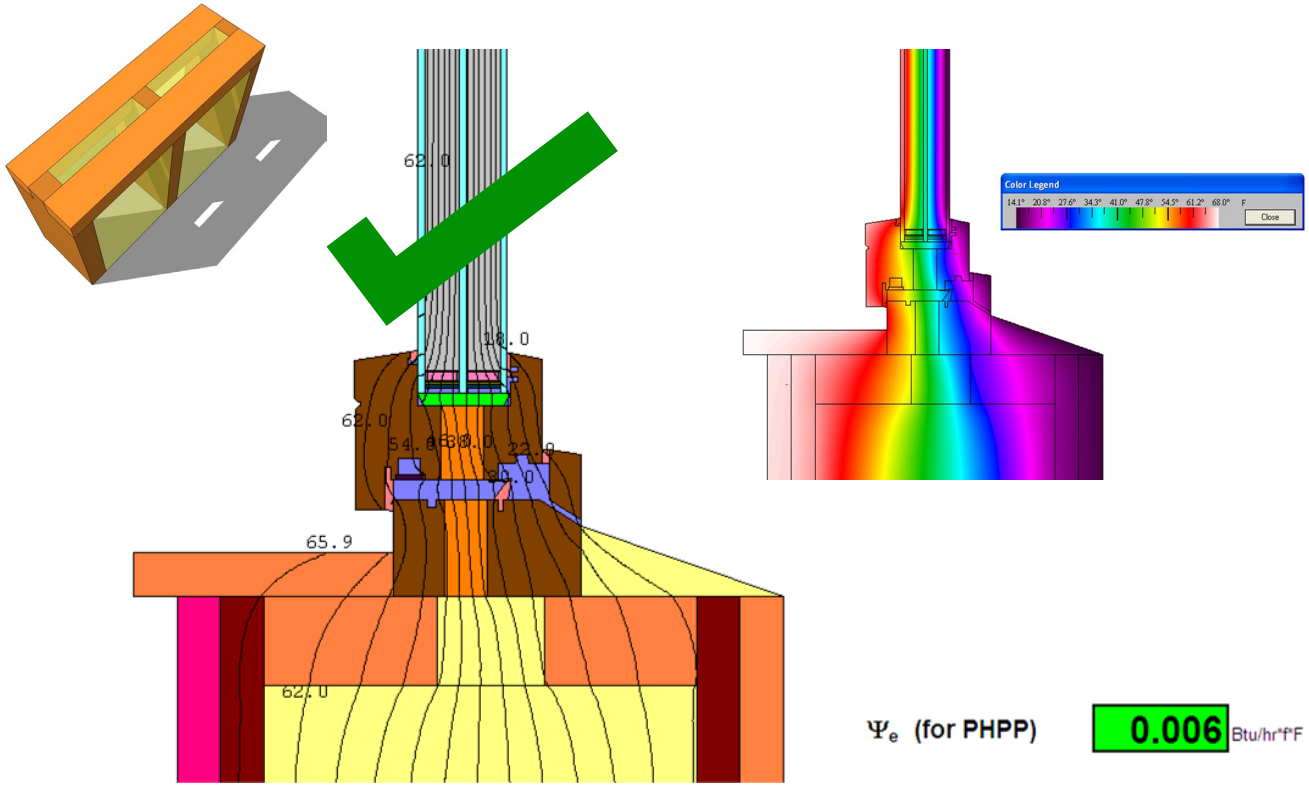
Recommended Installation



$U_{w\text{-installed}}$ = 0.215 Btu/hr.ft ^{2}.°F
($R_{w\text{-installed}}$ = 4.65 hr.ft ^{2}.°F/Btu)

