Introduction to Passive House

Presented By

CONNECTICUT PASSIVE HOUSE

AIA Connecticut

CONNECTICUT PASSIVE HOUSE

PRESENTERS:

George Penniman AIA, CPHD	George W. Penniman Architects
Leonard Wyeth AIA, CPHD	Wyeth Architects llc
Sara Holmes AIA, LEED BD+C, CPHD	Wyeth Architects llc
Phillipe Campus AIA, CPHD	PHC Architect

CONNECTICUT PASSIVE HOUSE

Passive House incorporates building science based strategies to minimize the use of energy while maximizing comfort and quality of life.

Connecticut Passive House is a community of like-minded professionals offering resources, education, and outreach using the broad knowledge base and skill-sets of our peers.

www.ctpassivehouse.org

Passive House: In the beginning

Kranichstein Passivhaus Darmstadt Germany

CTPH
CONNECTICUT PASSIVE HOUSE

Island Passive House, WA by The Artisans Group Inc.

CTPH
CONNECTICUT PASSIVE HOUSE

Leigh Overland house, Easton

CTPH
CONNECTICUT PASSIVE HOUSE


GO Logic, Bolton, CT
CTPH
CONNECTICUT PASSIVE HOUSE


Madrona Passive House by SHED

Passive House Che, Romania by Tecto Architectura

Taft School Faculty Housing by Trillium Architects

CTPH
CONNECTICUT PASSIVE HOUSE

North Avenue, Westport by Rountree Architects

CTPH
CONNECTICUT PASSIVE HOUSE

Balance Project by Jonah Stanford, Needbased Inc. NM

CTPH
CONNECTICUT PASSIVE HOUSE

Passive House Cabin by George Penniman Architects, ME

CTPH
CONNECTICUT PASSIVE HOUSE

Coastal Passive House by Philippe Campus, CT

CTPH
CONNECTICUT PASSIVE HOUSE

Delphi Haus, Olympia, WA by the Artisan Group

CTPH CONNECTICUT PASSIVE HOUSE

Harwinton, CT by Wolfworks

CTPH CONNECTICUT PASSIVE HOUSE


BPC Green Builders, Danbury
CTPH
CONNECTICUT PASSIVE HOUSE


Hudson, NY by Dennis Wedlick, Architect

CTPH
CONNECTICUT PASSIVE HOUSE

Stonington Passive House by Wyeth Architects

CTPH
CONNECTICUT PASSIVE HOUSE

Vancouver Spec House by Lanefab Design/Build

CTPH
CONNECTICUT PASSIVE HOUSE

Cohousing & Ecovillage, Belfast, ME by GO Logic

CTPH
CONNECTICUT PASSIVE HOUSE

Village Centre Apartments, Brewer, ME by CWS Architects

CTPH
CONNECTICUT PASSIVE HOUSE

Crown Street Project, Meriden, CT by Kenneth Boroson Architects

CTPH
CONNECTICUT PASSIVE HOUSE

Belfield Townhomes,
Philadelphia, PA
by Onion Flats

CTPH
CONNECTICUT PASSIVE HOUSE

Sol-Lux Alpha Condos, San Francisco, Off the Grid Design

CTPH
CONNECTICUT PASSIVE HOUSE

The Distillery North Apartments, Boston by ICON Architecture

CTPH
CONNECTICUT PASSIVE HOUSE

Crest Pavilion, Northern Ireland by Paul McAlister Architects

CTPH
CONNECTICUT PASSIVE HOUSE


RMI Innovation Center, CO by ZGF Architects

CTPH
CONNECTICUT PASSIVE HOUSE

Bushbury Hill Primary School, England by Architype

CTPH
CONNECTICUT PASSIVE HOUSE

Friends School of Portland, ME by Kaplan Thompson Architects

Waldorf School, Freeport, ME by Briburn Architects

CTPH
CONNECTICUT PASSIVE HOUSE

Garfield House – Williams College, MA by Thornton Tomasetti

CTPH
CONNECTICUT PASSIVE HOUSE


Stadhalle Boutique Hotel, Vienna

CTPH
CONNECTICUT PASSIVE HOUSE

Church by Barlis Wedlick Architects

CTPH
CONNECTICUT PASSIVE HOUSE

Pemberton all wood Industrial Facility, BC by Hemsworth Architecture

CTPH CONNECTICUT PASSIVE HOUSE

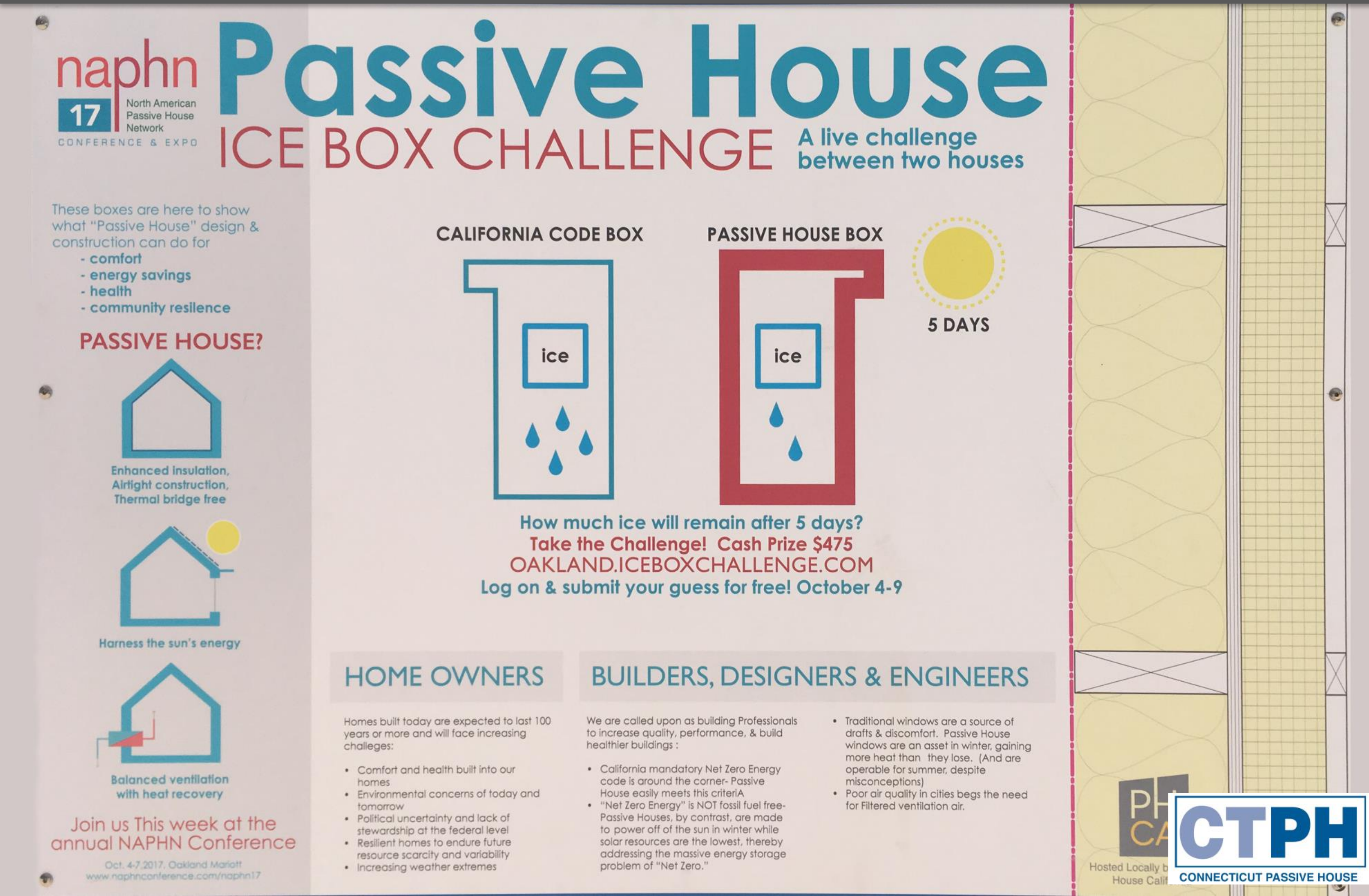
Passive House windows, NY

CTPH
CONNECTICUT PASSIVE HOUSE

Brooklyn Brownstone EnerPHit

CONNECTICUT PASSIVE HOUSE

Oakland Ice Box Challenge 2017



CTPH
CONNECTICUT PASSIVE HOUSE

The House at Cornell Tech, Handel Architects, NY

CTPH
CONNECTICUT PASSIVE HOUSE

Bolueta high rise, Spain
By VArquitectos

Winthrop Center
Boston
by BPDA/
Handel Architects

Passive House Myth

Common Passive House Myths:

- It’s only applicable to ‘houses’
- You can’t open the windows
- Air quality in an airtight building must be awful
- It has to be boxy and ugly
- It’s too expensive
- Restricted to temperate climates

All <u>false</u> notions

CTPH CONNECTICUT PASSIVE HOUSE

Passive House Reality

- Comfort: Even temperature, draft-free, quiet.
- Health: Continuous fresh, filtered air, no CO2 build-up
- Resiliency: Habitable interior without power
- Energy Efficiency: up to 90% reduction in heating and cooling demand over average existing building stock.
- Energy Security: Minimal utility costs, reducing burden on low-income households.
- Affordable: 5—8% increase in construction cost, off-set by reduced mechanical requirements, short payback.
- Best path to Net Zero: minimal use of renewables can off-set electricity consumption.
- Best path to goals of Paris Accord, Architecture 2030 and CT 80 x 50 targets for carbon reduction.
- Building Code in Brussels, Vancouver

CTPH
CONNECTICUT PASSIVE HOUSE

"Passive House Explained in 90 Seconds"

https://www.youtube.com/watch?v=CasrjYhZB1M

0:00 / 1:30

CTPH
CONNECTICUT PASSIVE HOUSE

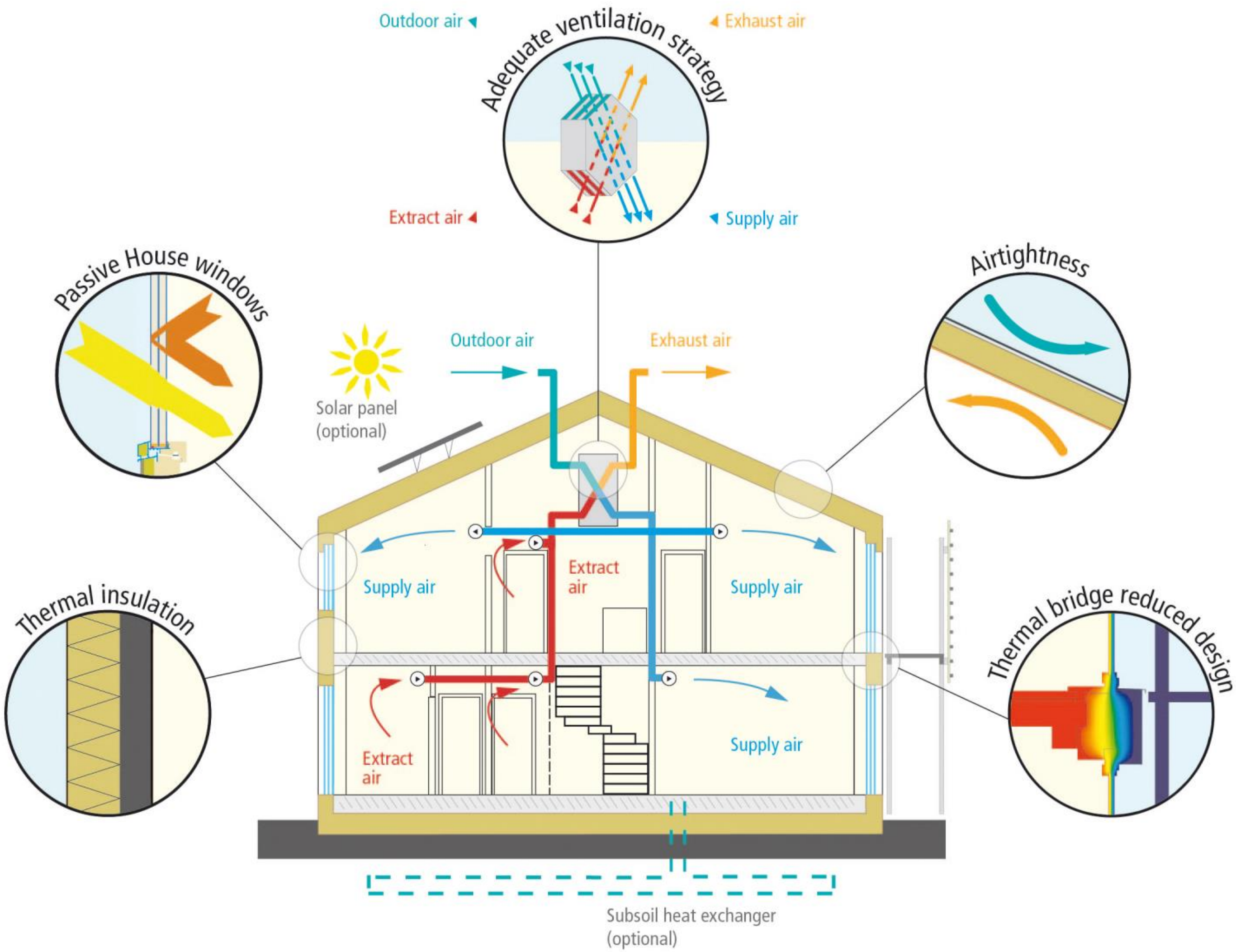
Performance

Passive House is a **performance based** standard:

- Scientifically validated energy model (PHPP);
- Strict standards testing protocols for key elements such as windows and ventilation;
- Verified construction details (for example thermal bridging);
- Photo documentation of details/assemblies required for certification;
- Blower door testing;
- Ventilation system commissioning and sign-off

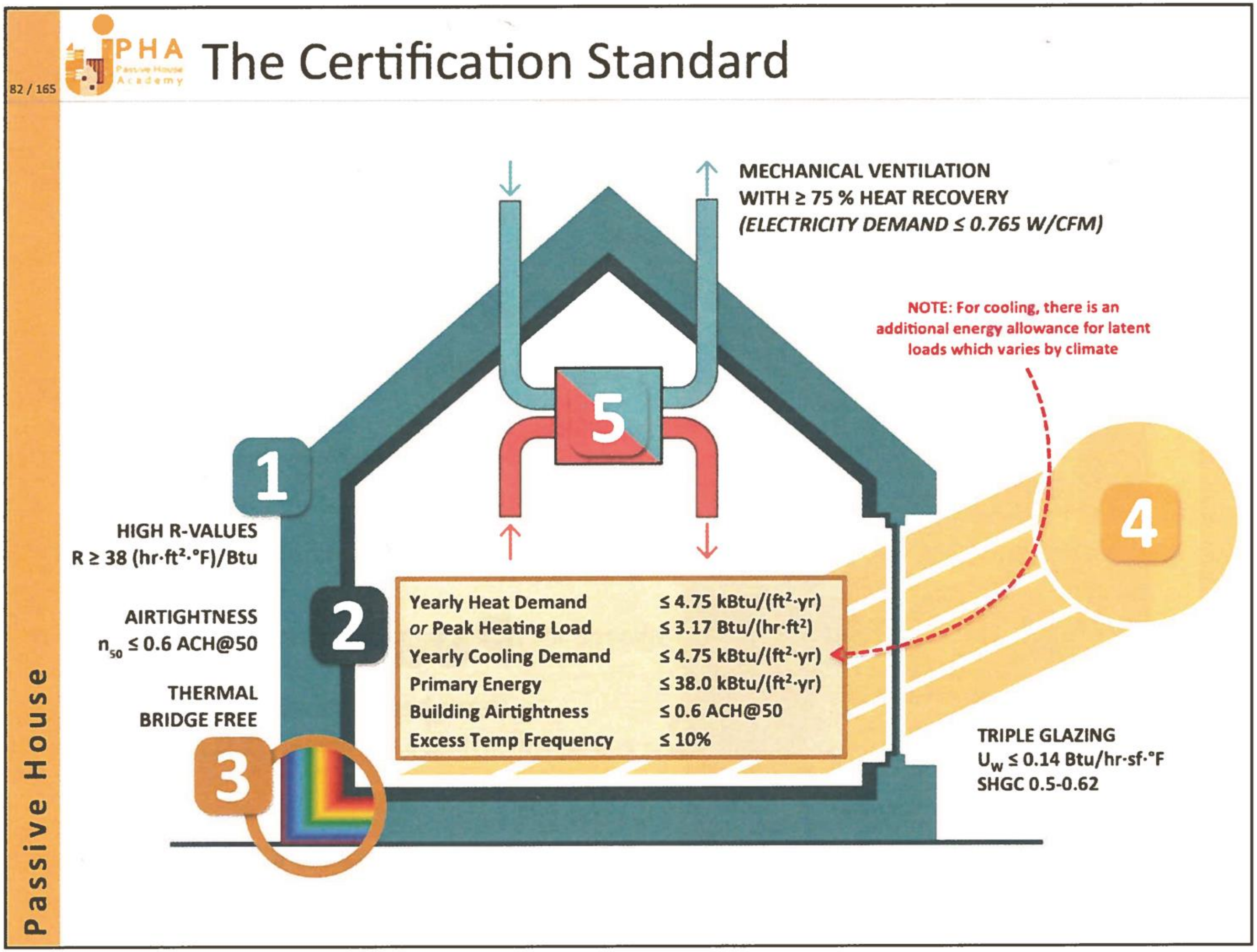
CTPH
CONNECTICUT PASSIVE HOUSE

5 Principles of Passive House



CTPH
CONNECTICUT PASSIVE HOUSE

The Certification Standard



CONNECTICUT PASSIVE HOUSE

5 Principles of Passive House

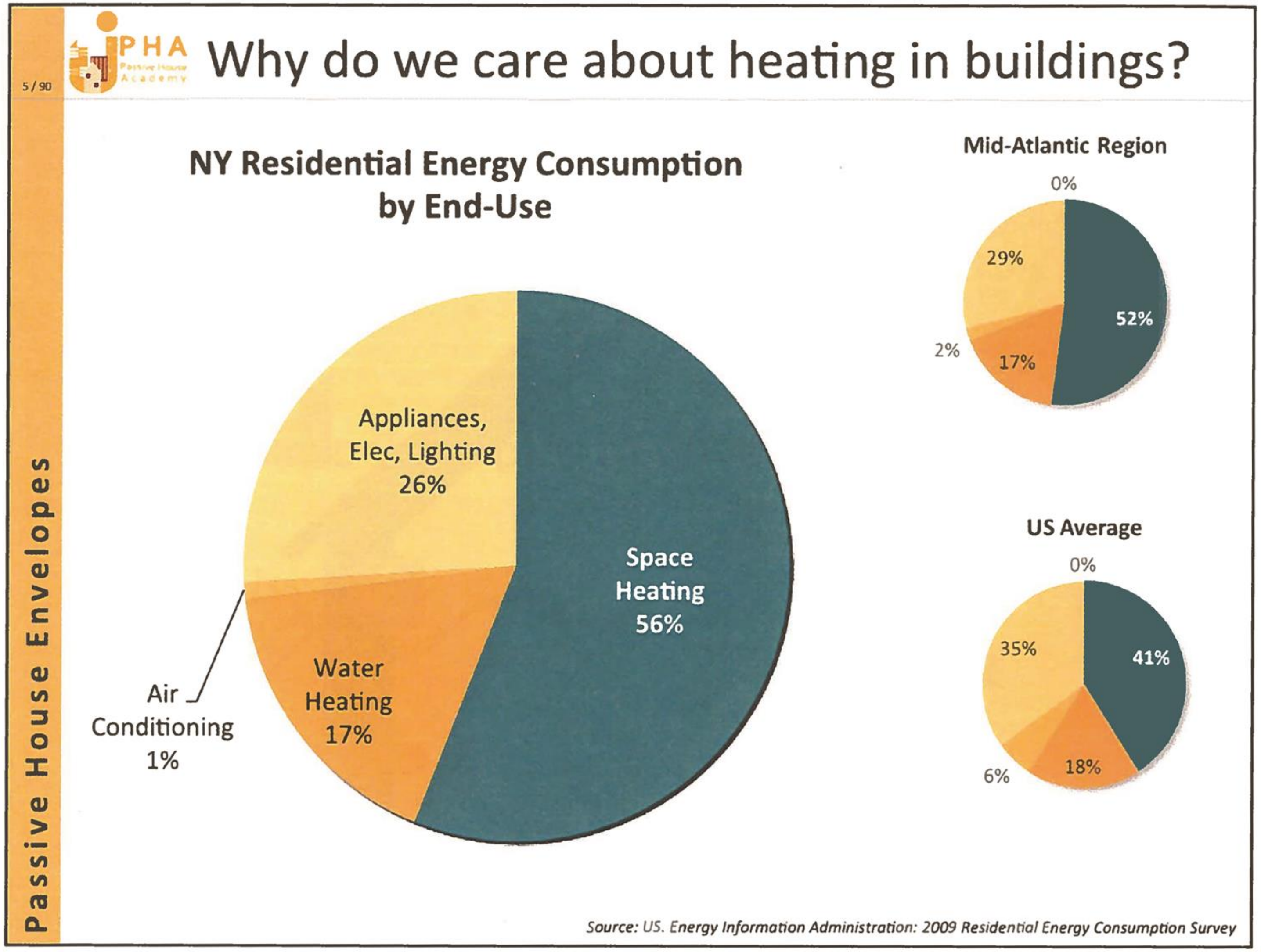
1. Insulation
2. Thermal Bridge Free
3. High-Performance Windows
4. Airtight
5. HVAC