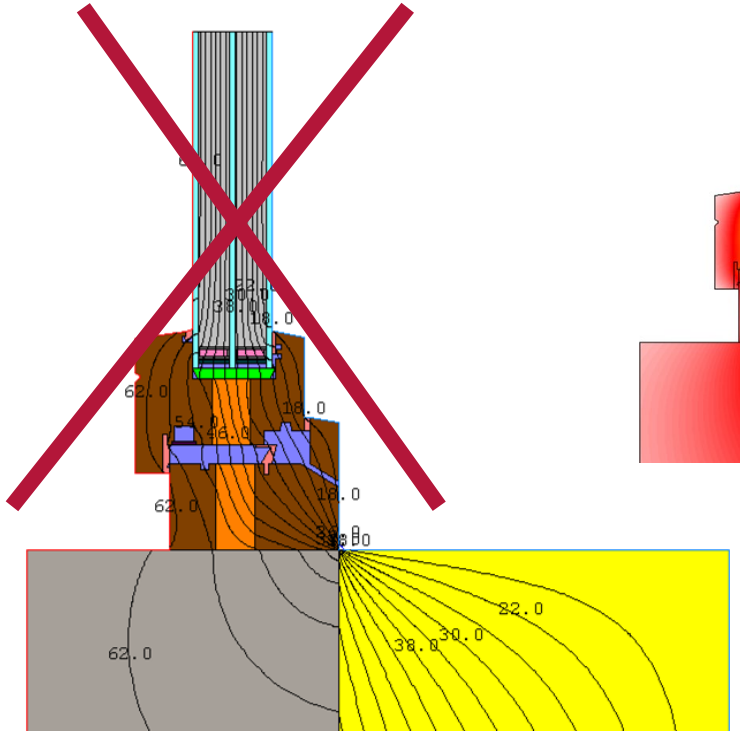
Poor Installation

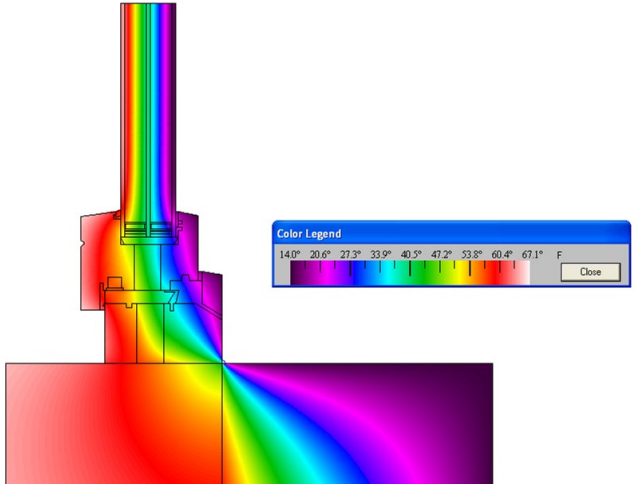
Double Stud Window Detail



Ψ_e (for PHPP) **0.006** Btu/hr*f*F

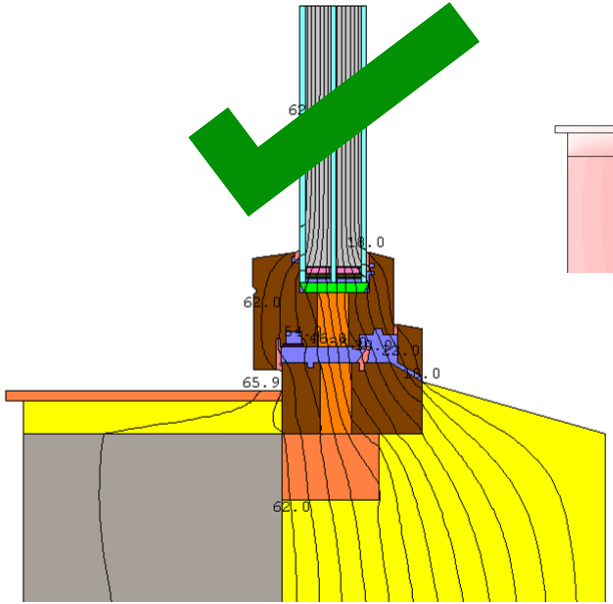
Window in Masonry Layer

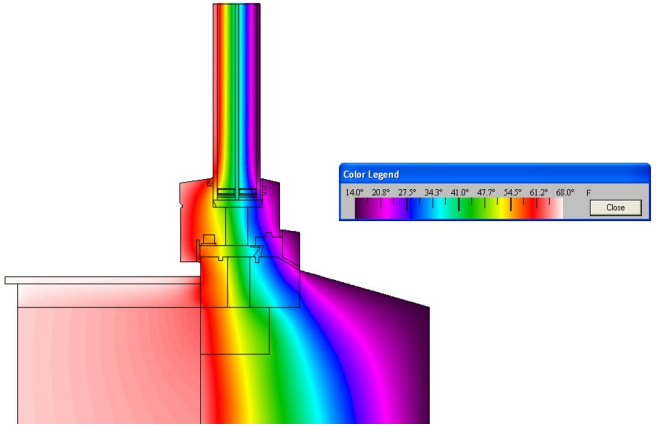




Ψ_e (for PHPP) **0.108** Btu/hr*f*F

Window External to Masonry Layer





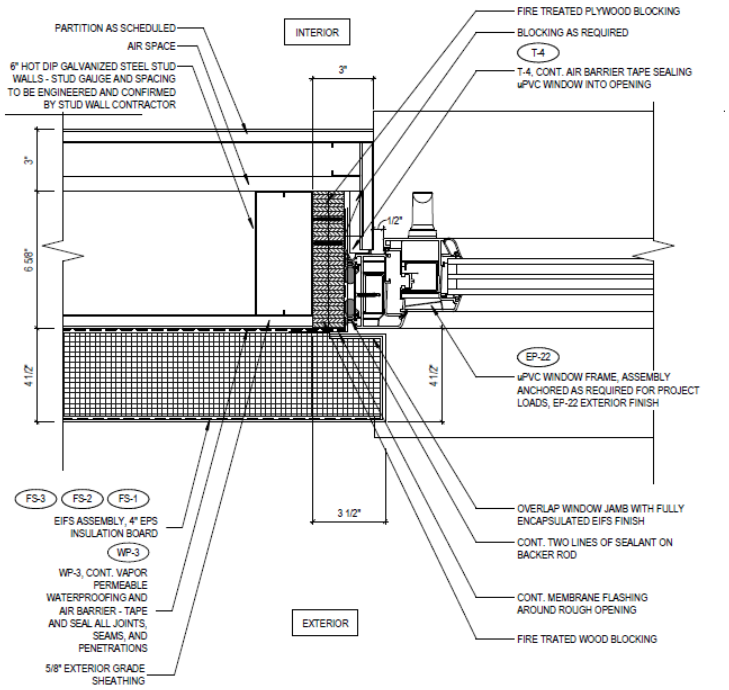
Ψ_e (for PHPP) **0.006** Btu/hr*f*F

Window Placed Outboard in Insulation Layer

Attachment with metal brackets (to be covered with insulation later)

Dense insulation blocking such as 'Compact' foam used to support the weight of the window whilst fixing into place

Window Install – Steel Stud



B-N, WT-2, uPVC WINDOW JAMB DETAIL, OPERABLE 10

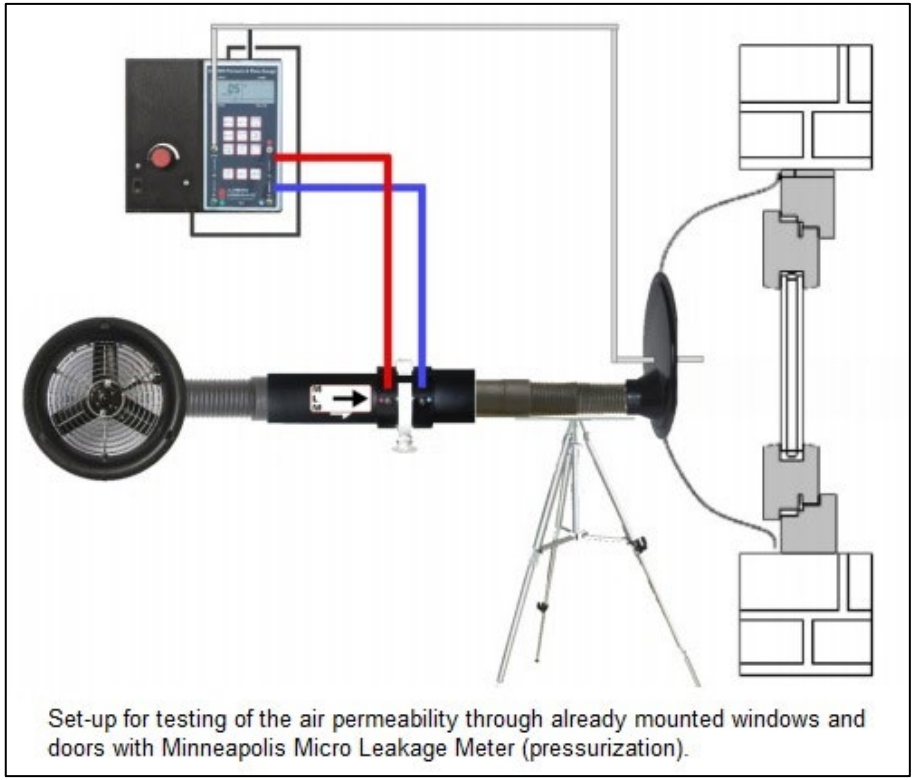
3" = 1'-0"

Pre taping for tight conditions.

Window Air Sealing Example

No Metal Sill Pans!

Window Install Testing: Sometimes Necessary



Set-up for testing of the air permeability through already mounted windows and doors with Minneapolis Micro Leakage Meter (pressurization).

Ventilation

Principle #5

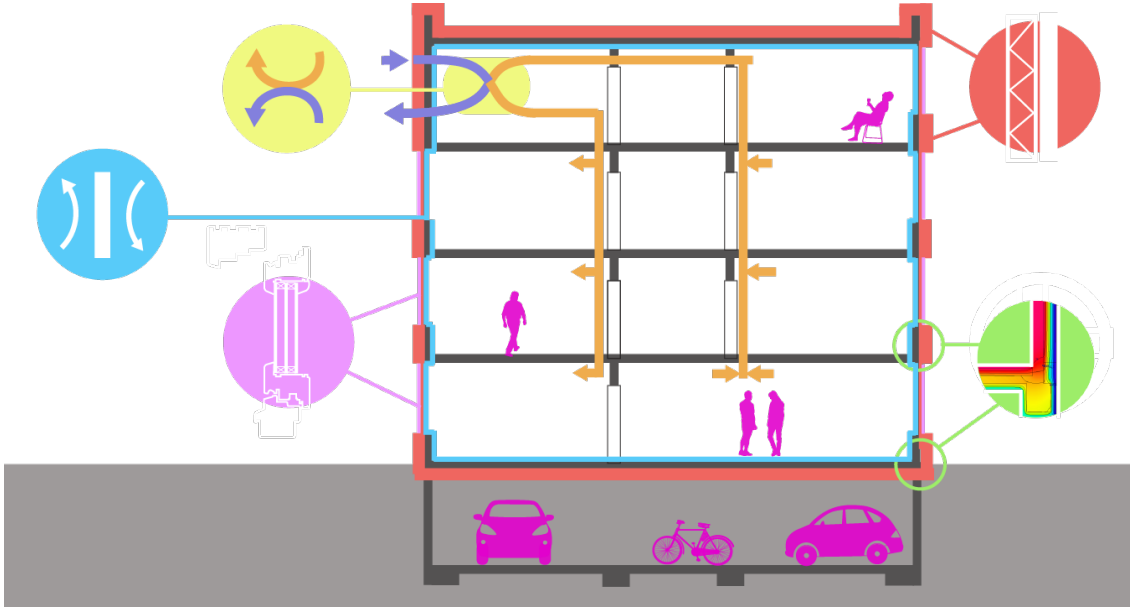
Passive House Ventilation

The Passive House Network

5.