5 Principles of Passive House

1. Insulation
2. Thermal Bridge Free
3. High-Performance Windows
4. Airtight
5. HVAC

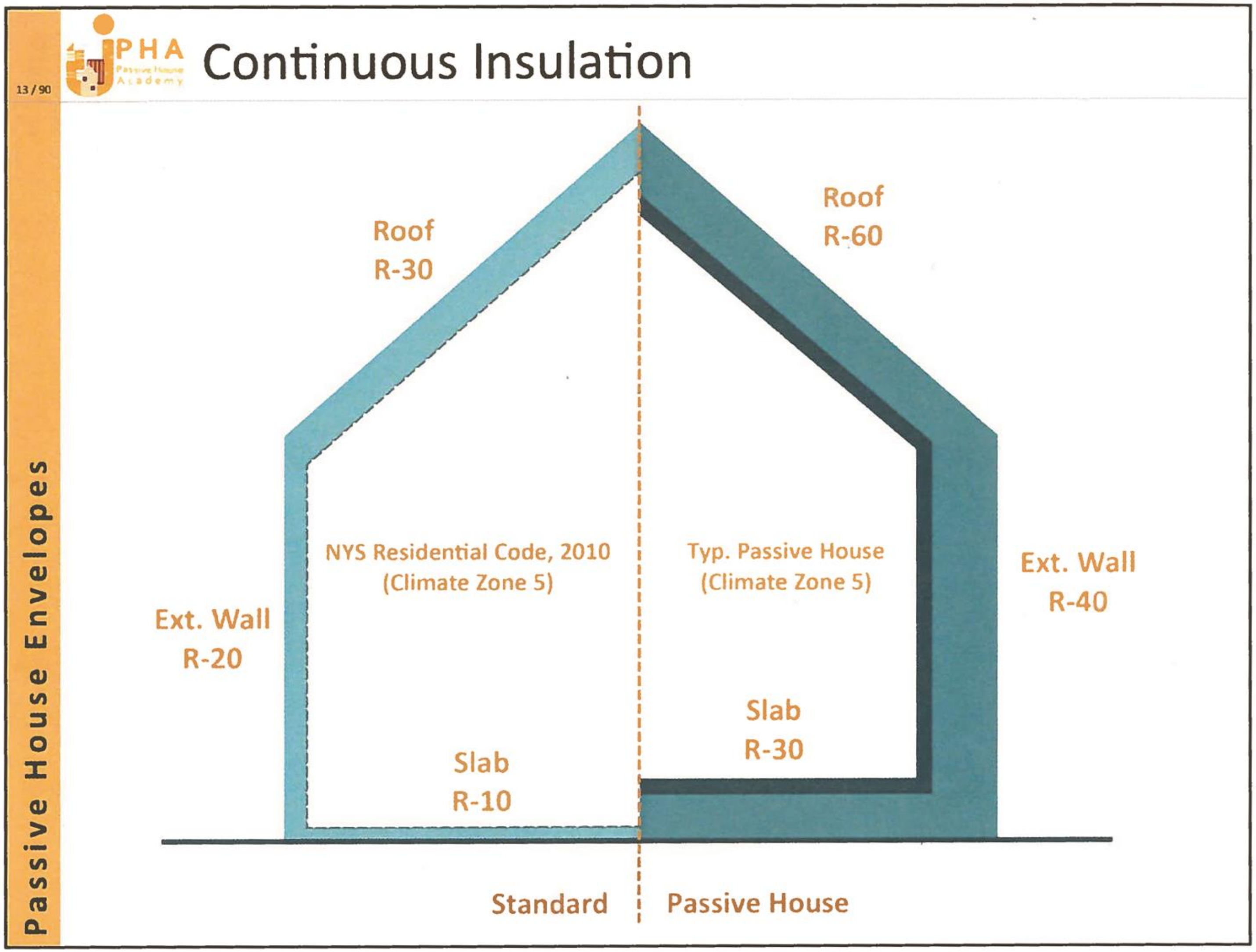
CTPH
CONNECTICUT PASSIVE HOUSE

Insulation



CTPH
CONNECTICUT PASSIVE HOUSE

Insulation



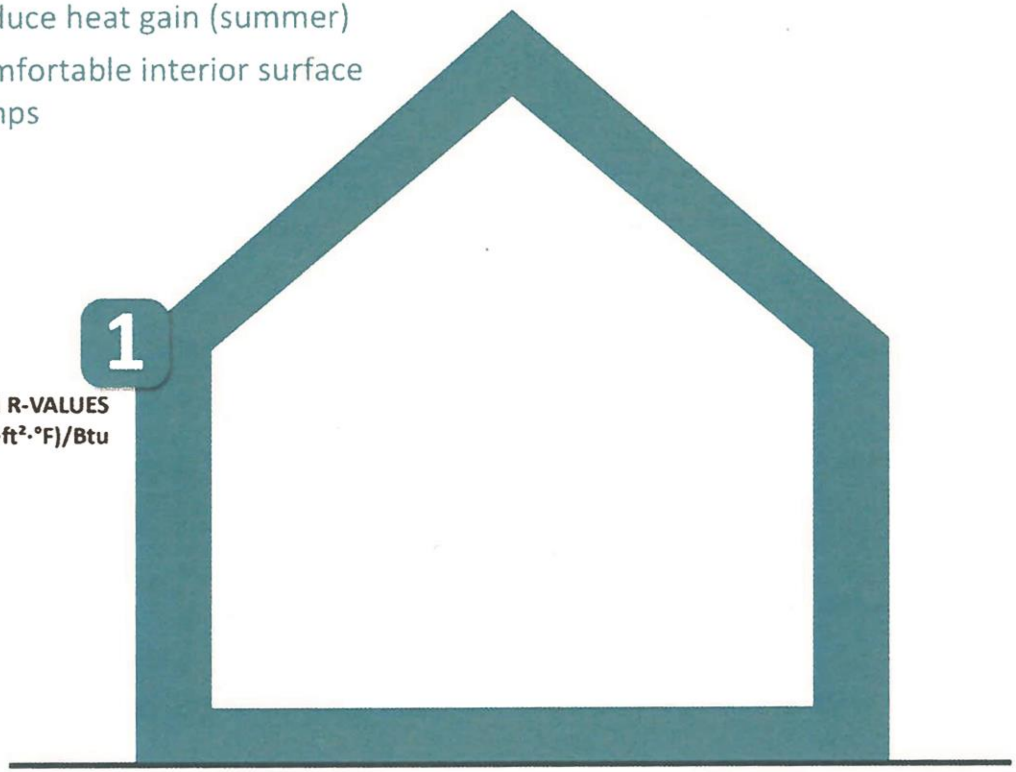
CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

PHA Passive House Academy

#1: High-R Value, Continuous Insulation

- Reduce heat loss (winter)
- Reduce heat gain (summer)
- Comfortable interior surface temps



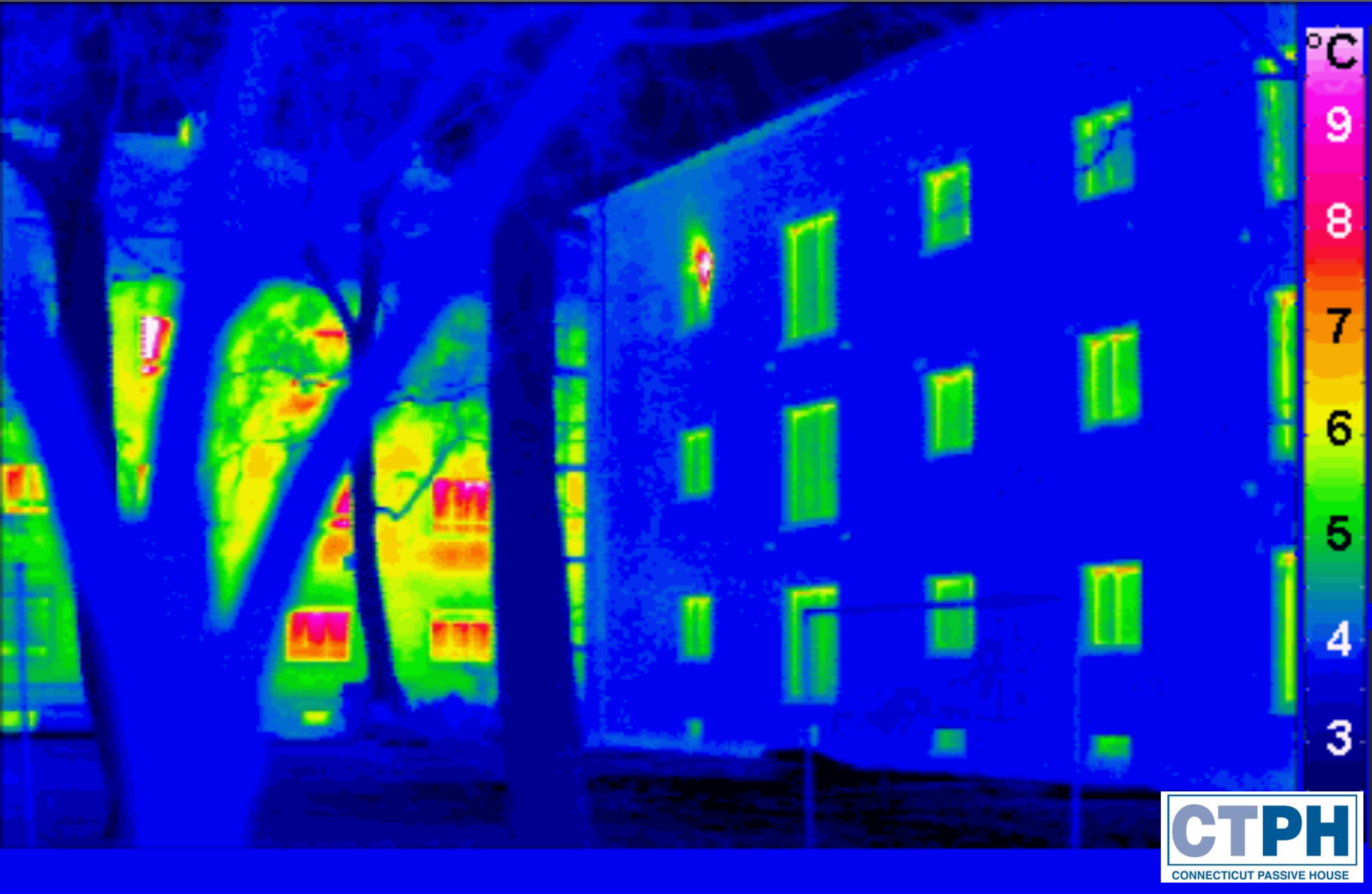
HIGH R-VALUES
R ≥ 38 (hr·ft²·°F)/Btu

Passive House

Insulation

CTPH
CONNECTICUT PASSIVE HOUSE

Insulation



CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

PHA Passive House Academy

Thermal Transmittance (U-value)

What does this mean?

$$BTU/(hr \cdot ft^2 \cdot F)$$

One BTU ≈ one burned match

How many **BTUs** move .....

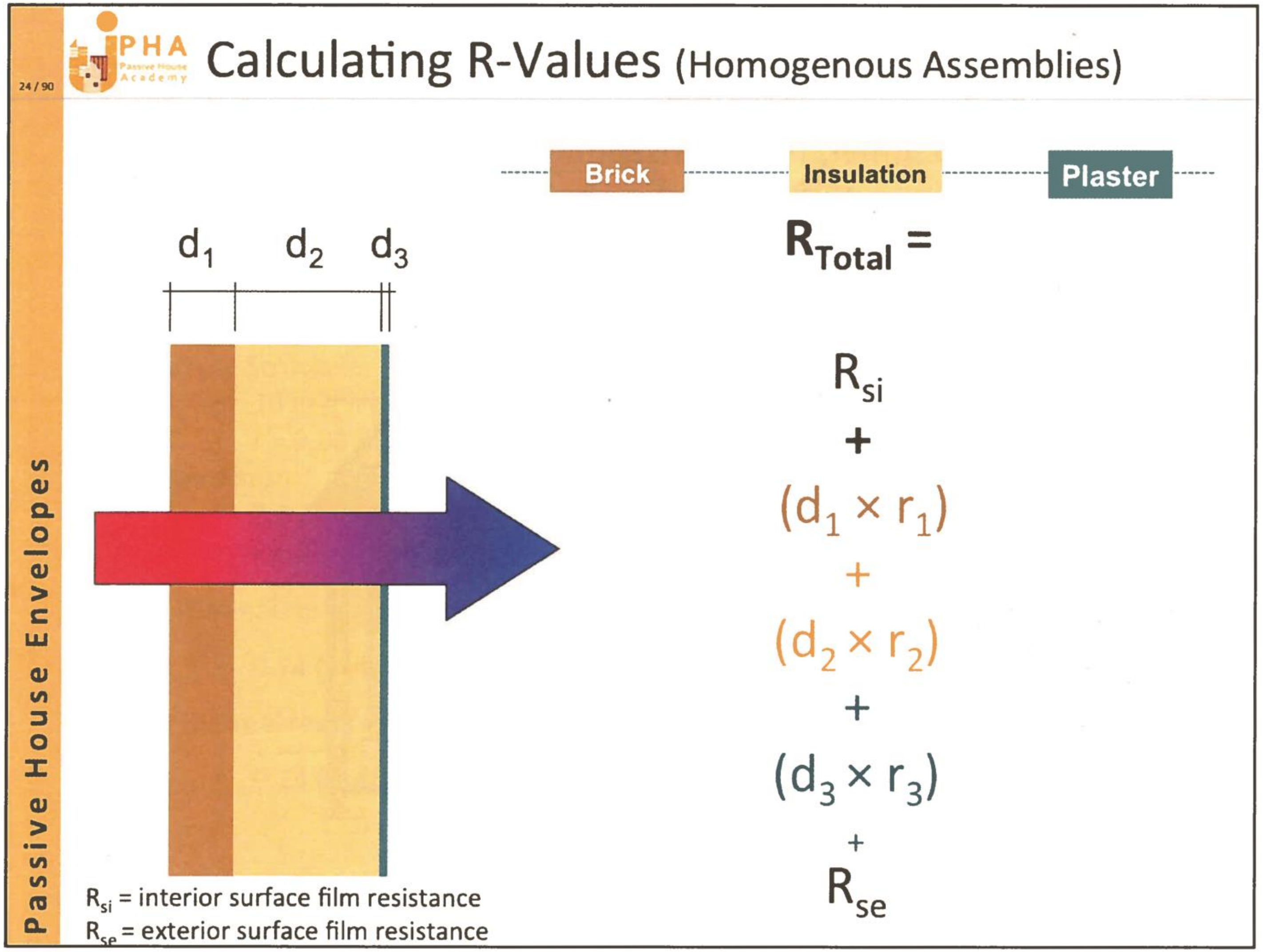
.... in one **hour** ....

.... for one **square foot** of surface area ....

.... for every **degree** of temp. difference between faces.

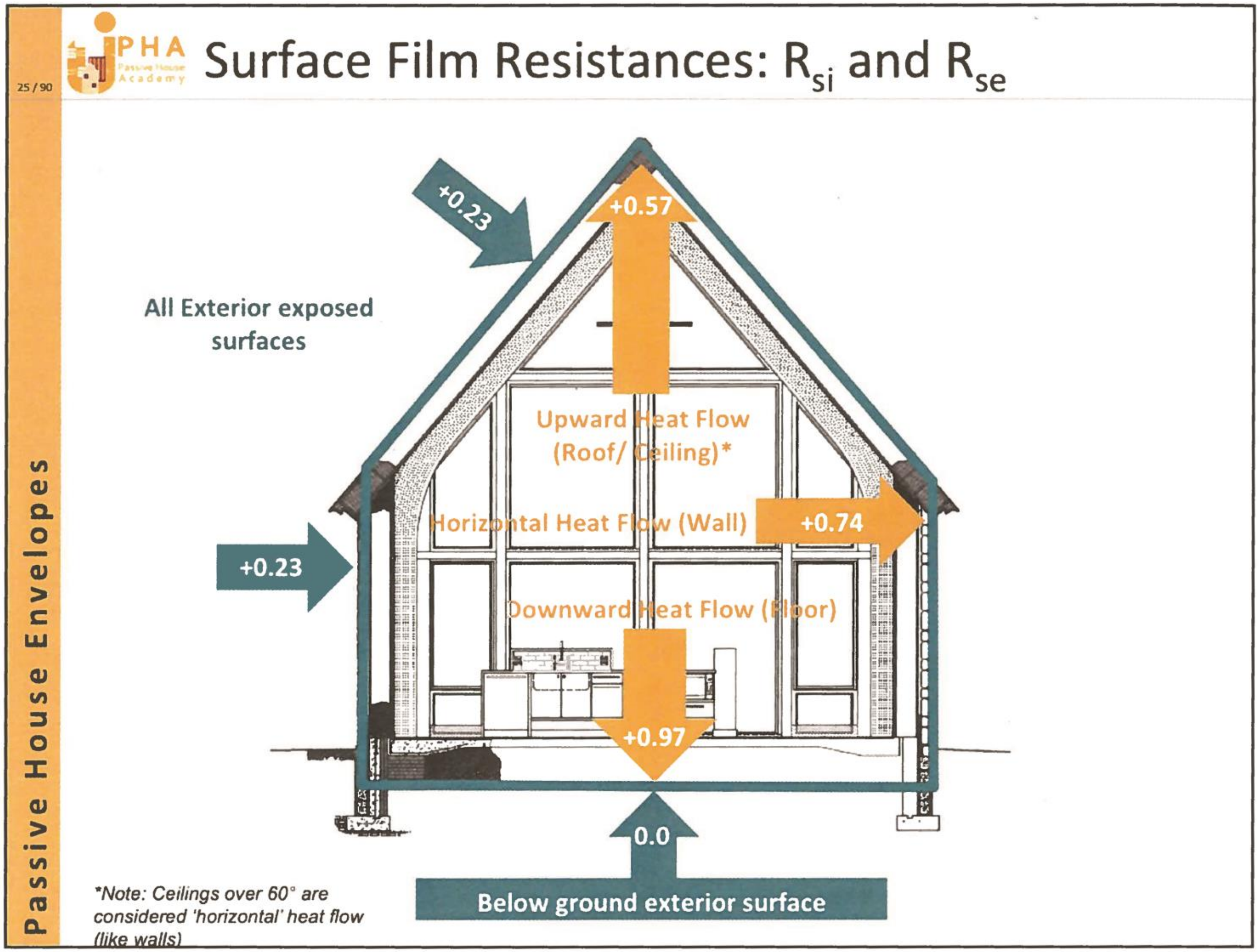
The **U-Value** is also called the HEAT TRANSFER COEFFICIENT or CONDUCTANCE of the **whole assembly** (not an individual layer!)

Insulation



CTPH
CONNECTICUT PASSIVE HOUSE

Insulation



CTPH
CONNECTICUT PASSIVE HOUSE

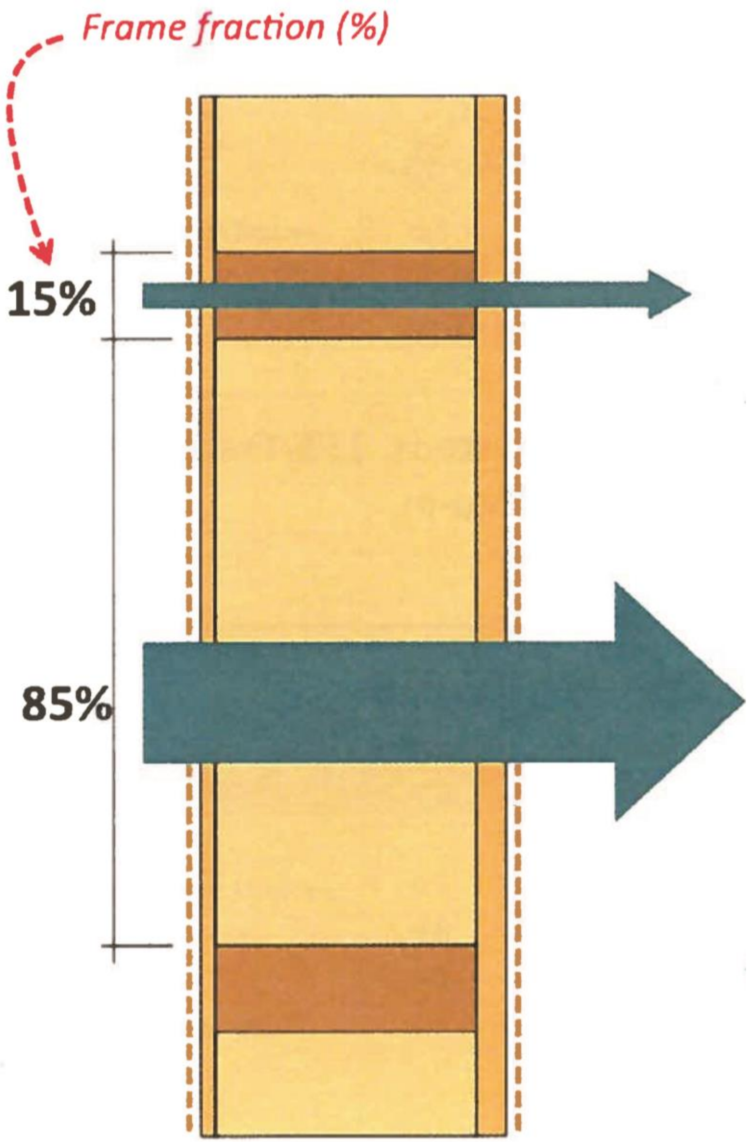
Insulation

R Value Calculation: Example

	Thickness (inches)		r per Inch (hr·ft²·°F)/Btu.in		Total Resistance (hr·ft²·°F)/Btu
R_{si} (Interior Horizontal Flow)					0.74
Layer 1 - Insulation	12.00	×	4.00	=	48.00
Layer 2 - Concrete Structure	10.00	×	0.08	=	0.80
Layer 3 - Plaster	0.50	×	0.20	=	0.10
R_{se} (Exterior)					0.23
					= 49.87

Total Resistance, (R-value): 49.9

Insulation



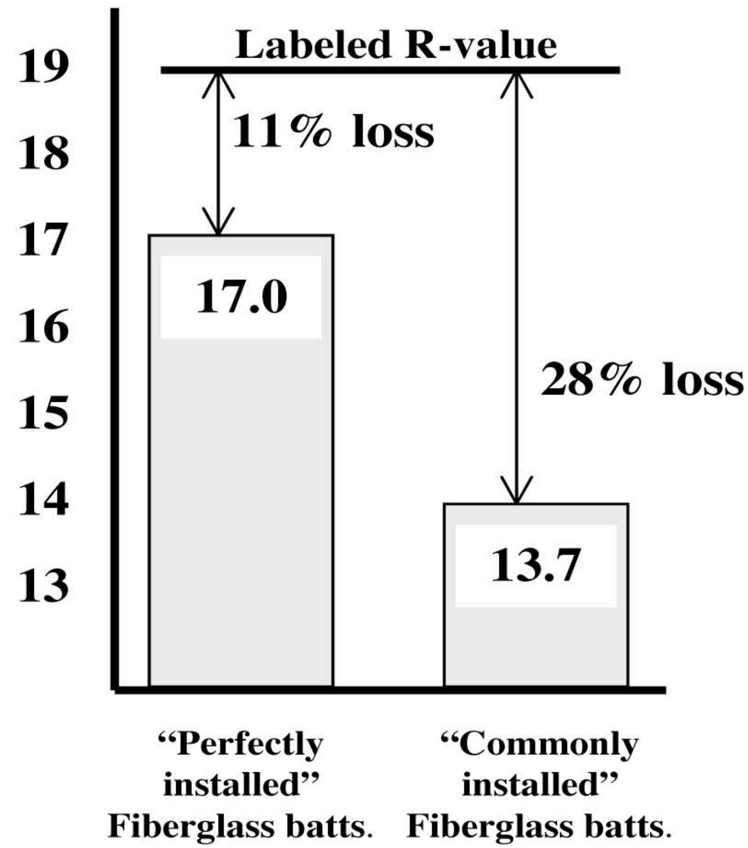


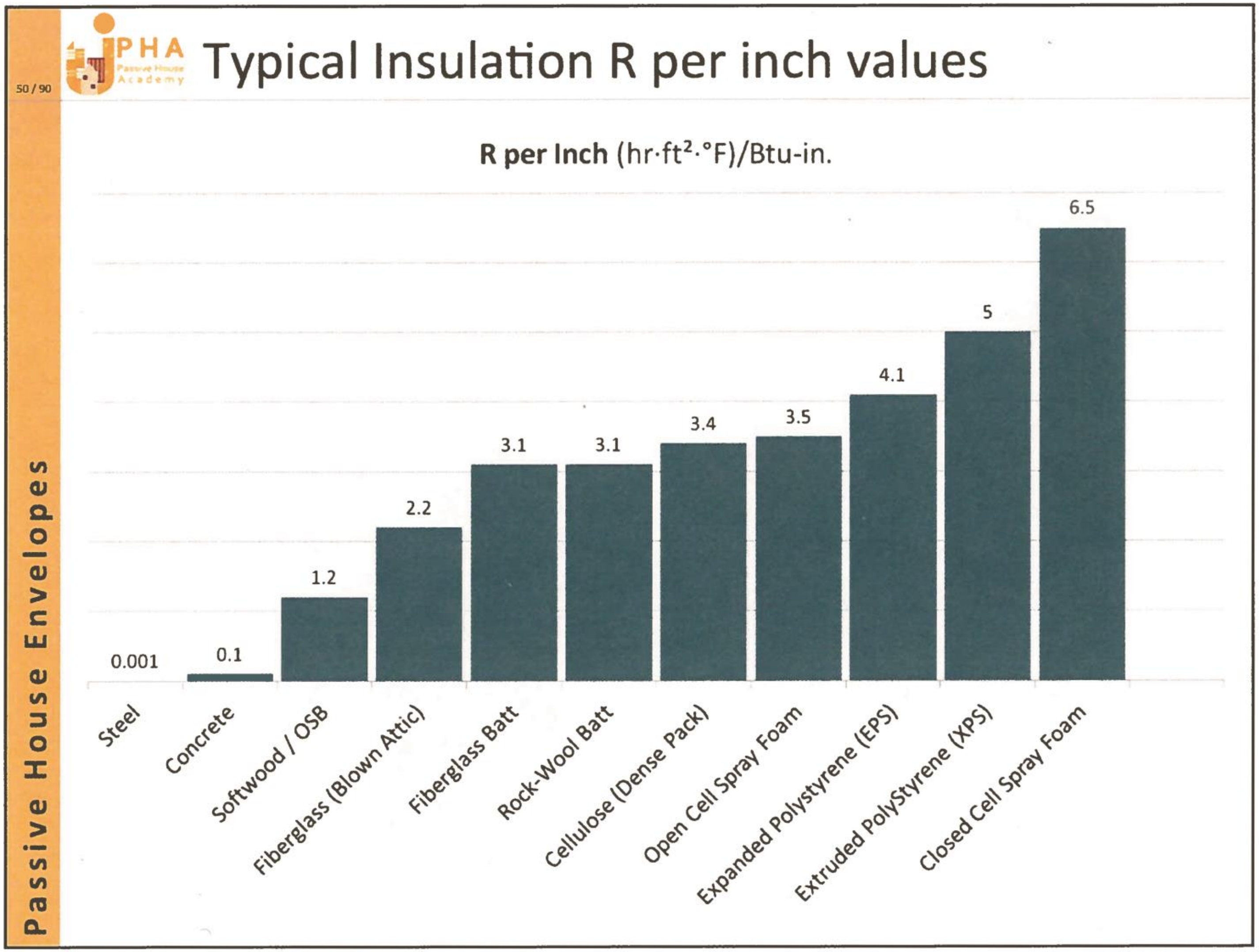
Figure 4 – Taking the framing, OSB, and gypsum board into account, the R-19 fiberglass batt insulation provided much less than its labeled R-value

Insulation

Insulation Types – Plenty to Choose From

- Cellulose (blown-in, ensure dense pack to avoid settling)
- Wood fibre (boards)
- Fibre glass (in batts, or blown-in)
- Mineral wool (in batts, or blown-in)
- Extruded / expanded polystyrene (XPS / EPS boards)
- Polyisocyanurate (dense foam boards)
- Spray foams, open cell and close cell

Insulation



CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

Typical Construction - Not a Passive House

PHA Passive House Academy

- 2x4 stud wall with too much wood and not enough room for insulation
- Crazy thermal bridging
- Severe heat loss in winter

Passive House Envelopes

CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

Wood Framing: Double Stud

SOURCE: Riverdale NetZero Project

CTPH
CONNECTICUT PASSIVE HOUSE

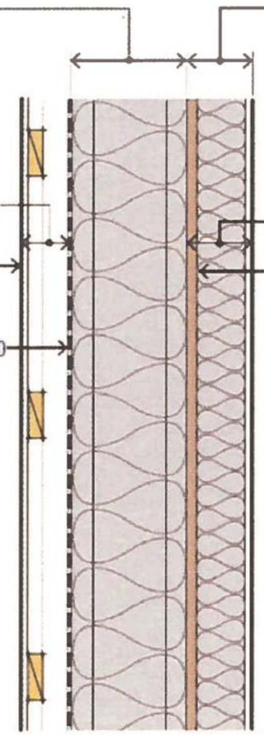
Insulation

56 / 90

PHA Passive House Academy

Wood Framing: Larsen Truss & Wood-I-Beam

Passive House Envelopes



SOURCE: EcoCor, Chris Corson

CTPH CONNECTICUT PASSIVE HOUSE

Insulation

Wood Framing: Thermally broken members

Passive House Envelopes

CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

PHA Passive House Academy

Wood Framing: SIP

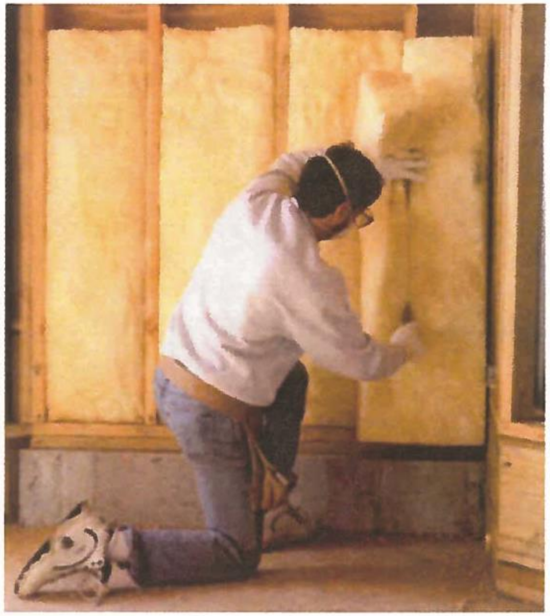
Passive House Envelopes

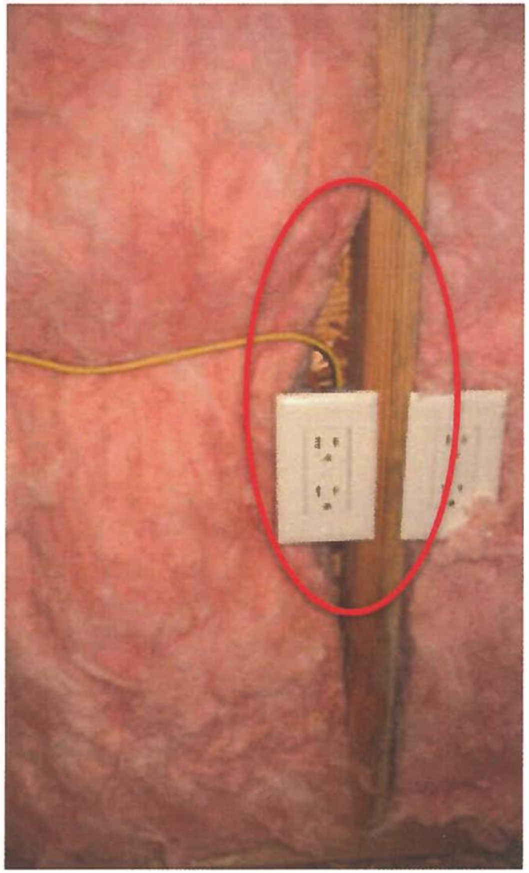
CTPH CONNECTICUT PASSIVE HOUSE

Insulation

PHA Passive House Academy

Insulation: Fiberglass Batt





Passive House Envelopes

CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

60 / 90

PHA Passive House Academy

Insulation: Blown-In Cellulose

SOURCE: Greenbuilding Advisor

Passive House Envelopes

CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

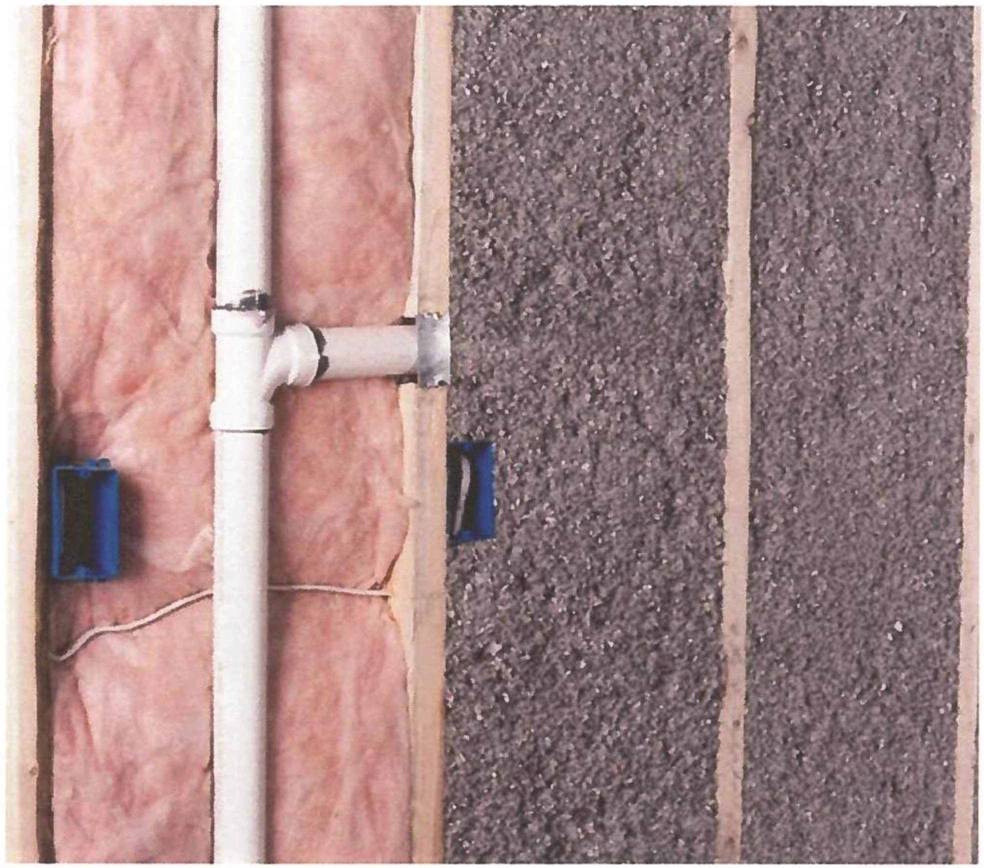
Insulation

PHA Passive House Academy

Insulation: Batt vs. Blown-In

61 / 90

Passive House Envelopes



SOURCE: *Factor Insulation*

CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

Insulation: SPIDER Blown-in Fiberglass

1.8 lbs / cf density
R-4.2 / In.

Photo: Alex Wilson

Insulation

PHA Passive House Academy

Insulation: Spray Foams

SOURCE: Uratex

Passive House Envelopes

CTPH
CONNECTICUT PASSIVE HOUSE

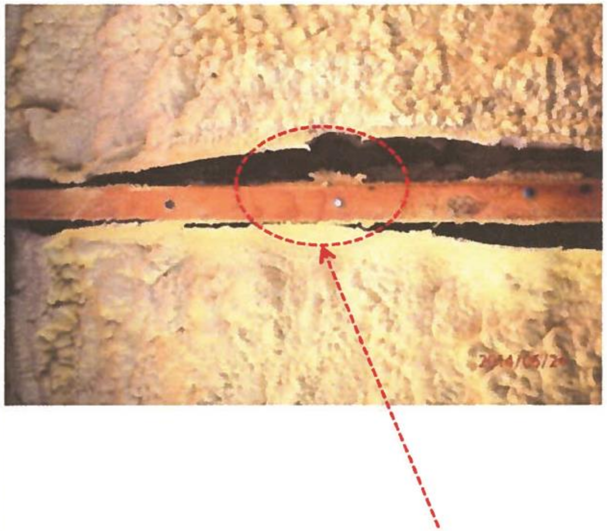
Insulation

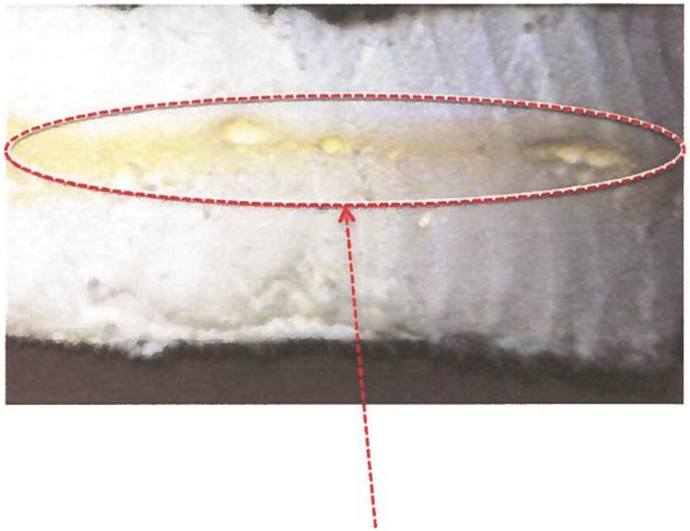
PHA Passive House Academy

Insulation: Spray Foams

Spray foams should be utilized carefully due to:

1. Shrinking over time (spray foam is NOT a long term air-barrier)
2. Incorrectly mixed or poorly applied (too cold, too dry, etc..)
3. Toxicity and lingering air-born chemicals
4. Fire Hazard and correct ignition barrier application
5. Overall material Global-Warming-Impact should be assessed*



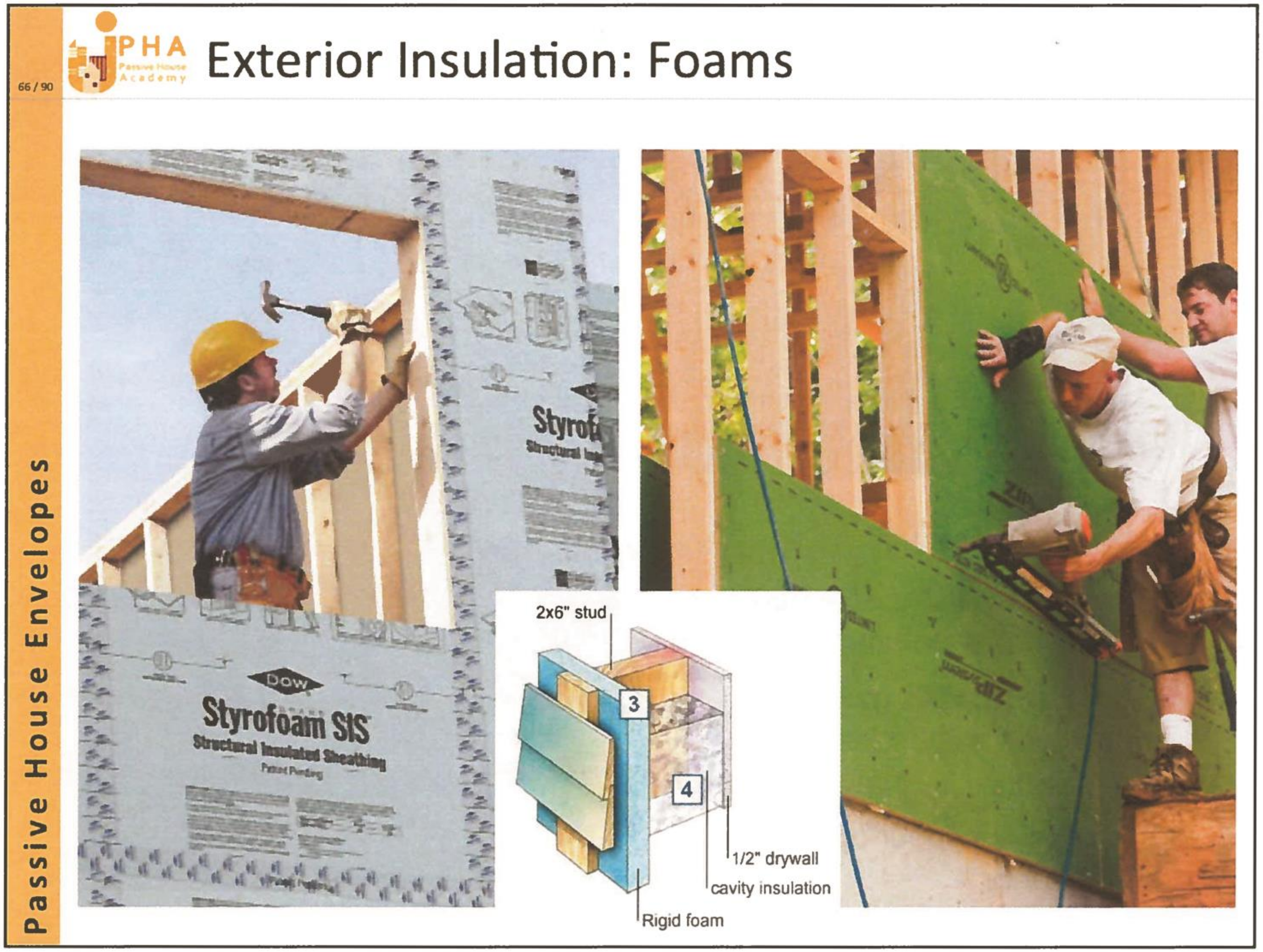


SOURCE: John Lapotaire

Passive House Envelopes

CTPH CONNECTICUT PASSIVE HOUSE

Insulation

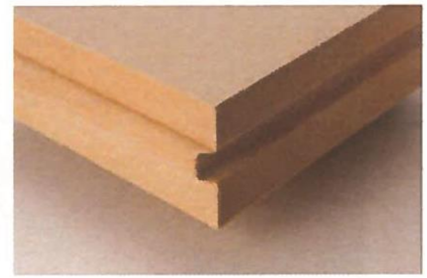


CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

PHA Passive House Academy

Exterior Insulation: Gutex (wood fiberboard)