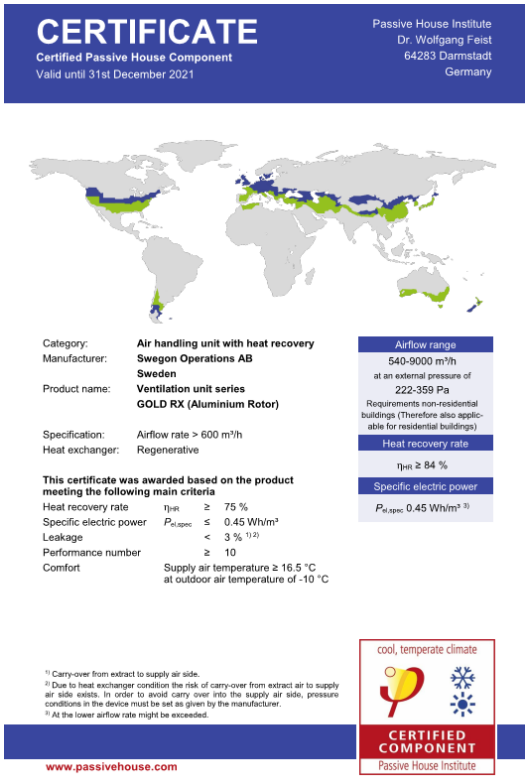
High Efficiency
Heat Recovery
Ventilation

- Good air quality
- Continuous Operation
- Balanced ventilation
- Heat/Energy recovery



PH Ventilation Design Criteria

- Energy recovery > 75%
- Fan power efficiency < 0.765 W/CFM.
- Supply > 62 °F on winter design day.
- Supply air to all served spaces: living rooms, bedrooms, offices, classrooms etc…
- Exhaust from all services spaces: kitchens, bathrooms, utility rooms etc...
- Overall supply and exhaust must be balanced to be with within 10% of each other.



CERTIFICATE

Certified Passive House Component

Valid until 31st December 2021

Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

Category: **Air handling unit with heat recovery**
Manufacturer: **Swegon Operations AB**
Sweden
Product name: **Ventilation unit series**
GOLD RX (Aluminium Rotor)

Specification: Airflow rate > 600 m³/h
Heat exchanger: Regenerative

This certificate was awarded based on the product meeting the following main criteria

Heat recovery rate	η_{HR}	≥	75 %
Specific electric power	$P_{el,spec}$	≤	0.45 Wh/m³
Leakage		<	3 % [1) 2)]
Performance number		≥	10
Comfort	Supply air temperature ≥ 16.5 °C at outdoor air temperature of -10 °C		

Airflow range
540-9000 m³/h
at an external pressure of
222-359 Pa
Requirements non-residential buildings (Therefore also applicable for residential buildings)

Heat recovery rate
η_{HR} ≥ 84 %

Specific electric power
$P_{el,spec}$ 0.45 Wh/m³ [3)]

1) Carry-over from extract to supply air side.
2) Due to heat exchanger condition the risk of carry-over from extract air to supply air side exists. In order to avoid carry over into the supply air side, pressure conditions in the device must be set as given by the manufacturer.
3) At the lower airflow rate might be exceeded.

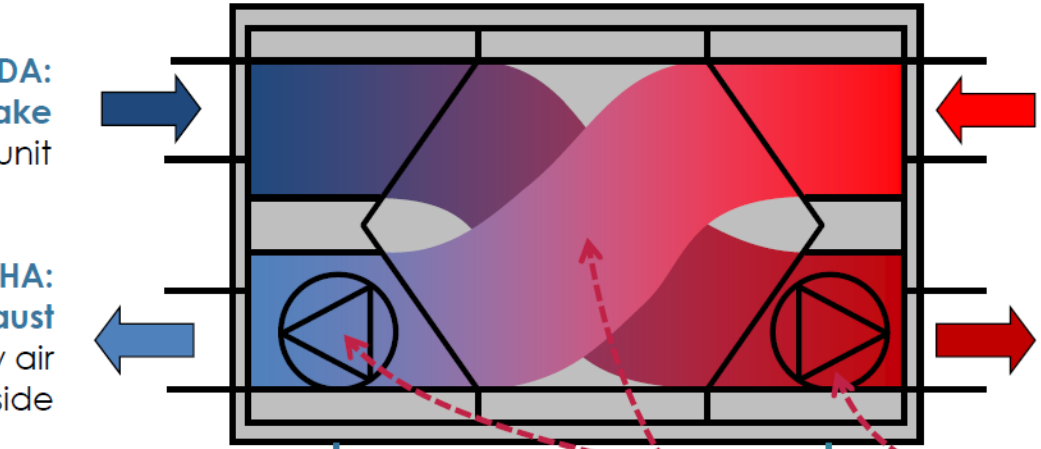
cool, temperate climate

CERTIFIED COMPONENT
Passive House Institute

www.passivehouse.com

Heat Recovery Ventilation Unit

The Passive House Network



ODA:
Outdoor air intake
fresh air into unit

EHA:
Exhaust
post-recovery air
to outside

EXT:
Extract air
stale air from
baths/kitchens/stores

SUP:
Supply air
fresh air into living rooms,
offices, classrooms

Fans

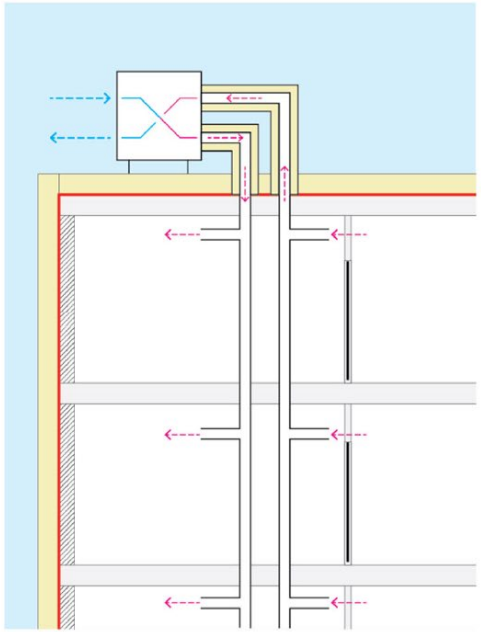
Heat/energy
recovery core

Balanced Ventilation

The Passive House Network

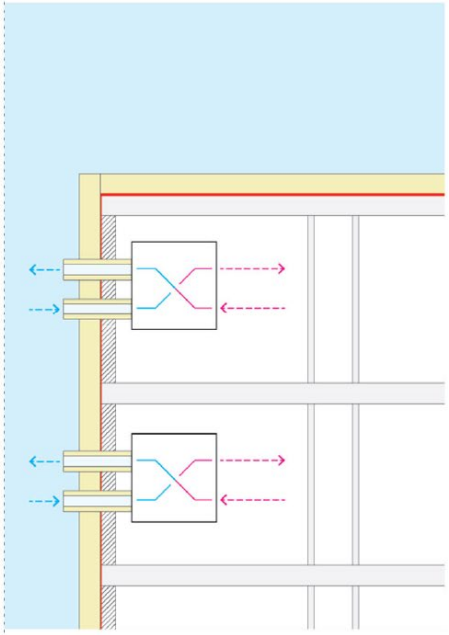
Centralized:

One main ventilator unit for the entire building



Decentralized:

Multiple ventilators distributed throughout the building

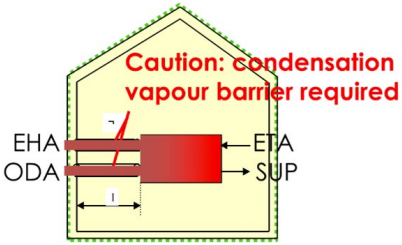


ERV/HRV – Single Unit

Source: Zehnder, Renewaire

PH Ventilation Systems Considerations

- Duct insulation for intake and exhaust ducts with vapor -tight seal.
- Sound level – ventilation system must not be noisy.
  - ⩽ 25 db(A): supply air to rooms
  - ≤30 db(A): rooms in non-residential buildings and exhaust air rooms in residential buildings
- Filtration for both supply and exhaust air.
  - MERV 13-14 to filter incoming air pollutants
  - MERV 6 to filter Extract return (only needed to protect heat exchange core)



Intake and exhaust duct insulation

Merv 13 filter sample

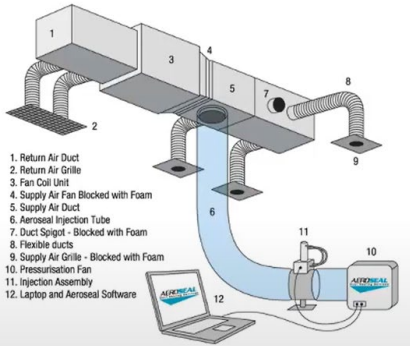
Source: Zehnder

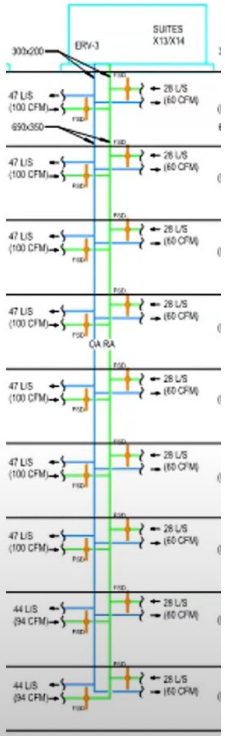
Duct Sealing & Testing for Large Buildings

The Passive House Network

- Ductwork needs to be airtight!
  - mastic duct sealant
  - mastic tape
  - preformed and insulated duct layouts
- Recommend to perform duct leakage testing to ensure system is well sealed.
- Balanced air flows is critical.
  - One strategy is to use Constant Airflow Regulators (CARs)

- Long ductwork requires careful planning
- Ensure CxA knows what the protocol is for measuring outlets – all outlets must be turned on, not just the suite being measured





- Proper duct sealing will only get you so far, a good design is always important!

Ventilation Balancing & Report

The Passive House Network

© Acin

Zero pressure compensating flow measuring instruments are the most accurate

Vane anemometers typically allow measurement of volumetric flow rate, air flow speed and temperature

Training for commissioning agents is vital for accurate results

FINAL PROTOCOL WORKSHEET for Ventilation Systems: Initial Start-up
Supply- / Extract-Air Ventilation System with Heat Recovery

Project	
Object:	End-terrace house
Location Street, No.:	Passive street 123
Location Postcode, Town:	12345 Passive City
Building Owner Name:	John Doe
Building Owner Phone No.:	0
Year of Construction:	2017

Initial Start-up	
Company:	Passive House Ventilation
Person in Charge:	John Smith
Street, No.:	Passive street 12
Postcode, City:	12345 Passive City
Phone No.:	00000
Date:	07 / 01 / 2017

Ventilation System	
Manufacturer:	Passive House Ventilation
Product Name:	Passive House unit
Unit No.:	00000
Control No.:	00000

1. Record of the air flow volumes, supply and extract air

Nr.	Room	Design			Measurement 1		Measurement 2		Measurement 3		Type of Valve	Adjustment	Flow-Through	Noise	Filter Grade	Filter Clean?
		V_{SU}	V_{EX}	$V_{THROUGH}$	V_{SU}	V_{EX}	V_{SU}	V_{EX}	V_{SU}	V_{EX}			$V_{THROUGH}$			
		m³/h	m³/h	m³/h	m³/h	m³/h	m³/h	m³/h	m³/h	m³/h			m/s	dB(A)		
1	Hobby room	35			45.1		30		37		Jet nozzle		0.6	20	F7	yes
2	Storage room		20			36		26		21	Poppet Exhaust Air		0.8	22	G4	yes
3	Technical space		20			41.2		18		20.3	Poppet Exhaust Air		0.7	22	G4	yes
4	Office	20			31.6		19.6		19.6		Jet nozzle		0.6	20	F7	yes
5	Living / kitchen	60	60		62.4	45.2	57.4	65.3	59.5	61.2	Jet nozzle/poppet exhaust air		1.0	20	F7/G4	yes
6	Master bathroom		40			12.7		34.2		41	Poppet Exhaust Air		0.6	22	G4	yes
7	Bedroom 2	20			21.9		26		20.7		Jet nozzle		0.6	20	F7	yes
8	Bedroom 3	20			28		26.9		19.1		Jet nozzle		0.6	20	F7	yes
9	Master bedroom	25			20.6		26.1		26.1		Jet nozzle		0.7	20	F7	yes
10	Bathroom		20			40.1		22.1		19.9	Poppet Exhaust Air		0.6	22	G4	yes
11	WC		20			43.6		23		19.6	Poppet Exhaust Air		0.7	22	G4	yes
12																yes / no
13																yes / no
14																yes / no
15																yes / no
	sum:	180.00	180.00	---	209.60	218.80	186.00	188.60	182.00	183.00			---	---	---	---

2. Balance of airflow volume

		Measurement 1		Measurement 2		Measurement 3		Disbalance	Type of Control	Adjustment	Noise	Filter Grade	Filter Clean?
		V_{AUL}	V_{FOL}	V_{AUL}	V_{FOL}	V_{AUL}	V_{FOL}				Measurement		
		m³/h	m³/h	m³/h	m³/h	m³/h	m³/h				dB(A)		
1	fresh air inlet	210	---	186	---	182	---	18	BUS		30	F7	yes
2	exhaust air outlet	---	219	---	189	---	183		BUS		30	G4	yes