1. Made of Recycled Wood-Chips
2. T&G all sides mean no need to align to framing (roof or wall)
3. Waterproof (WRB), Insulated sheathing + Windproofing in 1 step
4. Vapor Open (44 perm)

Insulation

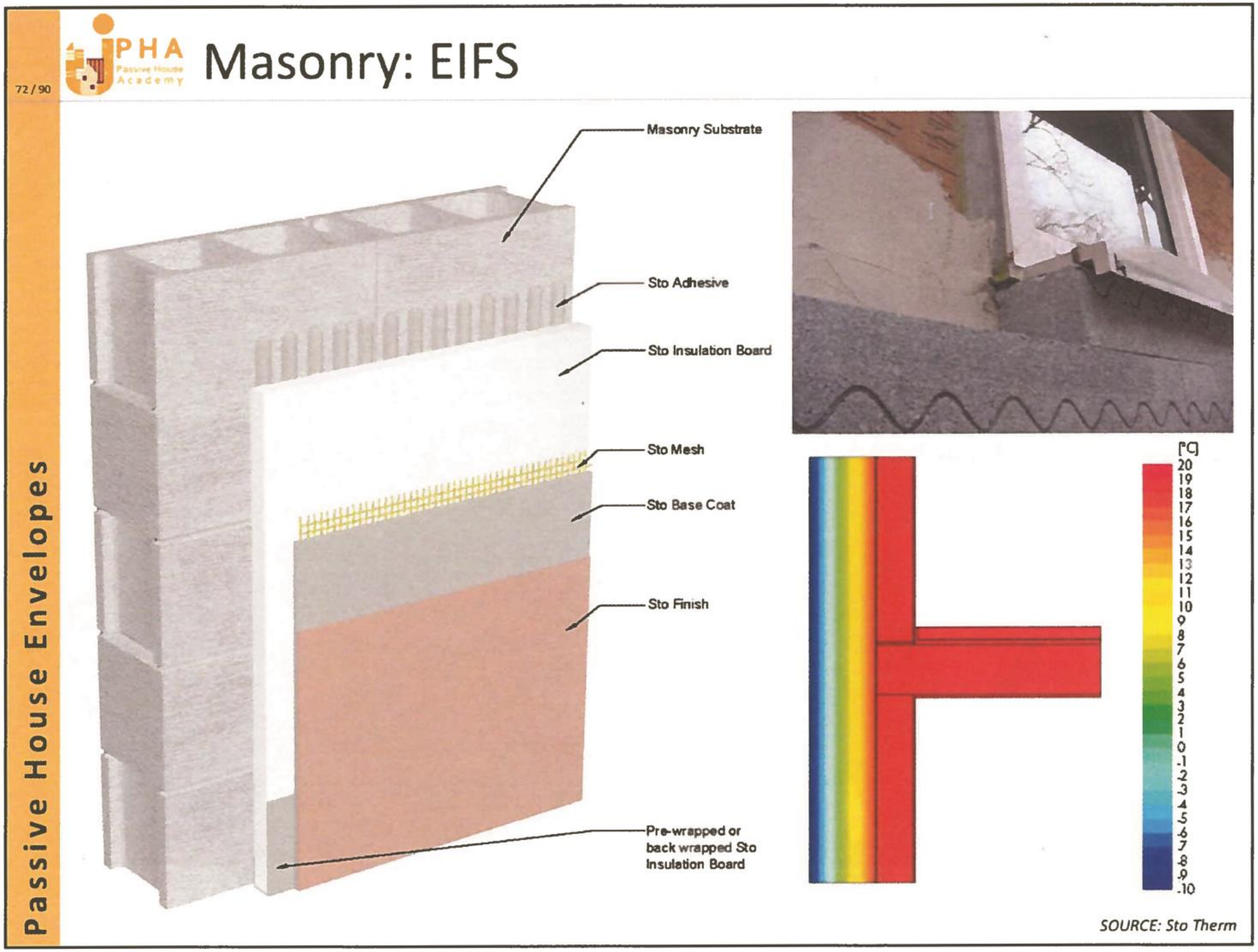
Exterior Insulation: Mineral Wool

SOURCE: Green Building Advisor

Passive House Envelopes

CTPH
CONNECTICUT PASSIVE HOUSE

Insulation



CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

Masonry: Low Conductivity Block

Durisol Hybrid Masonry Units

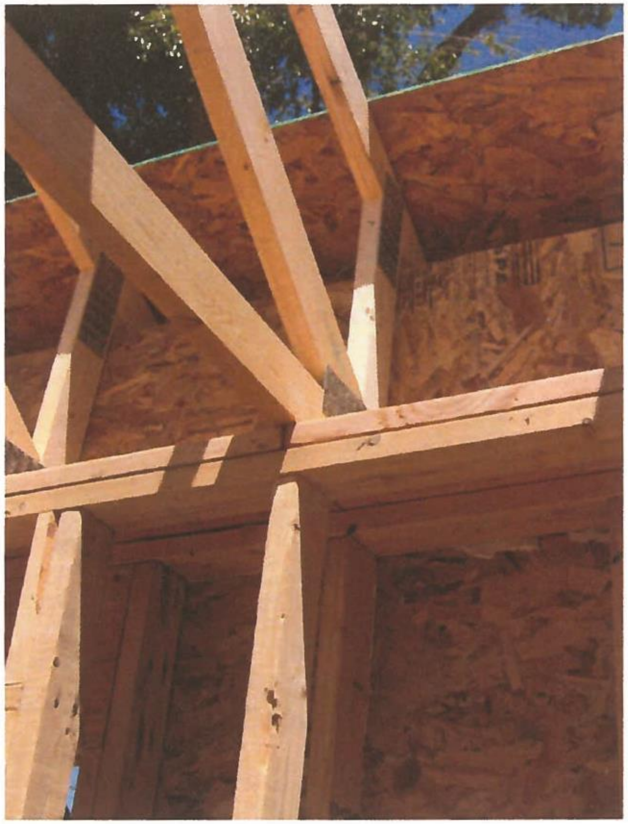
AAC Masonry Units

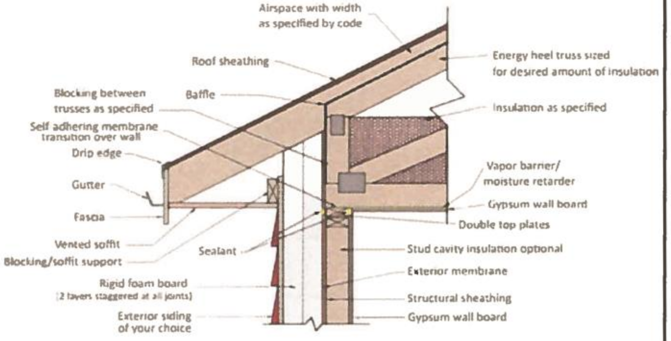
CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

PHA Passive House Academy

Roof: Raised Heel (Energy) Truss





SOURCE: REMOTE: Manual, COLD CLIMATE HOUSING RESEARCH CENTER

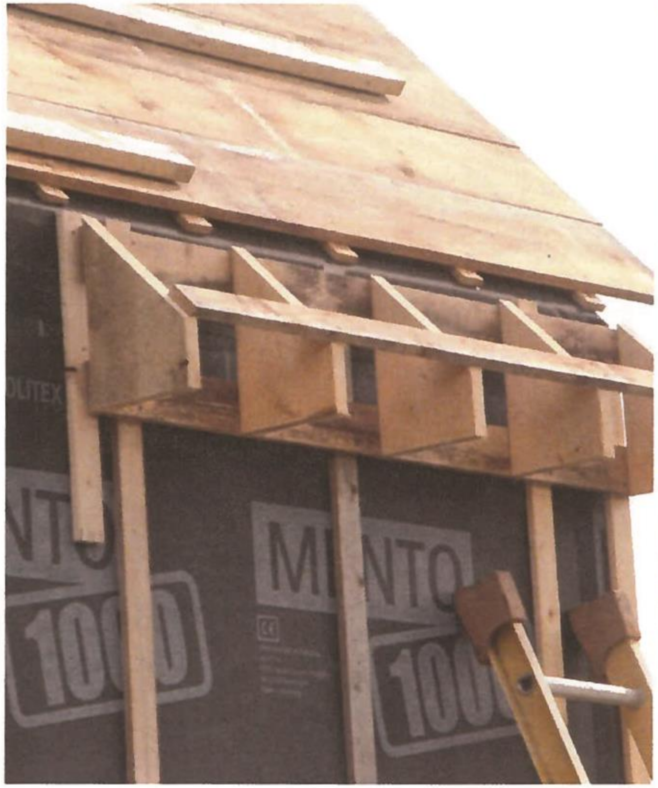
Passive House Envelopes

CTPH CONNECTICUT PASSIVE HOUSE

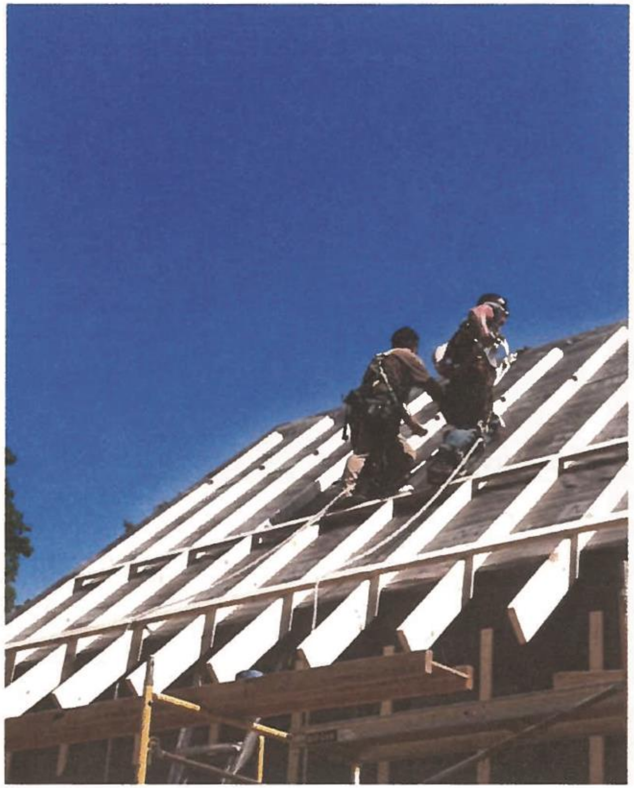
Insulation

PHA Passive House Academy

Roof: Thermal-Bridge Free Rafter Tails



SOURCE: Four Seven Five High Performance Building Supply

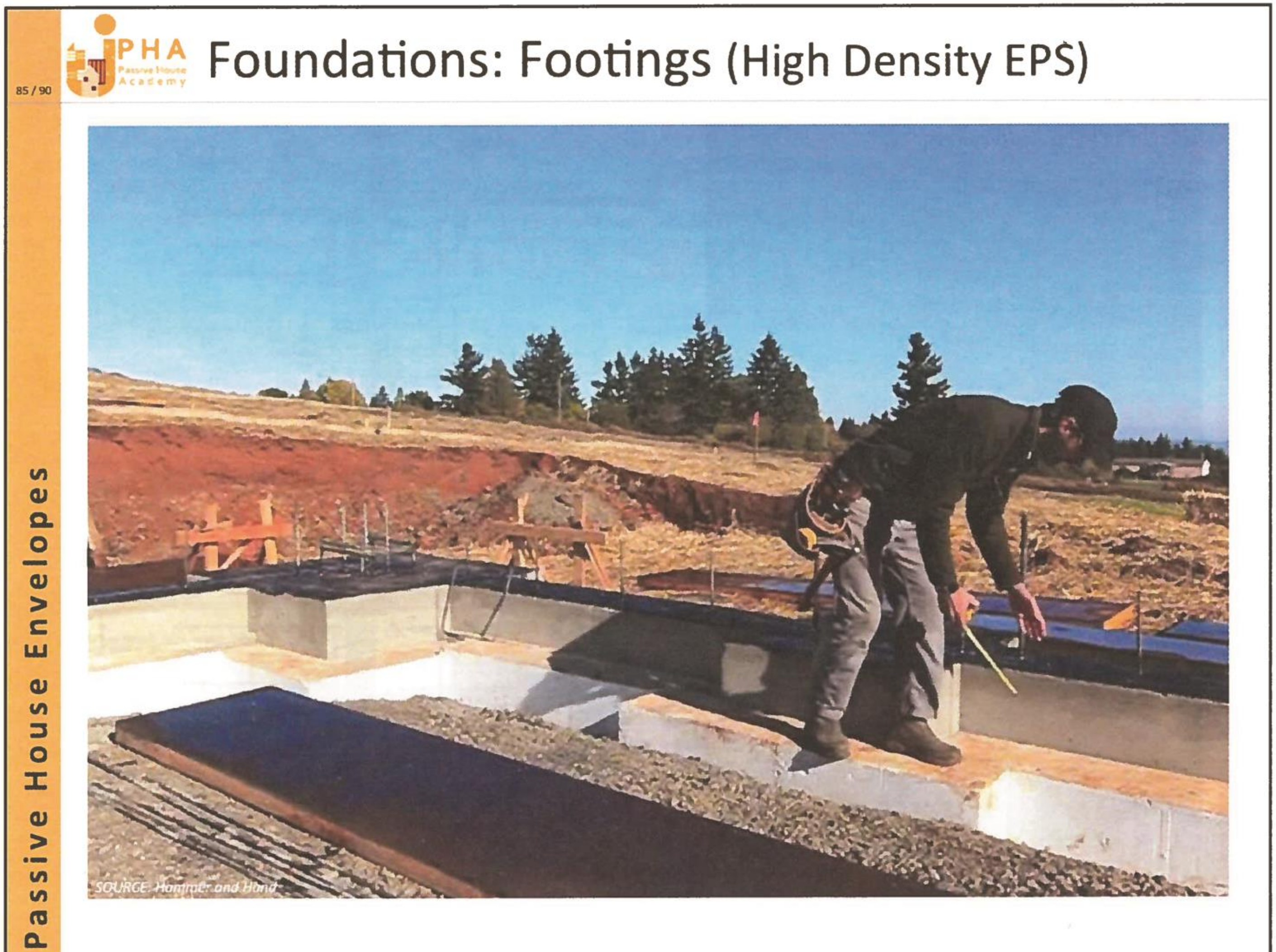


SOURCE: BLDGtyp, Wisconsin Cabin, 2012

Passive House Envelopes

CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

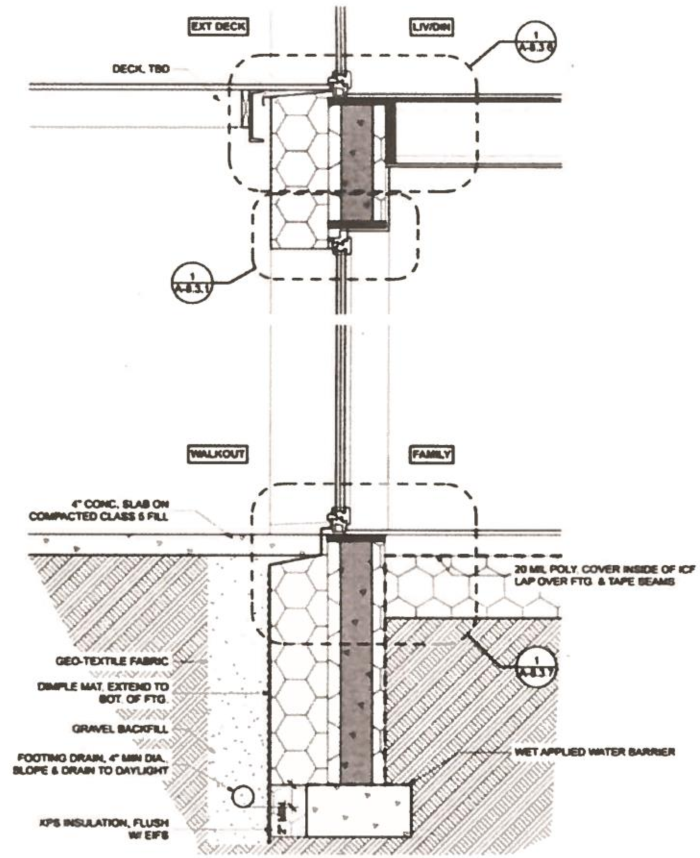


CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

PHA Passive House Academy

Foundations: ICF (Insulated Concrete Form)



SOURCE: *Mary James, Recreating the American Home*

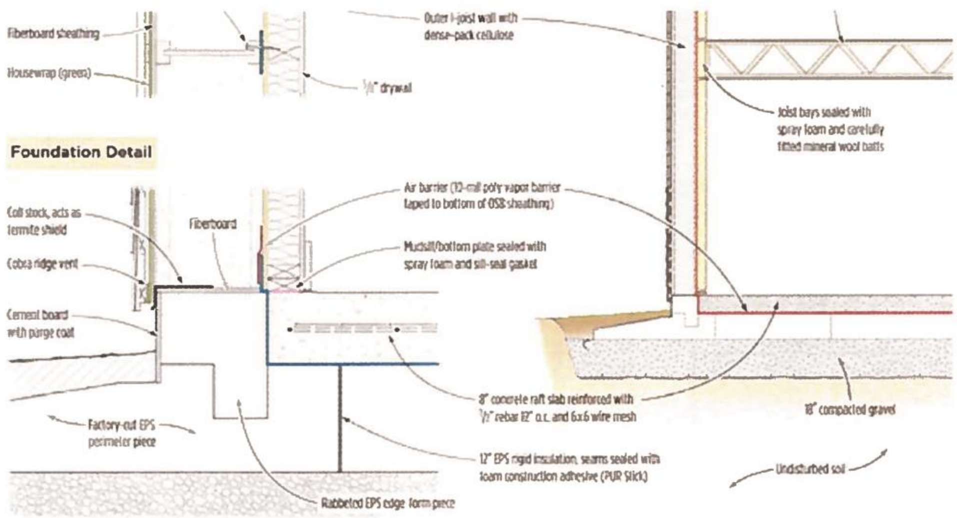
Passive House Envelopes

CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

PHA Passive House Academy

Foundations: Slab on Grade



MAY 2012 | JLC | 4

SOURCE: EcoCor, Chris Corson

Passive House Envelopes

CTPH CONNECTICUT PASSIVE HOUSE

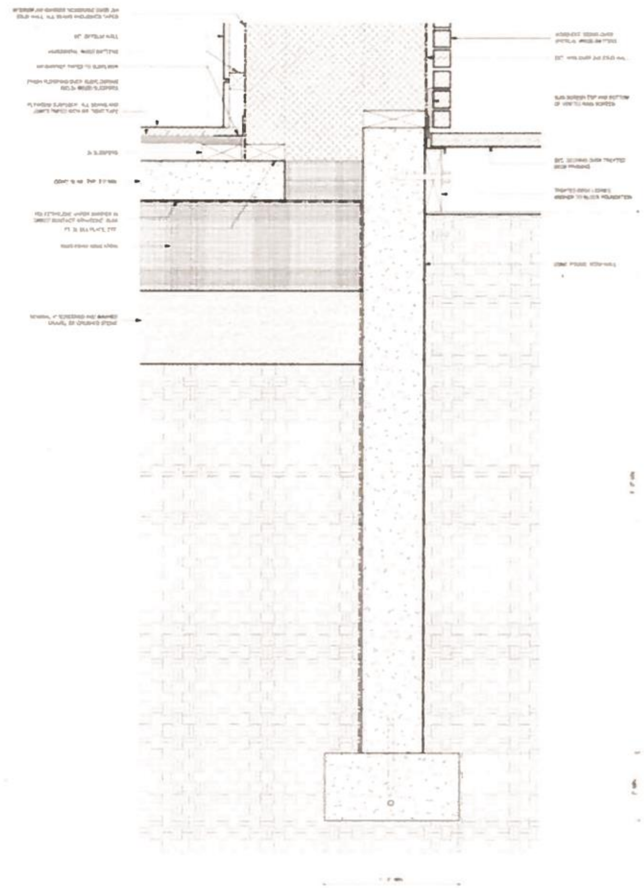
Insulation

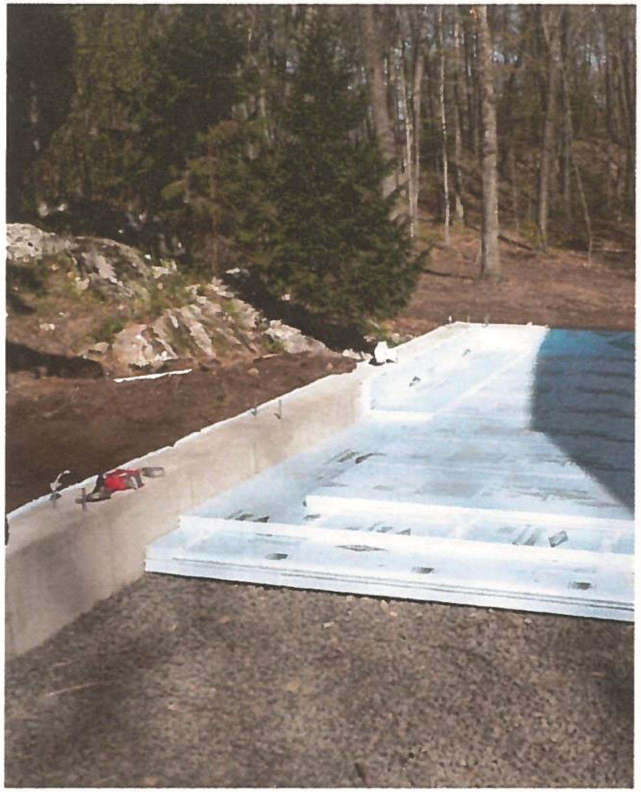
PHA Passive House Academy

88 / 90

Foundations: Sub-Slab Insulation

Passive House Envelopes





SOURCE: BLDGtyp. Anrcamdale Passive House
Source: Marcia + Tim's House Blog

CTPH
CONNECTICUT PASSIVE HOUSE

Insulation

5 Principles of Passive House

1. Insulation
2. **Thermal Bridge Free**
3. High-Performance Windows
4. Airtight
5. HVAC

CTPH
CONNECTICUT PASSIVE HOUSE

Thermal Bridge Free

DEFINITION

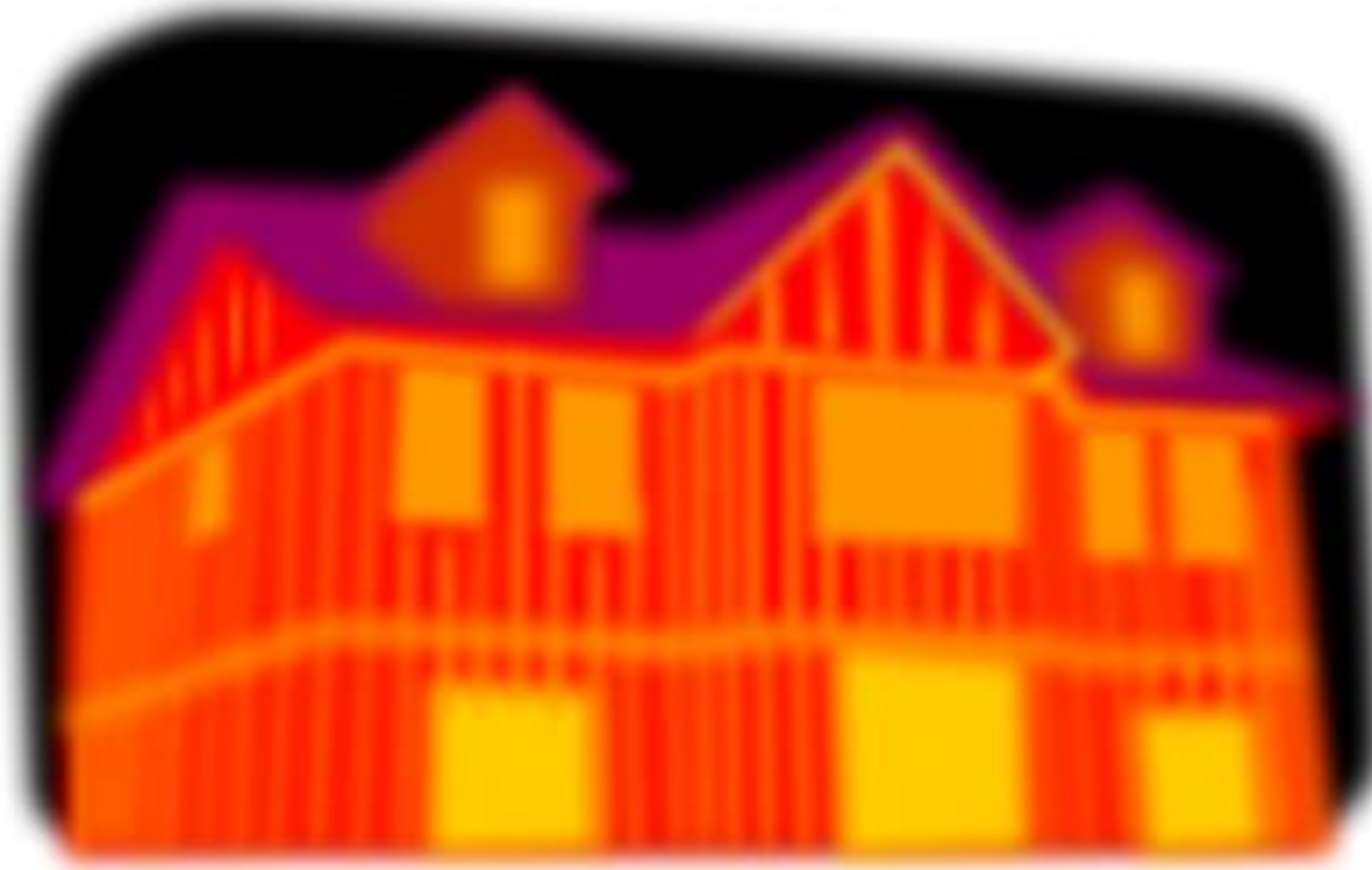
A **thermal bridge** (in construction) is a material component with a higher thermal conductivity than the surrounding materials, creating a path of least resistance for heat transfer.

- Thermal bridges impact the amount of energy required for heating and cooling.
- They cause condensation and other moisture related problems within the building & envelope.
- They cause thermal discomfort.
- They are bad.