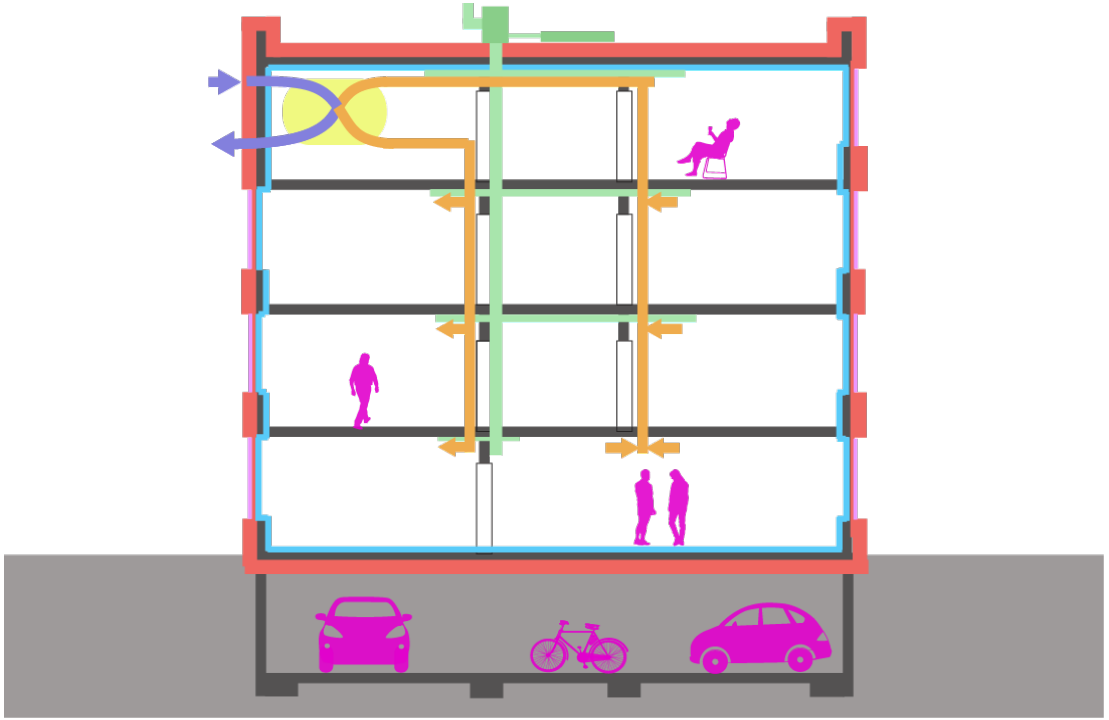
3. Initial start-up accomplished according to manufacturer's specifications: yes

Signature: Signature

Heating & Cooling Systems

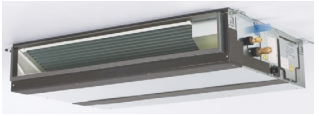
Right Size Heating & Cooling Systems

- Often up to 75% reduction in equip sizing.
- Practically any kind of heating and cooling system can be used in a Passive House.
- Critical is efficient design with relatively compact distribution and right sizing of equipment.
- Typically heat pump technology capable of providing heating and cooling.
- Typically runs separately from, and independently of, ventilation air.



Air Source Heat Pumps

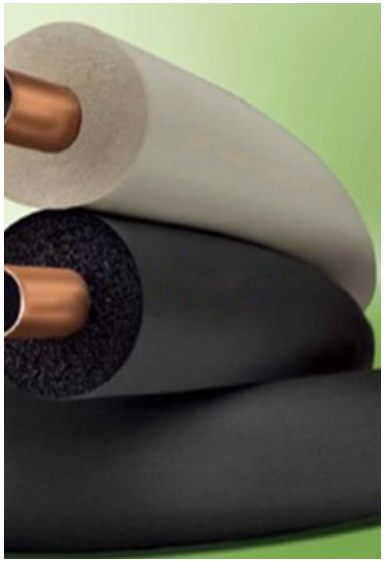
- Mini-Split
  - Split and mini (<1.5 tons or so)
  - Ducted (compact) or ductless
  - Usually 1:1
- Multi-Split (multi-port, multi-zone)
  - One outdoor unit, 2+ indoor units
  - Ducted, ductless, or mix
  - 1.5 to 4 tons typically
- VRF (variable refrigerant flow)
  - Numerous modular outdoor units, 6-12 tons typical
  - Many indoor units, many types



Duct and Refrigerant Piping & Insulation

- Insulate all air conditioning ducts.
- Insulate all refrigerant lines.

Source: Armaflex



DHW

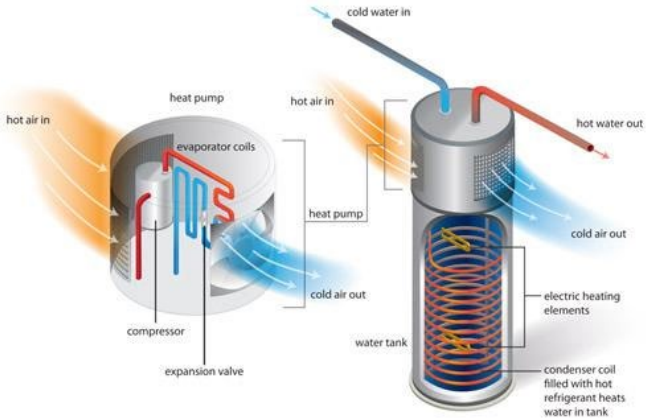
DHW and Energy Use

- **Reducing the use of hot water** is largely dependent on occupants, but an efficient water heater and distribution system can still make a big difference on the total energy used by **reducing unnecessary losses** .

- **Overall strategy:**
  - Minimize demand using low -flow devices
  - Use small-diameter pipes
  - Use the shortest possible pipe lengths
  - Minimize losses through insulation
  - Optional - use heat recovery from wastewater
  - Optional - generate hot water on -site from solar collector

Decentralized Hot Water

- Common options include
  - Conventional storage water heaters (gas, electric)
  - Tankless or on-demand water heaters (gas, electric)
  - Solar water heaters
  - Tankless coil / indirect water heaters
  - Heat pump water heaters