CTPH
CONNECTICUT PASSIVE HOUSE

Thermal Bridge Free

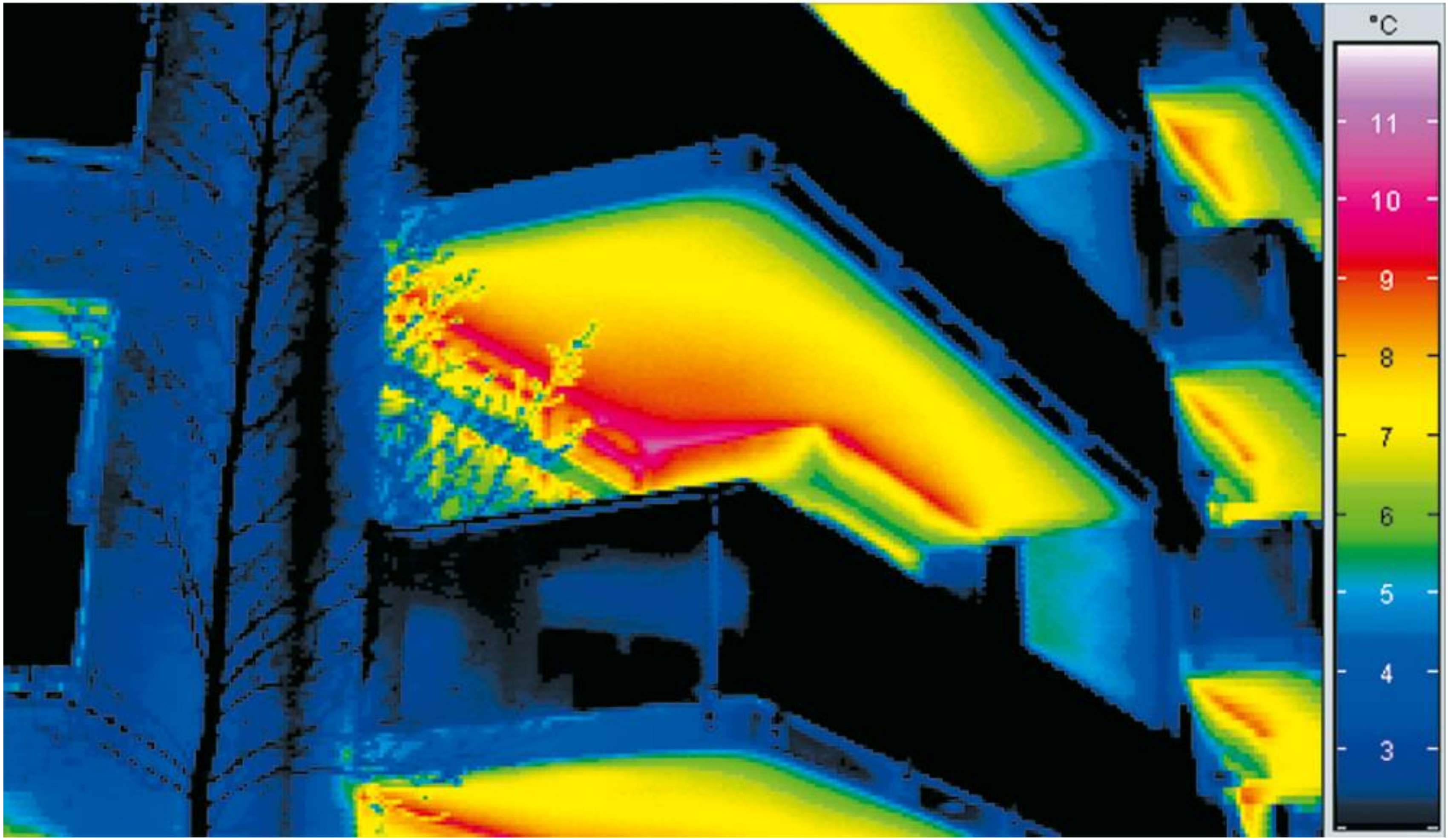
Thermal Bridge Free



CTPH
CONNECTICUT PASSIVE HOUSE

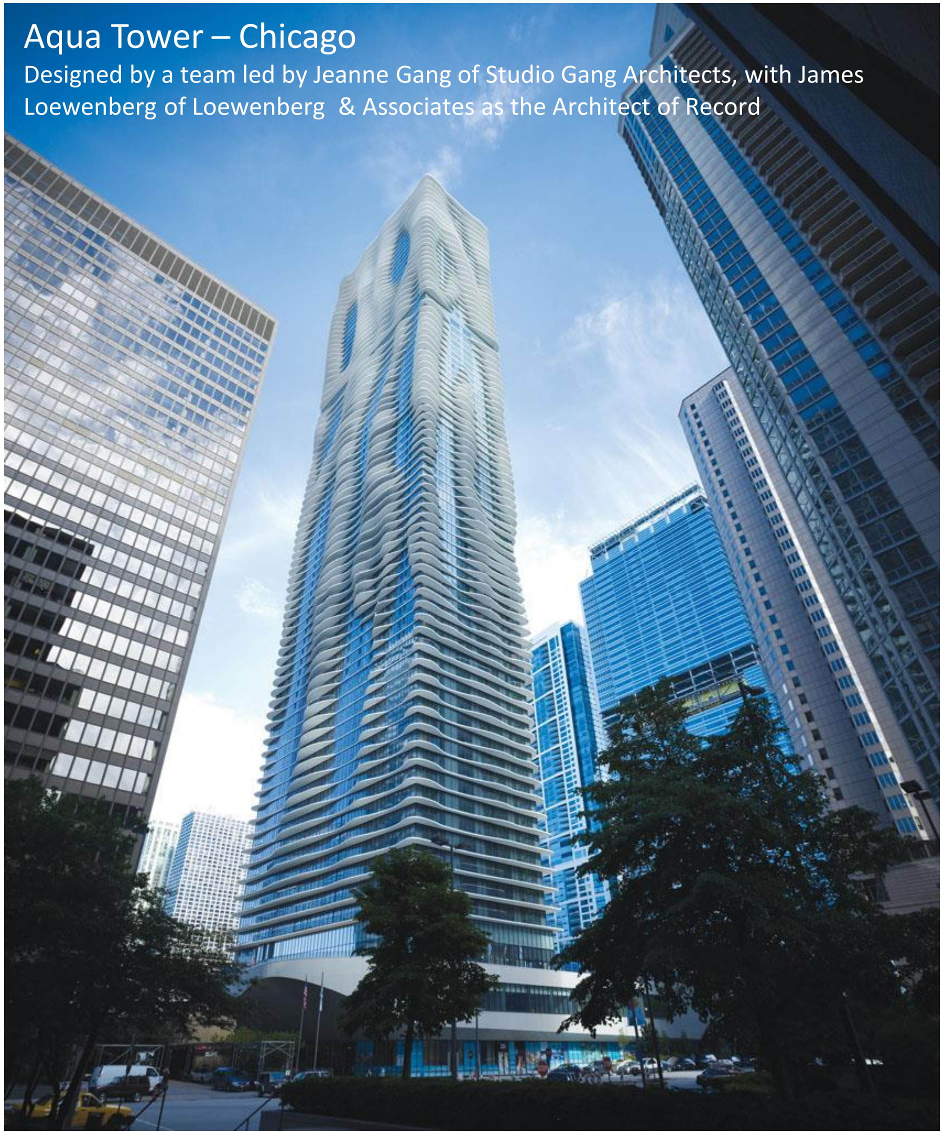
Thermal Bridge Free

Thermal Bridge Free



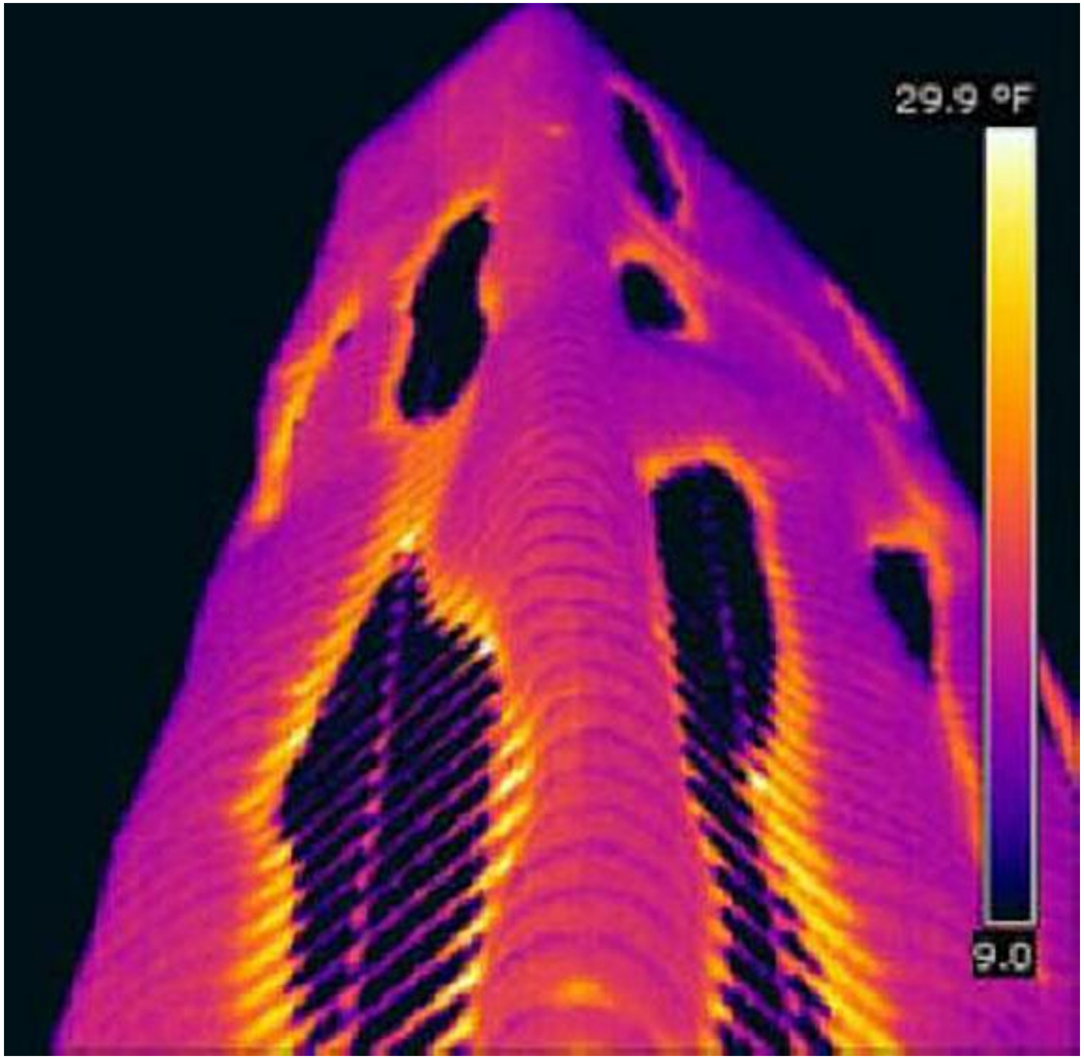
CTPH
CONNECTICUT PASSIVE HOUSE

Thermal Bridge Free



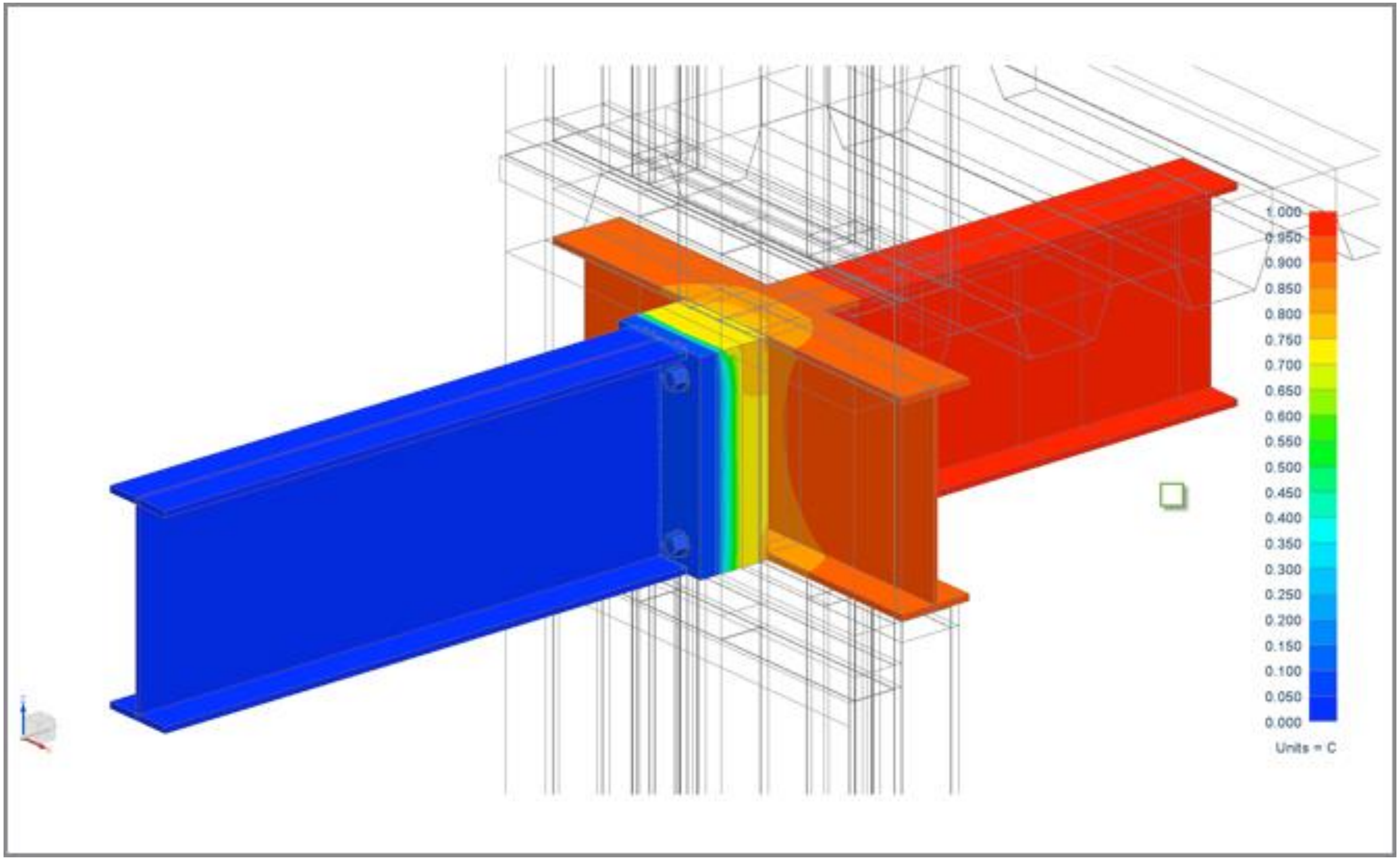
CTPH
CONNECTICUT PASSIVE HOUSE

Thermal Bridge Free



CTPH
CONNECTICUT PASSIVE HOUSE

Thermal Bridge Free

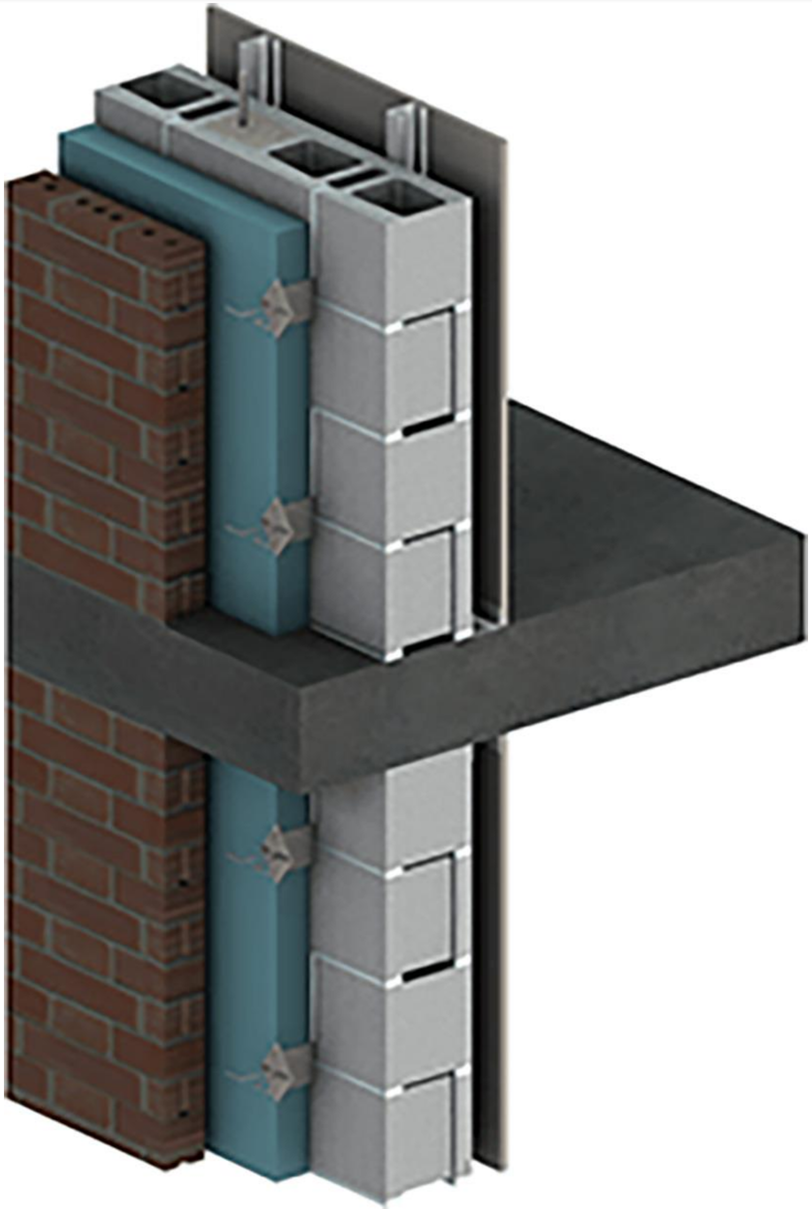


CTPH
CONNECTICUT PASSIVE HOUSE

Thermal Bridge Free

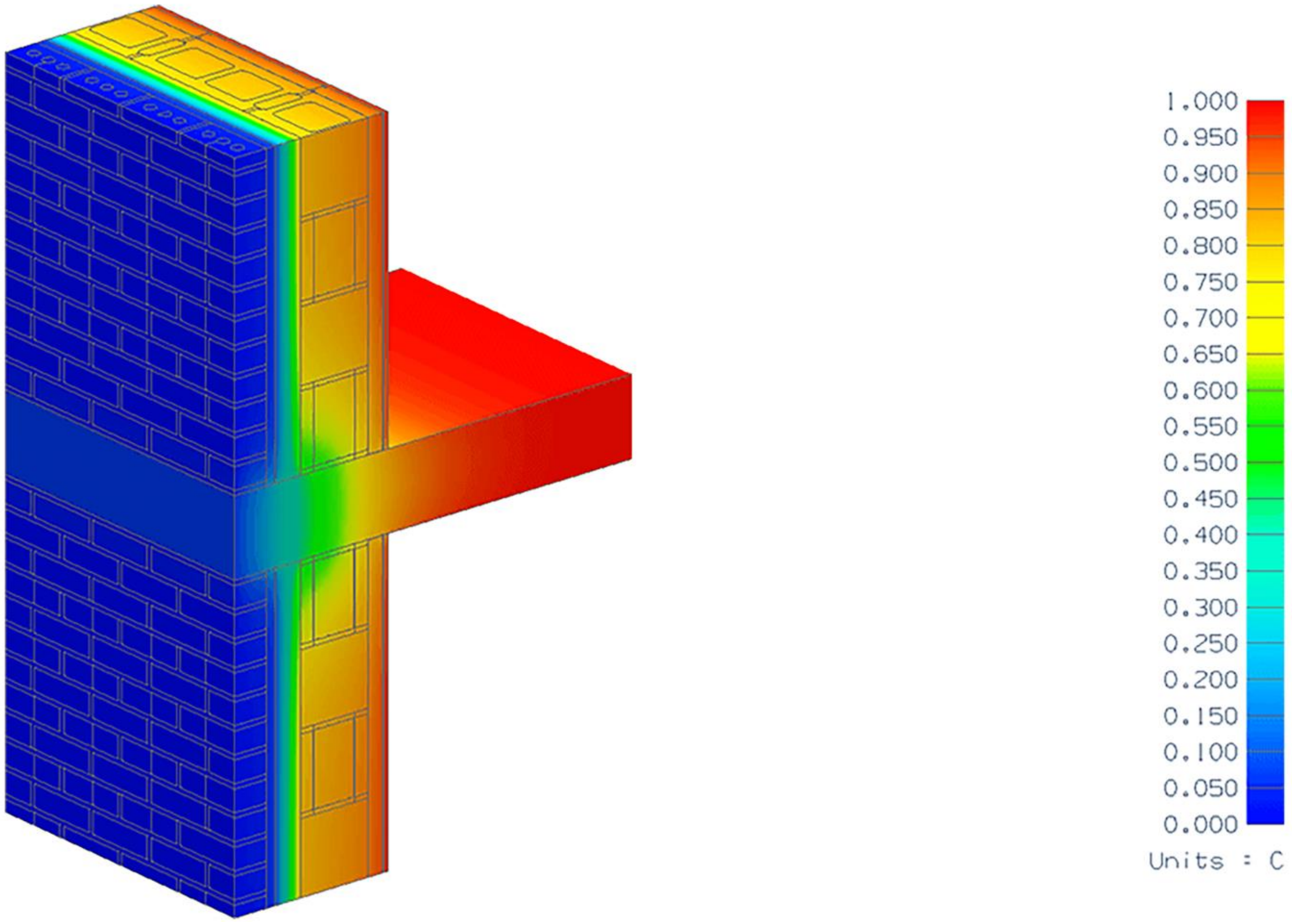
CTPH
CONNECTICUT PASSIVE HOUSE

Thermal Bridge Free



CTPH
CONNECTICUT PASSIVE HOUSE

Thermal Bridge Free

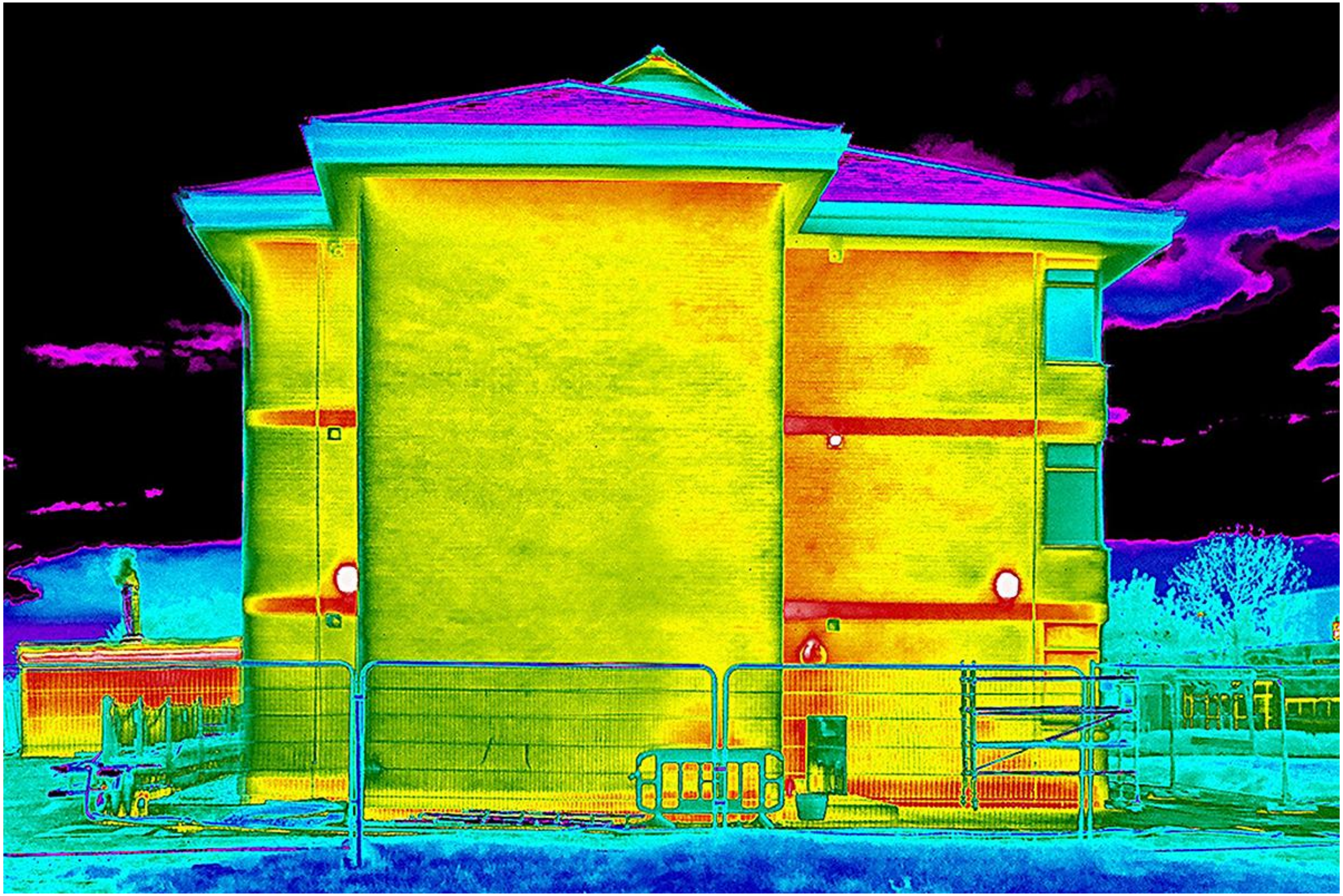


CTPH
CONNECTICUT PASSIVE HOUSE

Thermal Bridge Free

CTPH
CONNECTICUT PASSIVE HOUSE

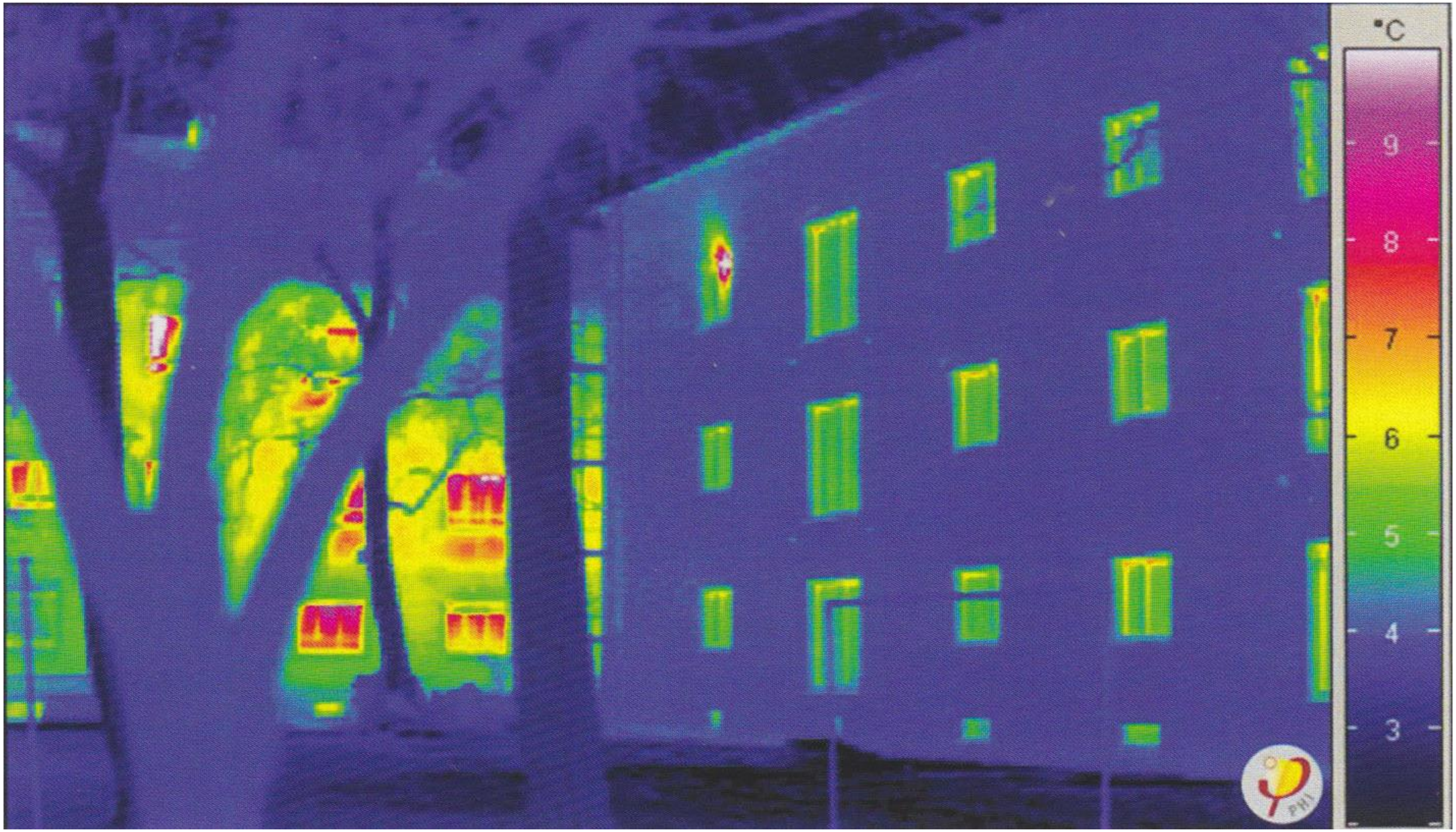
Thermal Bridge Free



CTPH
CONNECTICUT PASSIVE HOUSE

Thermal Bridge Free

Thermal Bridge Free



CTPH
CONNECTICUT PASSIVE HOUSE

5 Principles of Passive House

1. Insulation
2. Thermal Bridge Free
3. High-Performance Windows
4. Airtight
5. HVAC

Windows

Characteristics of Passive House Windows

1. Triple-glazing
2. Low-E
3. Gas-filled insulated glass units
4. Highly insulated frame
5. Low U-Value
6. Insulated glass edge
   (i.e. "warm edge" spacers)

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Triple-Glazing

As with most things in Passive House, we think about windows in terms of energy.

- *Single-glazed* with clear glass allows the highest transfer of energy (i.e. heat loss or heat gain depending on local climate conditions)

- *Triple-glazed* with coated glass allows a low transfer of energy.

CTPH
CONNECTICUT PASSIVE HOUSE

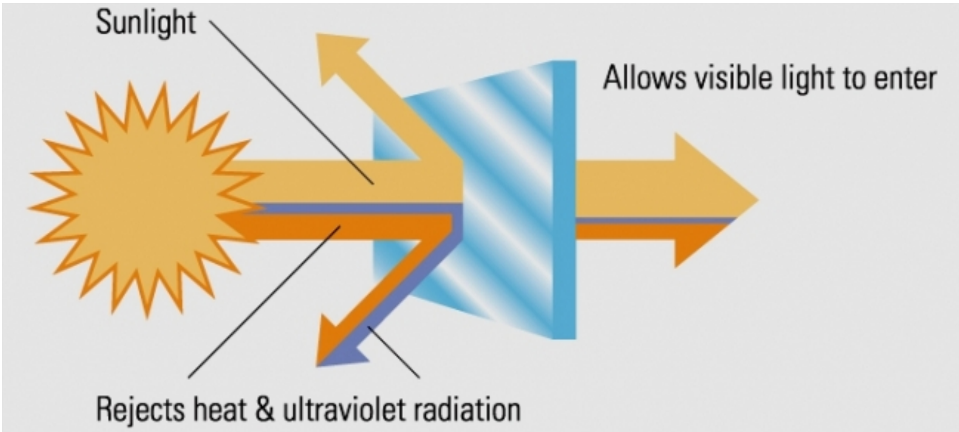
Windows

Low-E

= Low thermal emissivity

- Low-e coating reflects, absorbs, and emits radiant energy

- Keeps the energy (radiant heat) on the same side from which it originates while still letting in visible light.



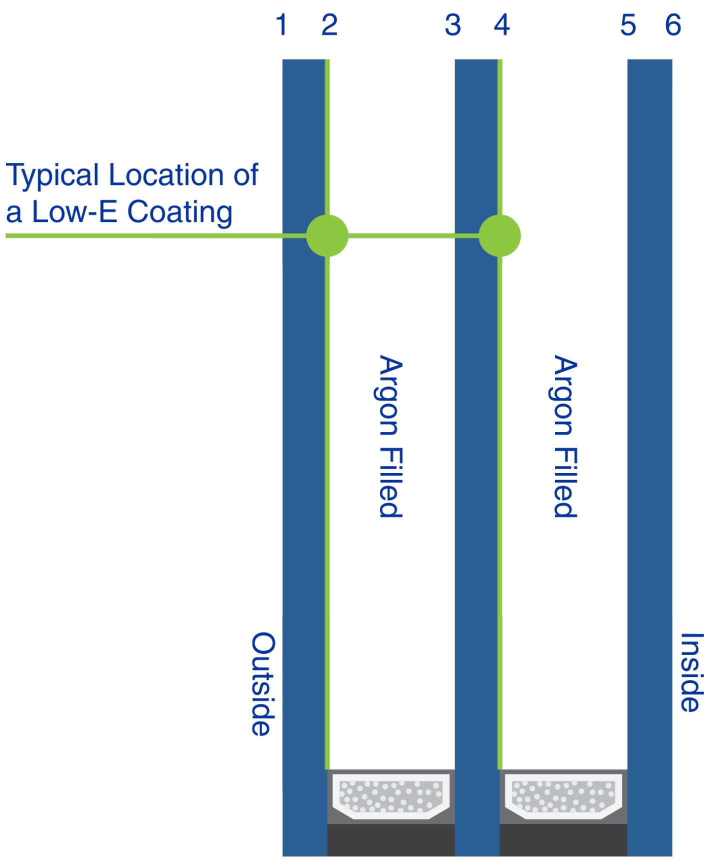
nachi.org

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Low-E

- Microscopically thin, transparent coating reflects radiant infrared energy (heat)
- Typically on glazing surfaces 2 & 4



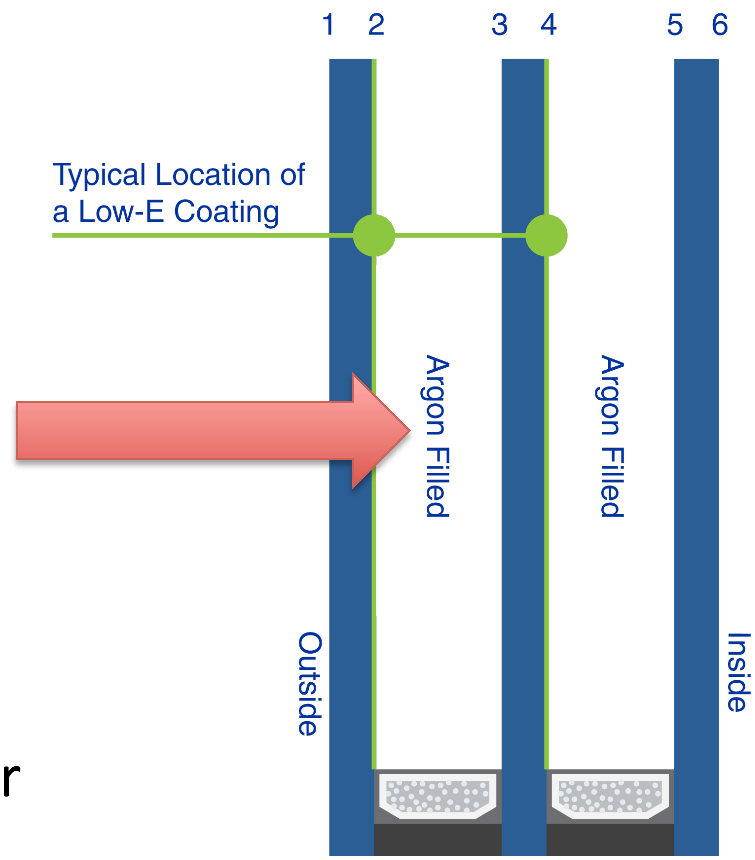
vitrum.ca

CONNECTICUT PASSIVE HOUSE

Windows

Gas-filled Insulating Glass Unit

- A noble (inert) gas, typically argon or krypton, within the vacuum
- Reduces heat transfer
- Argon has a 34% lower thermal conductivity than air.
- Krypton, more expensive, is a better insulator with 63% lower thermal conductivity than air.