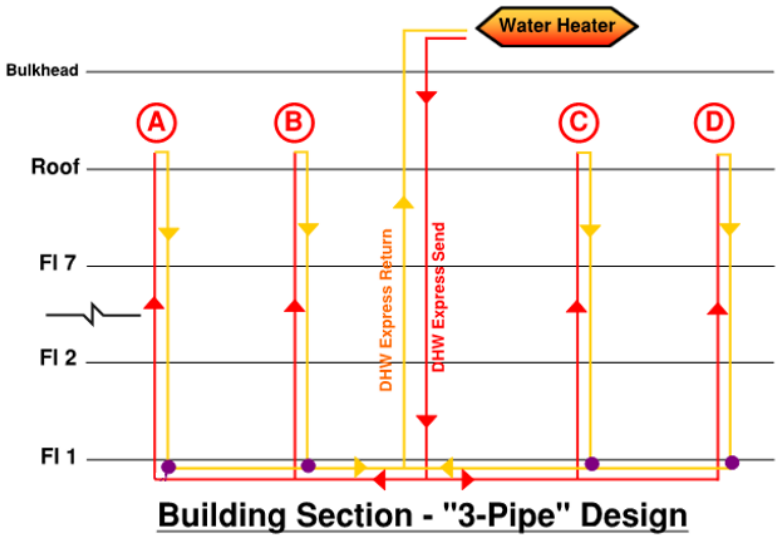


Combined Heat Pump System

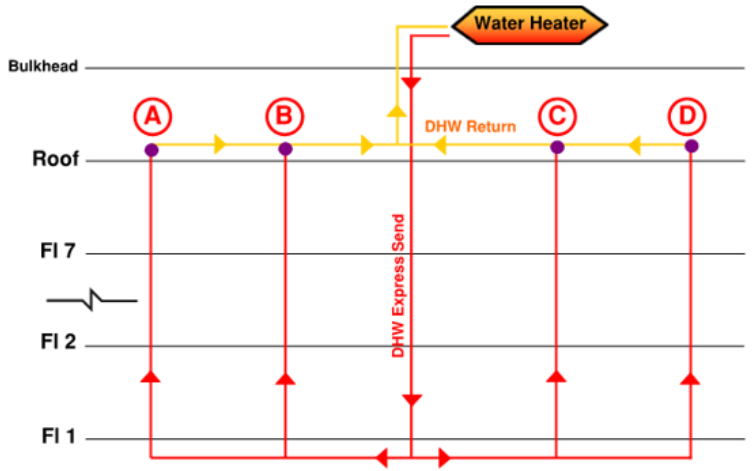
Source: Energy Star, SANCO2

Split Heat Pump System

Minimize Pipe Runs in Design & Installation



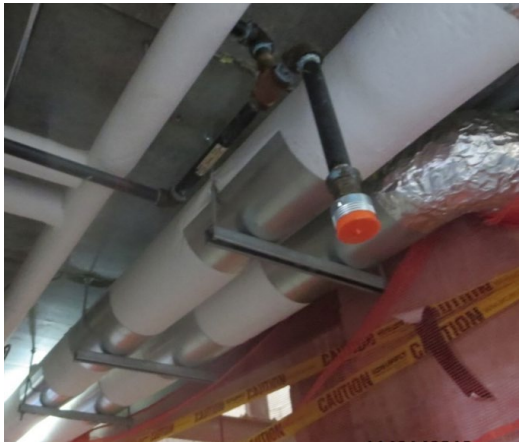
Building Section - "3-Pipe" Design



Building Section - "Box" Design

DHW Pipe Insulation

- Insulation thicknesses to align with PHPP assumptions and local energy code requirements.
- Insulation to be continuous at all hanger locations.
- Runout piping to be fully insulated to the greatest extent possible.



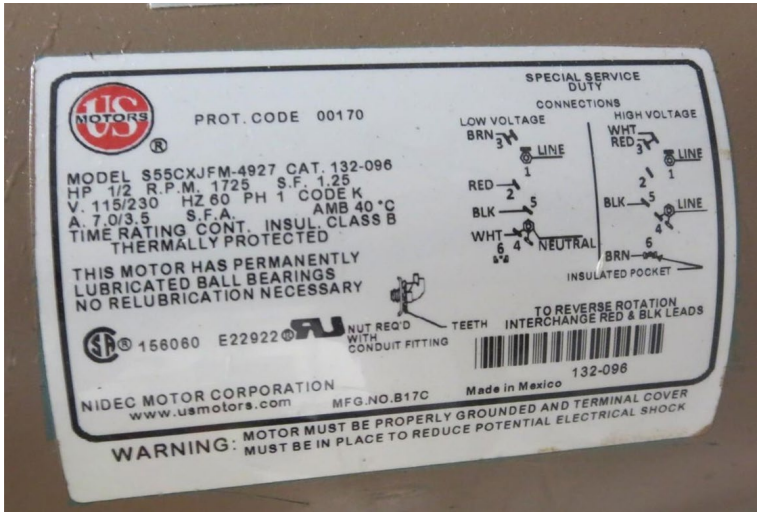
Pipe Insulation

- Pipes to be insulated include:
  - **Domestic hot water:** typically 1” insulation for smaller pipes, 1.5” insulation for larger pipes.
  - **Domestic cold water (best practice):** typically 1” all locations.
  - **Refrigerant lines (covered in the mechanical section):** typically 1” insulation for smaller pipes, 1.5” insulation for larger pipes.

Source: Johns Manville

DHW – Recirculation Pumps

- Ensure DHW pump sizes align with PHPP assumptions.
- Some systems may utilize a demand recirculation system that turns off the recirc pump during periods of low DHW use.



QA/QC

Assemble the team to deliver a Passive House

The Passive House Network

- Architects
- Engineers
- Consultants
- Passive House Consultant
- Verifier
- Inspectors
- Ventilation Commissioning
- Blower door testers
- Builder & Trades

+

Owner, Owner's Rep and Certifier

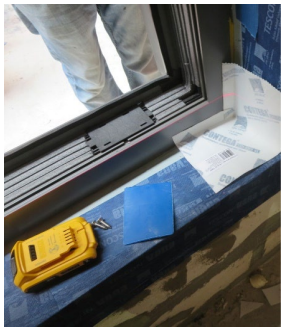
What a team needs:

1. common language
2. common goal: Passive House
3. good attitudes
4. enough training
5. willingness to work as a team and connect the dots.

Mock-Ups: Visual & Testing

- Mock-ups can vary in terms of extensiveness.

A simple mock-up could be the first window installed on the project.



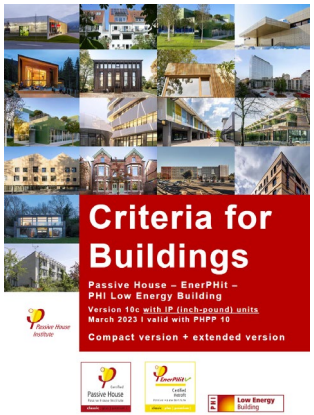
An extensive mock-up could be a full six-sided box with various details reflected.

Construction Schedule: Passive House line items…

The Passive House Network

Design Stage Open Items												
Close out unresolved items												
Submittals												
Verification Plan												
Product Specs												
Training & Mockups												
Envelope Connections												
Window Installation												
Inspections												
Representative Photos												
Ventilation												
Duct Leakage Testing												
Ventilation Commissioning												
Airtighness Testing												
Connections Mockup												
FInal Whole Building Blower door test												
As-Built Updates												
PHPP, Construction Drawings, Details, schedules and descriptions												
Photo "catalog"												
Builder Assurance Certificate												

Submittals for Certification



Photographs

3.2.11 Photographs

Back to compact version: ▶3.2.11

Criteria

Evidence of the progress of construction must be supported with photographs, but it is not necessary to provide complete photographic documentation of all measures.

Additional requirements

The construction progress must be documented with illustrative photographs. However, full photo-graphic documentation of all measures is not necessary. Photos should be taken preferably at a time when the installation situation is not yet covered by cladding etc. Typically, photographs of the following areas should be taken:

- Thermal insulation of the building envelope (preferably with a measuring ruler in the picture to show the insulation thickness)
  - floor slab or basement ceiling
  - perimeter area
  - wall insulation
  - roof insulation
- Product data labels of
  - windows frames and glazing
  - heating and cooling units
  - ventilation unit
- Insulation and attachments of the air ducts
- Insulation and attachment of heating, hot water and cooling pipes and fittings
- Other energy-relevant construction details, e.g. thermal bridges

Sample photographs

A checklist of the pictures of the building site to be submitted for certification can be downloaded at: www.passipedia.org
→ Passive House Certification → Building Certification
→ Examples of documents that need to be submitted for certification

Building Site Photos for the Passive House Certification

Please make sure that the photos can be assigned correctly.

		Comment
Foundation		
Photos of delivered insulation packages	Product name, thermal conductivity, thickness	
Photos of the installation	Insulation of the foundation area / basement (e.g. under the floor slab, perimeter insulation)	
	Joint between floor slab / basement ceiling to walls and pillars (e.g. thermal break, flank insulation)	
External walls		
Photos of delivered insulation packages	Product name, thermal conductivity, thickness	
Photos of the installation		
Thermal bridges		
Photos of thermal bridges	Balcony railings, canopies, fixed ladders, fall protection etc.	
	All places where the insulation is penetrated or weakened	
Windows		
Photos of delivered windows + doors	Technical data on glazing (glass thickness, spacers, filling gas)	
	Technical data on frame (description), photo of frame	
Photos of the installation: windows	lateral, top, bottom, different installation types	
	Fixing sun protection, fall protection	
Photos of the installation: doors	lateral, top, bottom, different installation types	
Roofs		
Photos of delivered insulation packages	Product name, thermal conductivity, thickness	
Photos of the installation		
Building Service		
Photos of specification plate	all devices (e.g. pumps, ventilation unit, heater, cooling system, elevator)	
Photos ventilation unit	Location, silencer, duct insulation (thickness)	
Photos of sanitary pipes	Insulation of hot water / solar / heating pipes, storage and insulation of down waste water pipes (thickness)	
Project Specific Details depending on the project additional photos may be necessary		

Photographs of the construction process demonstrating that:
a) the specified products have been installed
b) correct installation practices have been followed

1. Photos must show the make model of the equipment
2. A description of what the photo captures must accompany each photo
3. All construction photos should be taken prior to interior finishes
4. Photos of all product types / variants of the following must be submitted:

Assemblies	Each insulation product for each wall, roof, floor, and foundation type
Junctions	Each junction in the building, as per Junctions worksheet
Windows	Each window and door type
	Each operable window type in fully open and tilted positions to demonstrate how far they open
	Compensatory window heater
Ventilation Systems	Each type of HRV / ERV unit
	Outdoor and extract air filters for each HRV / ERV type
	Ductwork & insulation for the supply, extract, outdoor and exhaust air ducts for each HRV / ERV type
	Duct attachements (hangers, etc)
	Volume Flow Dampers
	Internal and external vents / grilles, showing sufficient space between intake and exhaust
	Air transfer grilles AND / OR door under/overcut height
	Frost protection system
	Acoustic Attenuators
	Supply air heater
	In-unit occupant control devices for each HRV / ERV type
Heating and Cooling Systems	Each type of heat and cooling generator
	Each type of humidification / dehumidification system
	Distribution pipe insulation product and thickness, including valves & T junctions
	Distribution pumps
DHW Systems	Each type of heat generator
	Each type of storage tank
	Insulation product and thickness of primary pipes and recirculation pipes
	Pipe attachments (hangers, clips, etc)
	Circulation pumps
	Sanitary system - AAVs, backwater valves, pipe insulation, alternative approach
	Rainwater pipes - Ptraps, alternative approach
	Solar thermal panels
Electrical Equipment	Each type of light fixture and lamp
	Each appliance type
	Elevators
	Solar PV panels
	Any other relevant equipment
Airtightness Testing	During search for areas of additional air leakage - showing method of detection.
Shading	Include photographs of:
	a. Each elevation of the building
	b. Window and door overhangs and reveals (from exterior)

Organize daily/weekly throughout…don't wait!

Note: Typically conducted as part of inspection regime by independent verifier.

Contractor may submit photographs to document fixes.

Construction Managers Declaration

Signed Declaration	Include a completed and signed copy of the Declaration of Conformance form from the construction supervisor.

Project name:	
Location:	
Project name on Certification platform:	
Construction manager (First name, Surname):	
Project manager (First name, Surname):	

Construction manager declaration

In order for the quality inspection to award the "Certified Passive House" seal for the above mentioned construction project, we hereby assure that the on-site execution is in accordance with the planning documents, technical documents and textual descriptions that have been uploaded to the Passive House Institute's certification platform up to and including / / (and not marked as "obsolete").

This has been checked through regular site visits.

https://passipedia.org/_media/picopen/construction_manager_declaration.pdf

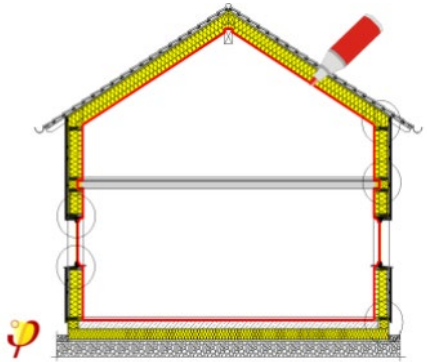
Construction management Date, Signature	Project management Date, Signature

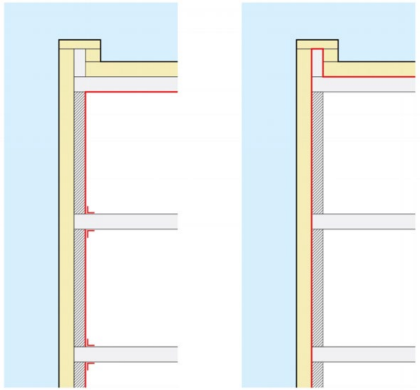
Checklists for Use During Construction

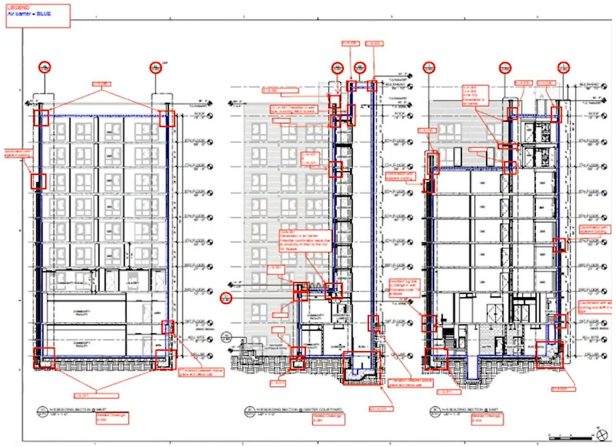
- Helpful for the field verifier and the contractor to understand what is expected for the project

- Below-grade insulation
- Above-grade wall insulation
- Roof insulation
- Air barrier
- Fenestration performance values
- Duct Sealing
- Pipe insulation
- HVAC and DHW equipment
- Lighting and lighting controls

Airtightness Plan & Culture

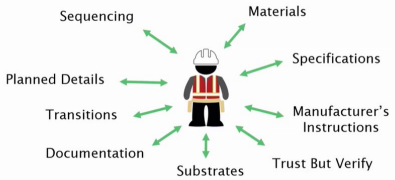




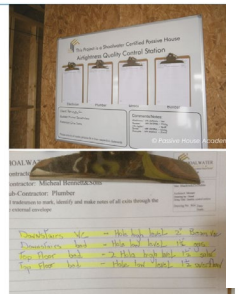


- Combination of hands-on practice and theoretical principles
- Focus on continuity of insulation and airtightness
- Change of mindset and attitude – 'thinking' fingers

The "Air Boss"



- Airtightness 'control station' strategically located at project
- All penetrations must be noted in writing
- Airtightness coordinator checks the log of penetrations daily and repairs holes



General Takeaways – Do This

- Insist on training for the construction staff.
- All subs should be aware of the project goals even if not directly related to Passive House.
- Architect, owner, and energy consultant need to be involved throughout the construction.
- Plan for a mock -up to see project details implemented.
- Plan for interim blower door tests.
- Focus on air tightness with a specific person taking responsibility for its execution and completion.
- Prepare and use checklists throughout construction to keep track of items for verification.
- Keep open lines of communication between the architect, CPHD, field verifier, certifier, and contractor.