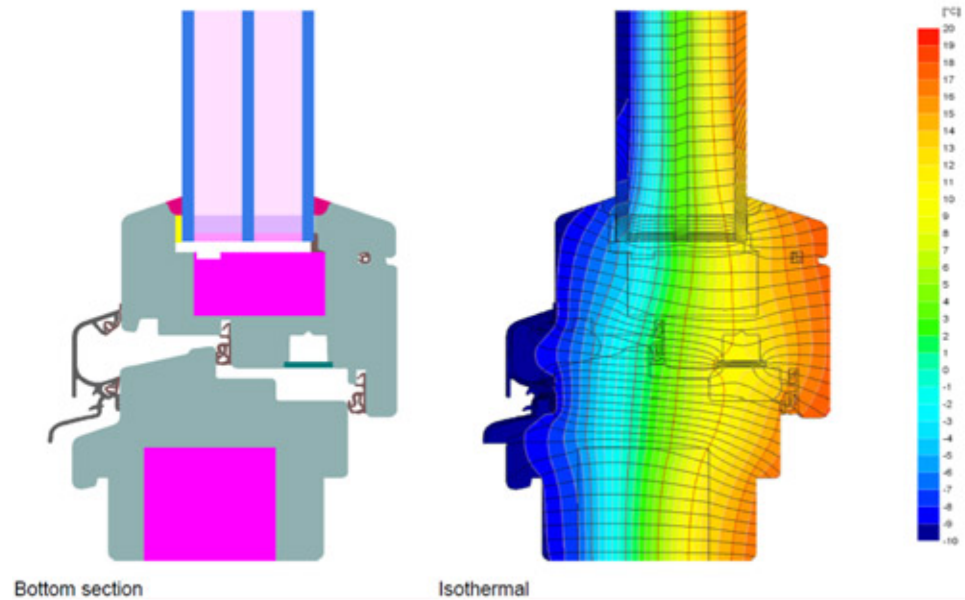
vitrum.ca

CTPH CONNECTICUT PASSIVE HOUSE

Windows

Insulated Frame

- Thermally broken = less heat energy is lost
- Made of any material – uPVC, wood, clad, etc
- Airtight



livingwoodwindows.co.uk

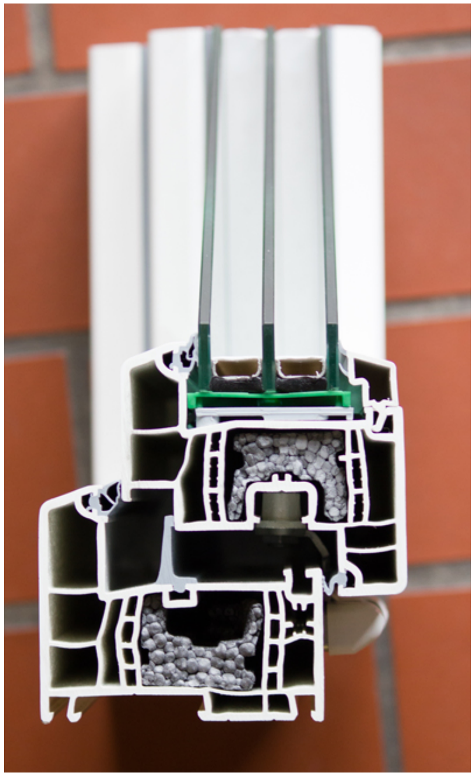
- The frame material is usually a poor insulator and loses more heat than the glass.
- Thinner styles offer more glass and less frame.

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Insulated Frame

Alpen Tyrol



WASCO GENEO

Zola ThermoPlus Clad

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

U-Value

- U-value is the "heat transfer coefficient," describing how well a building element conducts heat. The lower the number, the better the insulator. U-value is the inverse of…

- R-value which represents thermal resistance – the higher number the better the insulator.

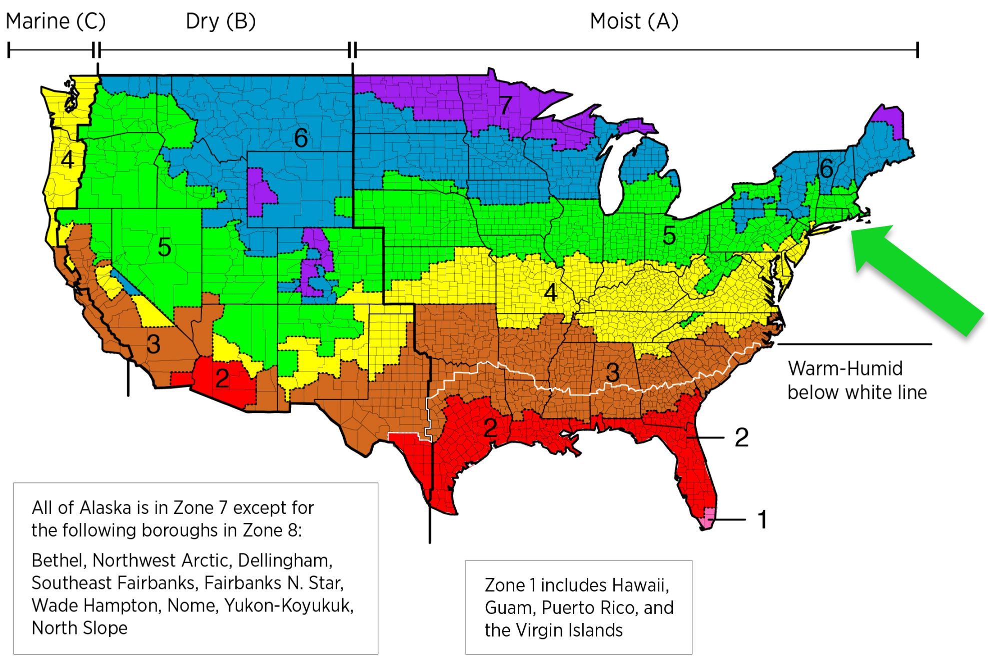
- Passive House windows are concerned about U-values for the entire window unit including all its components (glass, frame, spacers, etc)

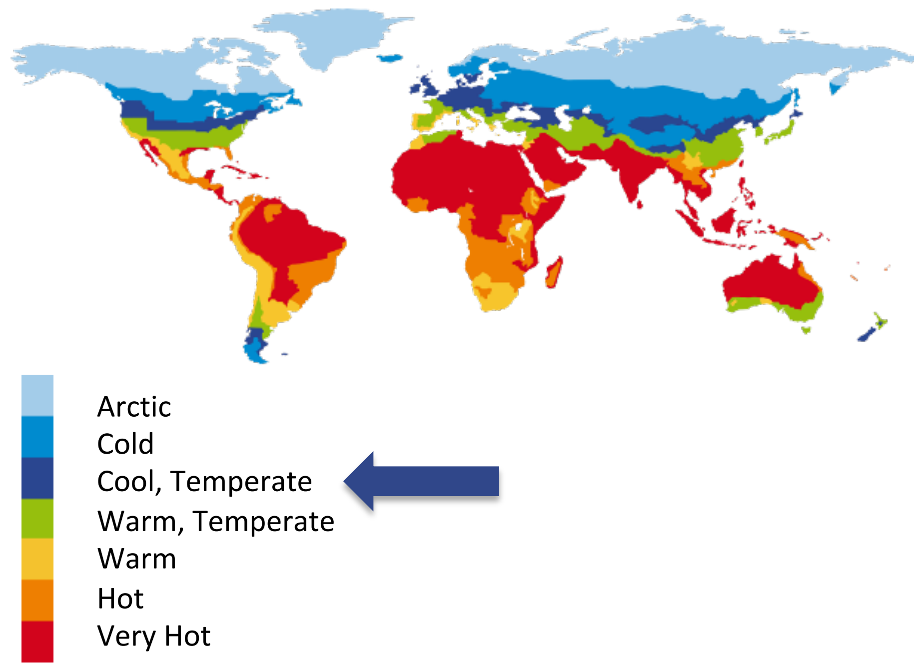
CTPH
CONNECTICUT PASSIVE HOUSE

Windows

PHIUS uses the US Climate Zone Map per 2009 International Energy Conservation Code (IECC)

PHI uses their own map for various climate regions for Passive House windows





PHIUS, in Climate Zone 5 requires:

- Center-of-glass U-value of less than or equal to 0.13 BTU/hr•SF•degree F
- Overall installed window U-Value of less than or equal to 0.14 BTU/hr•SF•degree F

PHI, in the Cool, Temperate climate requires:

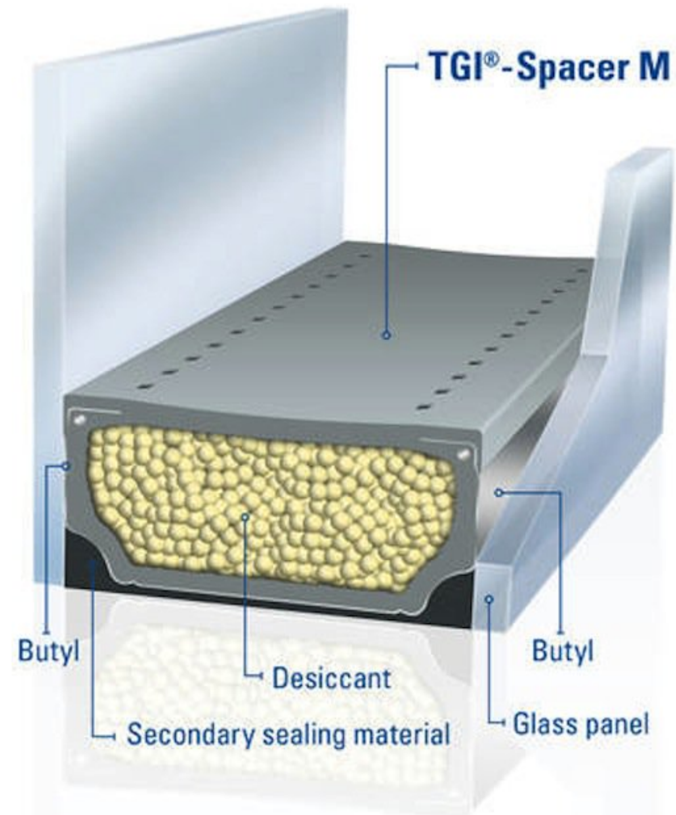
- Component U-value: maximum of 0.14 BTU/hr•SF•degree F
- U-value installed: maximum of 0.15 BTU/hr•SF•degree F

CONNECTICUT PASSIVE HOUSE

Windows

Warm-Edge Spacers

- Traditionally, spacers are aluminum, which is a very good conductor of heat and therefore, a thermal bridge.
- Warm-edge spacers made from plastic or composite materials conduct about half the heat of aluminum spacers.
- Even stainless steel outperforms aluminum



facilityexecutive.com

CTPH
CONNECTICUT PASSIVE HOUSE

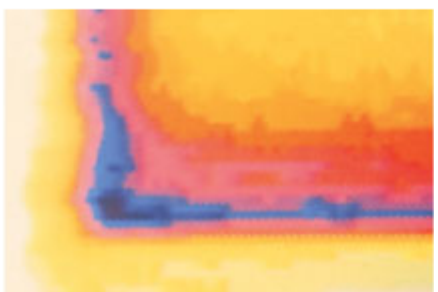
Windows

Warm-Edge Spacers

With aluminum spacer:

With composite spacer:

Condensation at window edge



Glass temperature at window edge

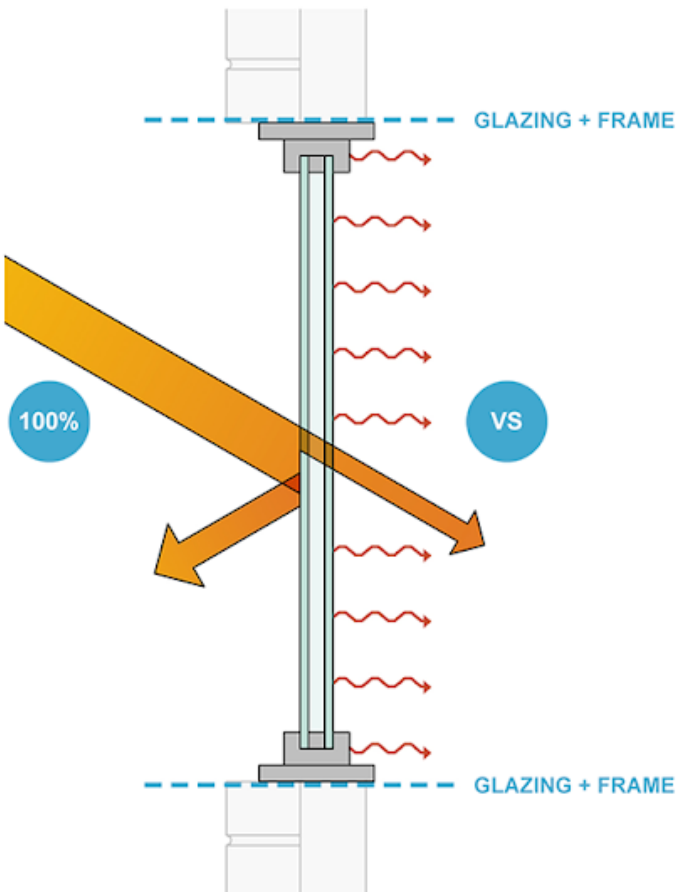
factoryinstalledwindows.com

Conditions:
Cold side temperature = 0°F
Room side temperature = 72°F
Room side relative humidity = 25%

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Solar Heat Gain Coefficient (SHGC)



SOLAR HEAT GAIN COEFFICIENT (SHGC)

danieloverbey.blogspot.com

- The SHGC is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward.

- SHGC represents the ability of glazing assembly (including both the glass and frame) to resist heat gain from solar radiation.

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Solar Heat Gain Coefficient (SHGC)

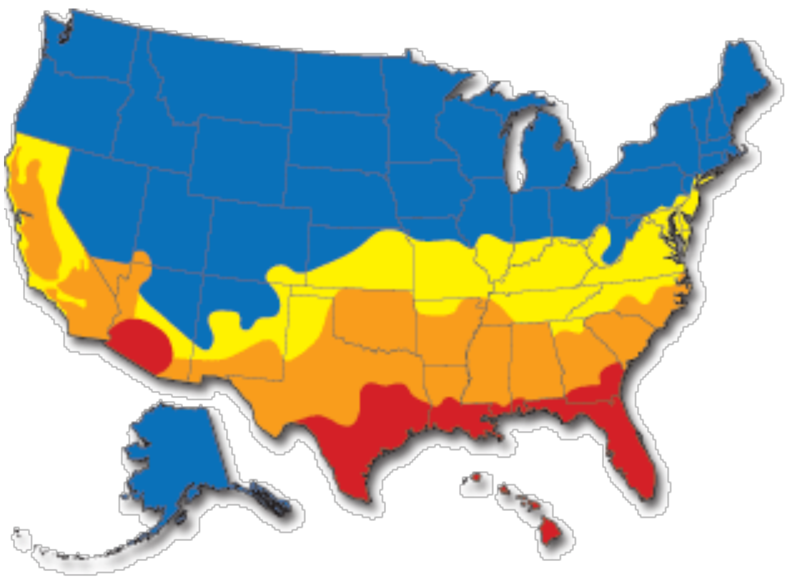
- SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits.
- A *low* SHGC indicates good resistance. Only a small percentage of the sun's rays makes it through the window, helpful when cooling is the dominant need.
- A *high* SHGC indicates poor resistance. Most of the solar radiation arriving to the window is getting inside and turning into heat.
- Used strategically, SHGC can work in your favor.

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Solar Heat Gain Coefficient (SHGC)

ENERGY STAR* zones:



Northern Zone (mostly heating)
North/Central Zone (heating & cooling)
South/Central Zone (heating & cooling)
Southern Zone (mostly cooling)

* Determined by The Department of Energy (DOE) and the Environmental Protection Agency (EPA)

- Solar heat gain can provide free heat in the winter but can also lead to overheating in the summer.

- How to best balance solar heat gain with an appropriate SHGC depends upon:
  - climate
  - orientation
  - shading conditions
  - and other factors

CTPH CONNECTICUT PASSIVE HOUSE

Windows

Solar Heat Gain Coefficient (SHGC)

Representative Solar Heat Gain Coefficients (SHGC)

Description*	***SHGC****
Single glazing, uncoated clear	0.71
Single glazing, gray	0.53
Double glazing, uncoated clear / clear	0.61
Double glazing, uncoated high-performance green / clear	0.35
Double glazing, clear low-e (0.2) on surface 3	0.57
Double glazing, clear low-e (0.2) on surface 2 / clear	0.53
Double glazing, clear low-e (0.1) on surface 2 / clear	0.45
Triple glazing, clear / clear / clear	0.54
Triple glazing, high-performance green / clear / clear	0.31
Triple glazing, low-e (0.2) on surface 2 / clear / clear	0.47
Triple glazing, low-e (0.1) on surface 2 / clear / clear	0.33
Triple glazing, low-e (0.05) on surface 2 / low-e (0.05) on surface 4 / clear	0.24

** All with 1/4 in. panes.*

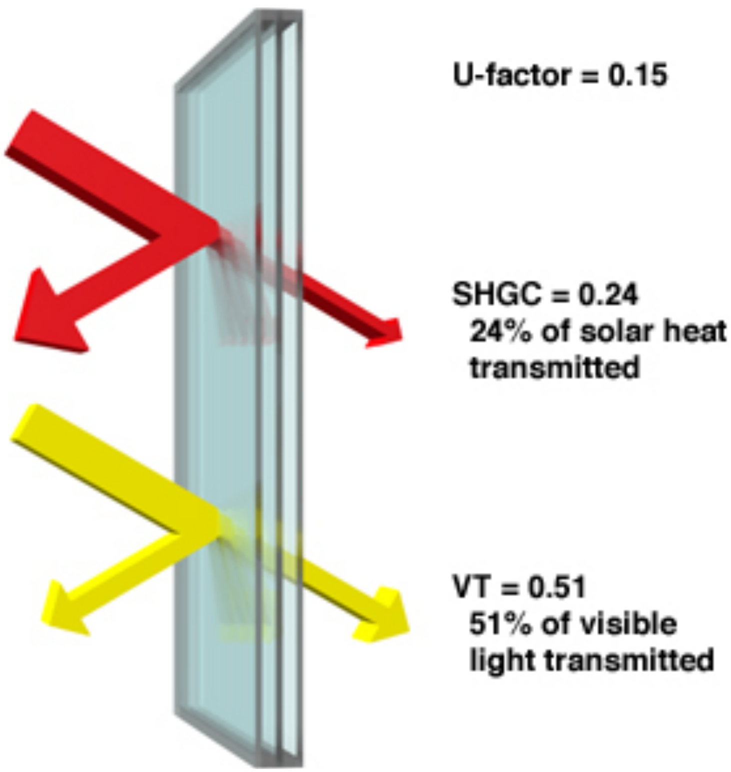
** Assembly SHGC values.*

Adapted from Walter Grondzik, et al., Mechanical and Electrical Equipment for Buildings, *John Wiley & Sons (2010)*

danieloverbey.blogspot.com

Windows

A Good Window



efficientwindows.org

Triple-Glazed, Low-solar-gain, Low-E Glass
= a window is best suited for climates with both significant heating and cooling loads.