Quality Issues, Quality of Organization

The Passive House Network

Verification and Certification are not held up so much on technical questions, so much as organizational issues.

- Design stage review open items - difficult to get closed
- Mock-ups & trainings not happening
- Team focus on critical Passive House issues is lacking
- Responsibilities not clearly defined
- Non-certified components are substituted for certified components
- **Team not in regular contact with Certifier giving updates and needed corrections**

Build a Culture of Quality!

The Passive House Network

Focus on the 5 principle drivers, and the comfort, hygiene & efficiency goals.

With focus and a little training, anyone can build a Passive House.

Resources

The Passive House Network

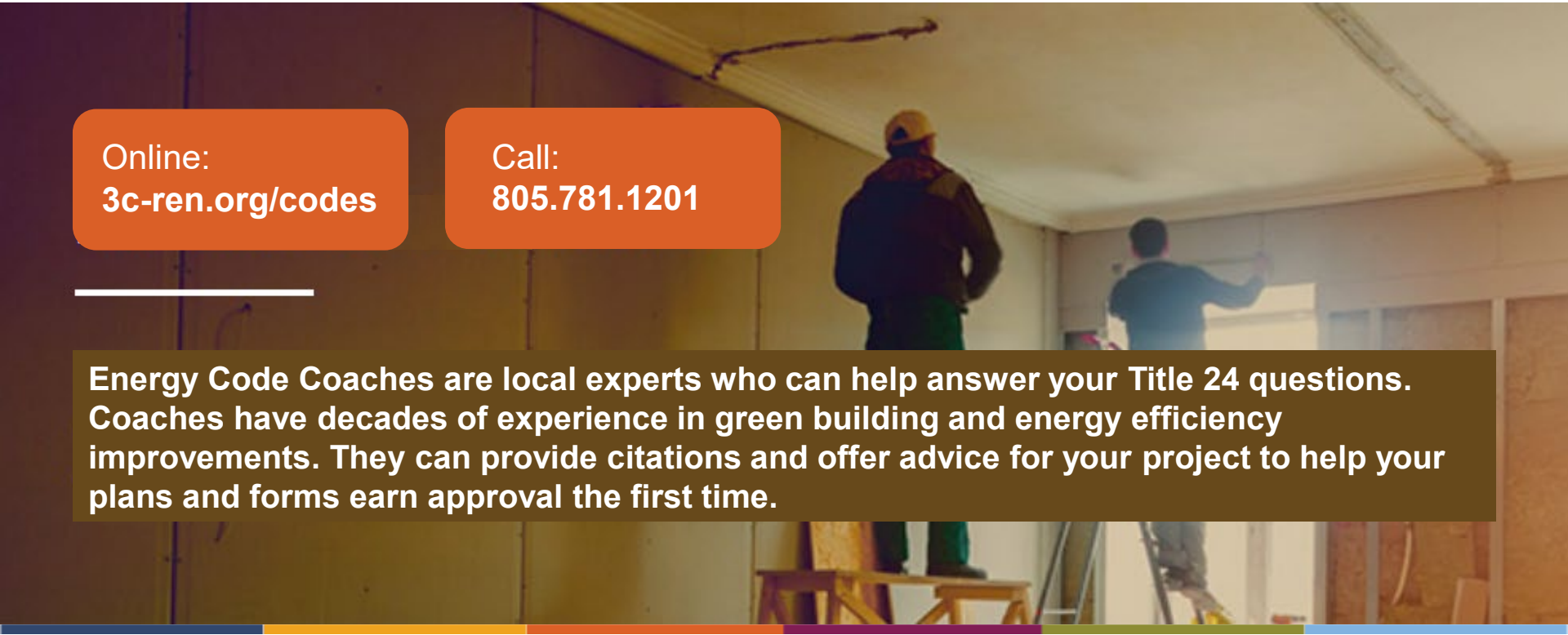
Building Database - https://passivehouse-database.org/index.php?lang=en
Certification Criteria - https://passivehouse.com/03_certification/02_certification_buildings/08_energy_standards/08_energy_standards.html
Certification Guide - https://passivehouse.com/03_certification/02_certification_buildings/09_guide/09_guide.html
Certified Components - https://database.passivehouse.com/en/components/
Certifiers Globally - https://passivehouse.com/03_certification/02_certification_buildings/03_certifiers/01_accredited/01_accredited.html
Certified Passive House Designer Training - https://passivehousenetwork.org/designer-training/
Certified Passive House Tradesperson Training - https://passivehousenetwork.org/tradesperson-training/
ISO 9972 - https://www.iso.org/standard/55718.html
Manager Declaration Sample - https://passipedia.org/_media/picopen/construction_manager_declaration.pdf
North American Certifiers Circle - https://passivehousenetwork.org/wp-content/uploads/2023/01/NACC-Brochure-Jan-2023.pdf
Passipedia - https://passipedia.org/start
Passive House Accelerator - https://passivehouseaccelerator.com/
Passive House Certification - https://passivehousenetwork.org/certification/
Passive House Definition - https://passipedia.org/basics/the_passive_house_-_definition
Passive House - Historical Review - https://passipedia.org/basics/the_passive_house_-_historical_review
Passive House Planning Package (PHPP) - https://passivehouse.com/04_phpp/04_phpp.htm
Safe at Home PHN Report - https://passivehousenetwork.org/safe-at-home/
Sample Submission Documents - https://passipedia.org/certification/certified_passive_houses/example_documents
Summer Comfort - https://passipedia.org/planning/summer_comfort
Thermal Comfort - https://passipedia.org/basics/building_physics_-_basics/thermal_comfort
Vancouver Passive House Checklist - https://passivehousenetwork.org/wp-content/uploads/2024/07/Vancouver-Passive-House-Verification-Plan-Checklist-2023.pdf
Ventilation Duct Leakage Testing - https://passivehousenetwork.org/product/multifamily-ventilation-duct-leakage-targets-strategies-and-lessons-learned/

Thank you.

www.passivehousenetwork.org

Questions about Title 24?

3C-REN offers a *free* Code Coach Service



Online:
3c-ren.org/codes

Call:
805.781.1201

Energy Code Coaches are local experts who can help answer your Title 24 questions. Coaches have decades of experience in green building and energy efficiency improvements. They can provide citations and offer advice for your project to help your plans and forms earn approval the first time.

Closing

- Continuing Education Units Available
  - Contact shuskey@co.slo.ca.us for AIA LUs
- Coming to Your Inbox Soon!
  - Slides, Recording, & Survey – Please Take It and Help Us Out!
- Upcoming Courses:
  - September 5th - Passive Design/Build™ Boot Camp – Free info session
  - September 12th - All-Electric Accessory Dwelling Units (ADUs)
  - September 24th - Building Electrification, Passive House PER & California
  - September 30th – October 4th - Passive Design/Build Boot Camp with Emu Passive – Hands On Training and Exam (FREE!)
  - October 9th - All-Electric Retrofits with Electrical Panel Constraints
  - October 10th - Certified Passive House Designer/Consultant (CPHD/C) Pacific Fall Hybrid Cohort
- Visit www.3c-ren.org/events for our full catalog of trainings.

Thank you!

For more info:
3c-ren.org

For questions:
info@3c-ren.org

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