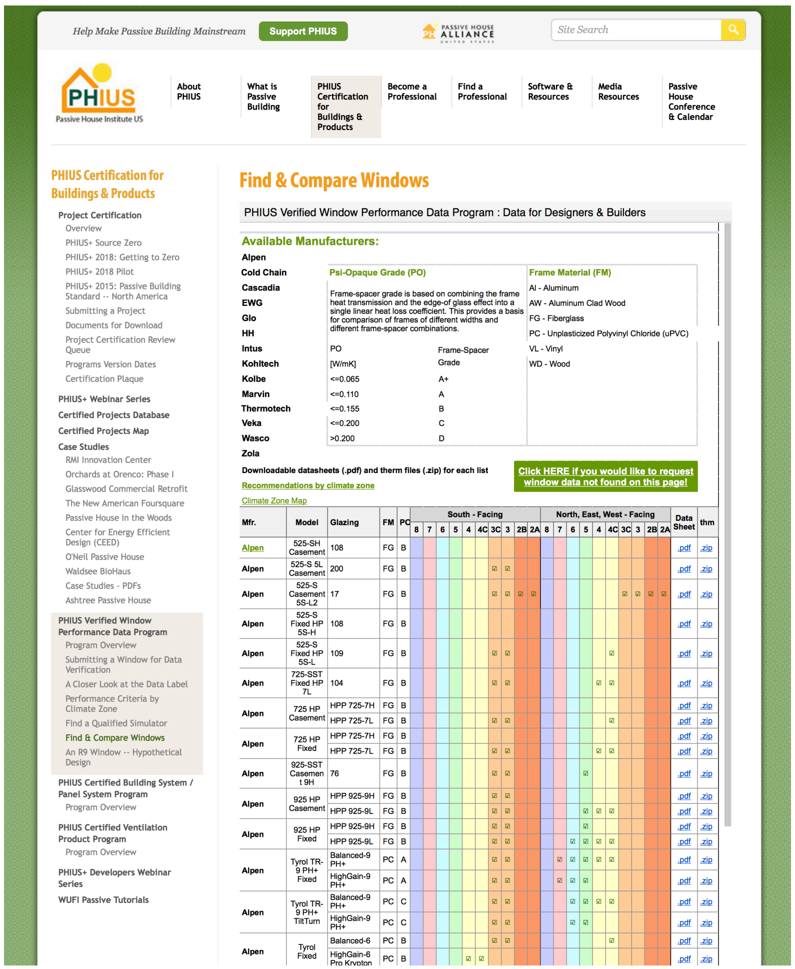
- Three glazing layers
  (The middle layer can be glass or suspended plastic film)
- Two low-e coatings
- Gas-filled
  (½" argon gas or ¼" krypton gas fill between glazing)
- Low-conductance edge-spacers
- Low U-value (=low heat loss rate)
- Low SHGC (= low solar radiation transfer) *or*
  High SHGC (= high solar radiation transfer)
  used strategically with orientation

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

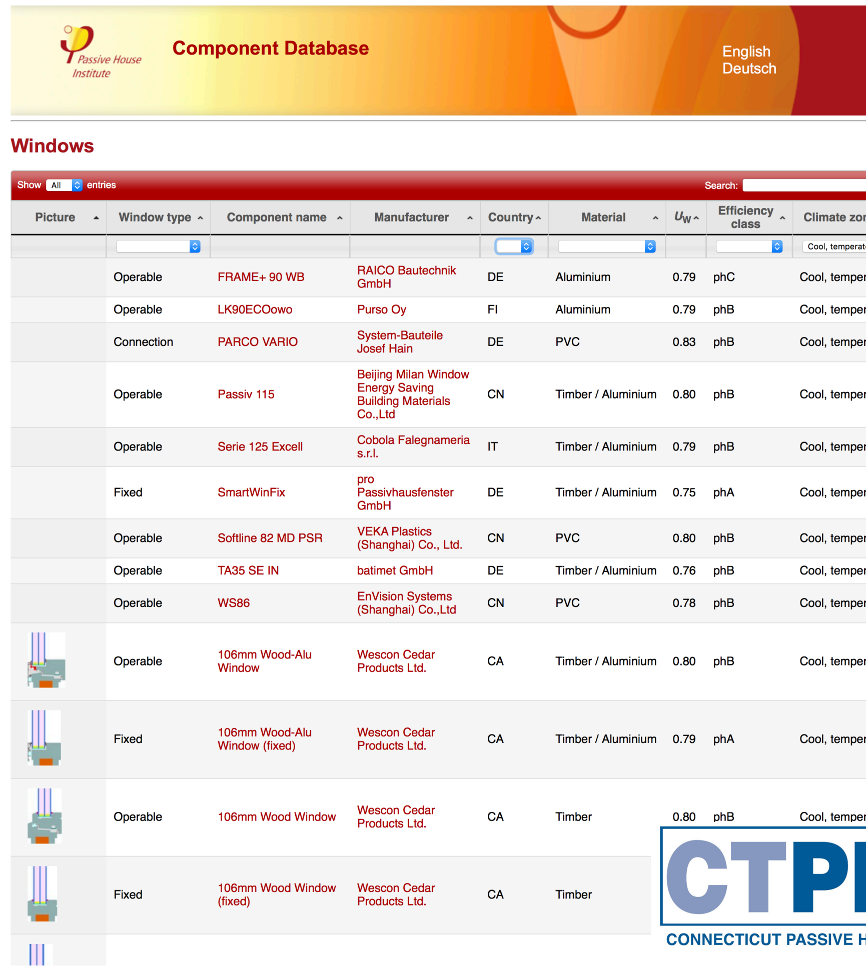
PHIUS-Verified windows

phius.org



PHI-Certified windows

database.passivehouse.com



CTPH
CONNECTICUT PASSIVE HOUSE

Windows

PHIUS-Verified windows

phius.org

PHI-Certified windows

database.passivehouse.com

North American Manufacturers

PHIUS-Verified:

Alpen*
Cascadia**
Glo European Windows*
HH Windows & Doors, Inc.*
Intus*
Kohltech**
Kolbe*
Marvin*
Thermotech**
Veka*
WASCO*
Zola Windows*

PHI-Certified:

Alpen*
Cascadia Windows & Doors**
Deceuninck North America*
EuroLine Windows Inc.**
Innotech Windows + Doors, Inc.**
REHAU Construction (WASCO)*
Wescon Cedar Products Ltd.**
Westeck Windows & Doors**
Zola Windows*

** US*
*** Canada*

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Orientation

- Window area and placement must be carefully designed to balance heat loss and heat gain because solar orientation impacts solar gain.

- Optimizing windows means considering the solar gain in the context of other aspects of design... Passive House is INTEGRATED DESIGN.

- Passive House design methodology often results in large window areas on the south façade, with minimal amounts of windows on the east, west, and especially the north façade.

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Thermal Comfort

- Thermal comfort is important for health and well-being.

- A lack of thermal comfort causes stress among building occupants. When they are too warm, people can feel tired; when too cold, they can be restless and distracted.

- It has more to do than just air temperature; it's also balanced with humidity and air movement.

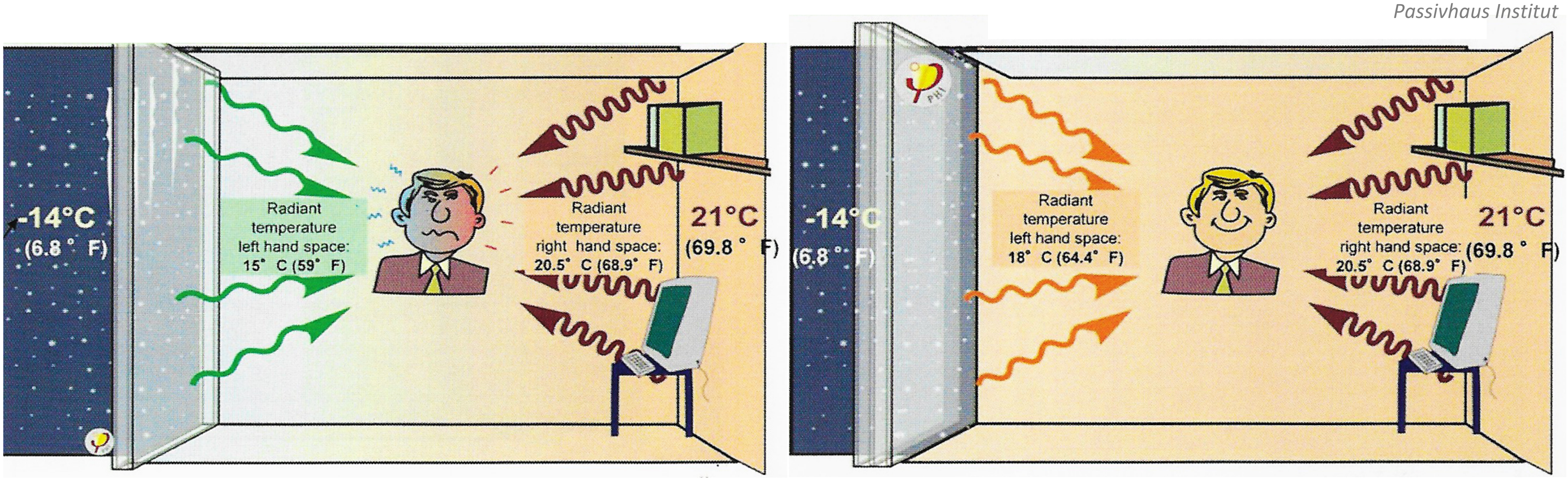
- High-performance windows are one component of the whole building's integrated design.

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Thermal Comfort

Passivhaus Institut



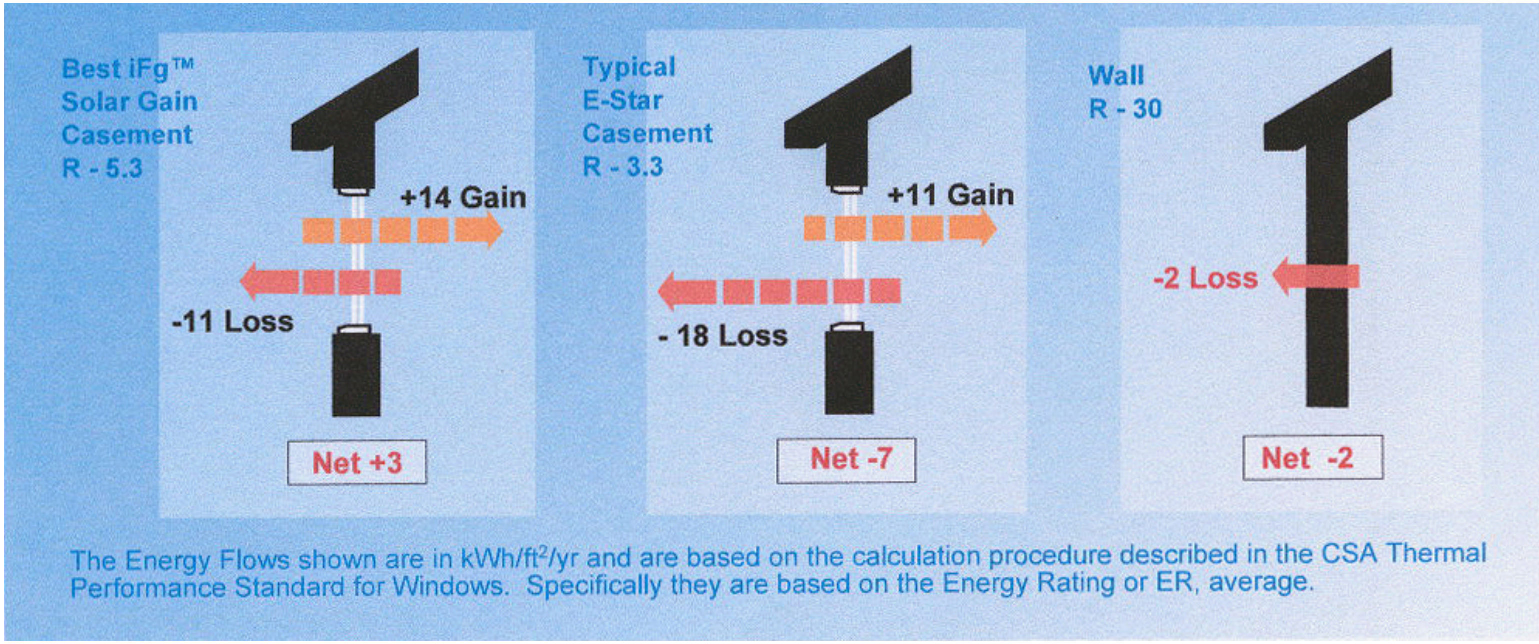
- In cold climates, poorly insulated windows will cause relatively cold surfaces at the façade and will require active heating near the windows to compensate for cold air drops, drafts, and "cold radiation" caused by the cold.
- The radiant temperature asymmetry is too high. A compensating heating surface near the window is required.

- Highly insulated windows will make an <u>active contribution</u> to increasing the level of comfort.
- Thermal comfort needs are met without a radiator placed under the window.

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Positive Energy



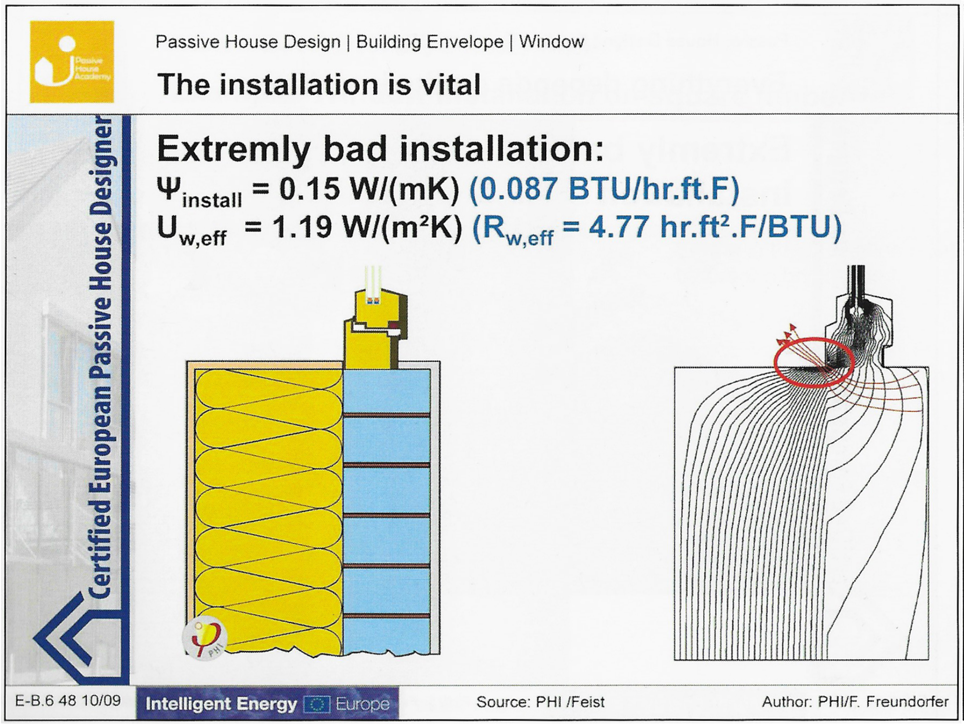
thermotechfiberglassfenestration.com

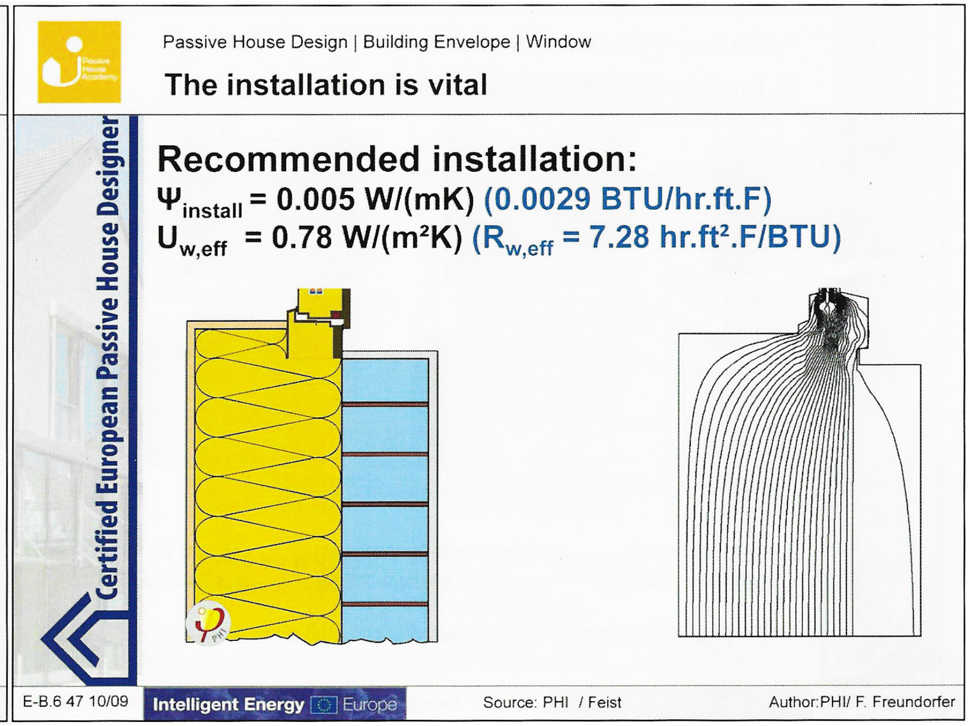
- Net-gain energy
- In cold climates, capturing and retaining heating-season solar gains is critical to making buildings energy efficient.
- In a heating climate, having windows that are more energy efficient than walls is key.

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

Optimized Installation





Installation-based thermal bridge occurs at corner of frame and wall.

Window is in line with the insulation layer and the frame is covered, preferably entirely, with insulation.

PHI

CTPH
CONNECTICUT PASSIVE HOUSE

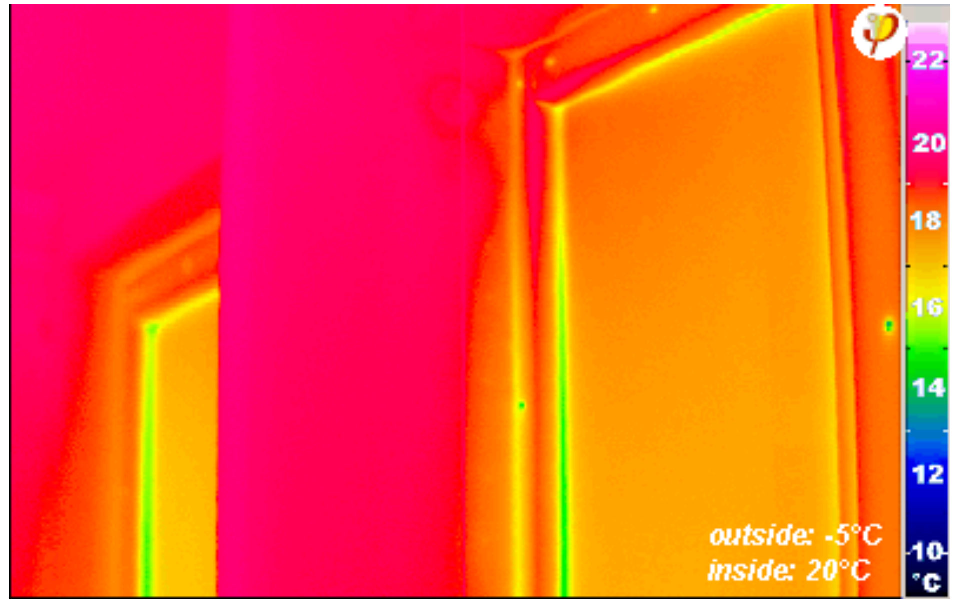
Windows

Infrared image of an insulated glass window in an old building:

outside: 23°F
inside: 68°F

- The average surface temperatures are less than 57°F here.
- The installation also shows conspicuous thermal bridging especially at the concrete lintel.

Infrared image of a Passive House window from the inside.



outside: 23°F
inside: 68°F

- All surfaces (window frame, casements, and glazing) are pleasantly warm (above 62°F).
- The temperature doesn't fall below 59°F even at the glass edge.

passipedia.org

CTPH
CONNECTICUT PASSIVE HOUSE

Windows

You SHOULD open the windows

- With the right conditions, opening windows is the cheapest, easiest, most effective and environmentally friendly way of cooling your building with cross ventilation.
- Even in cold periods, it’s nice to open the windows to get a blast of fresh air, for example during a party.
- Connection to the outside world
- Cleaning
- Egress

CTPH
CONNECTICUT PASSIVE HOUSE

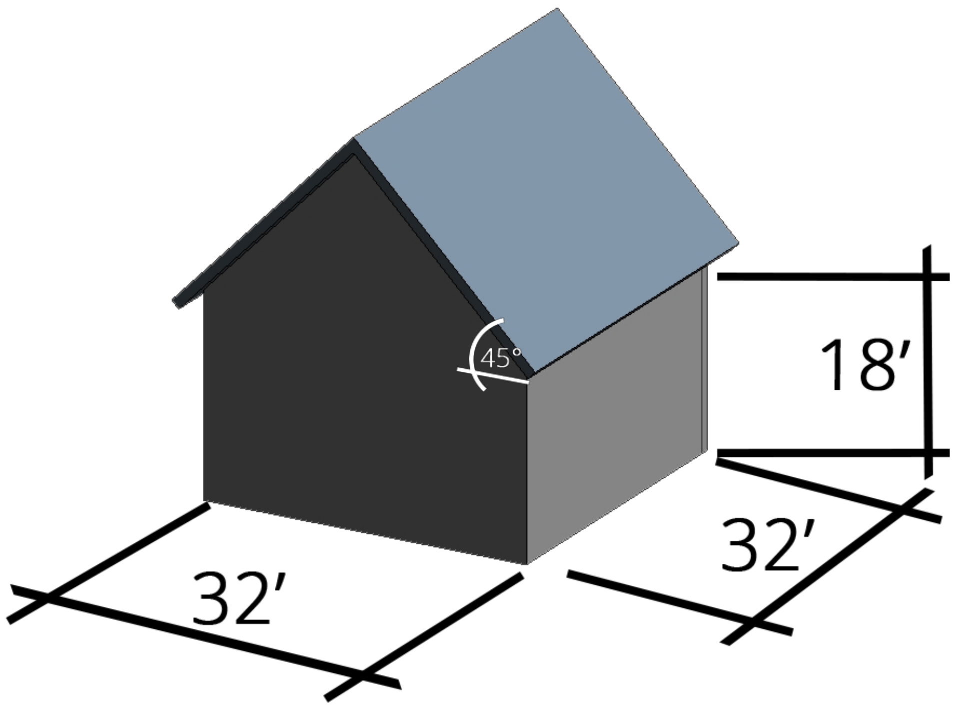
5 Principles of Passive House

1. Insulation
2. Thermal Bridge Free
3. High-Performance Windows
4. **Airtight**
5. HVAC

CTPH
CONNECTICUT PASSIVE HOUSE

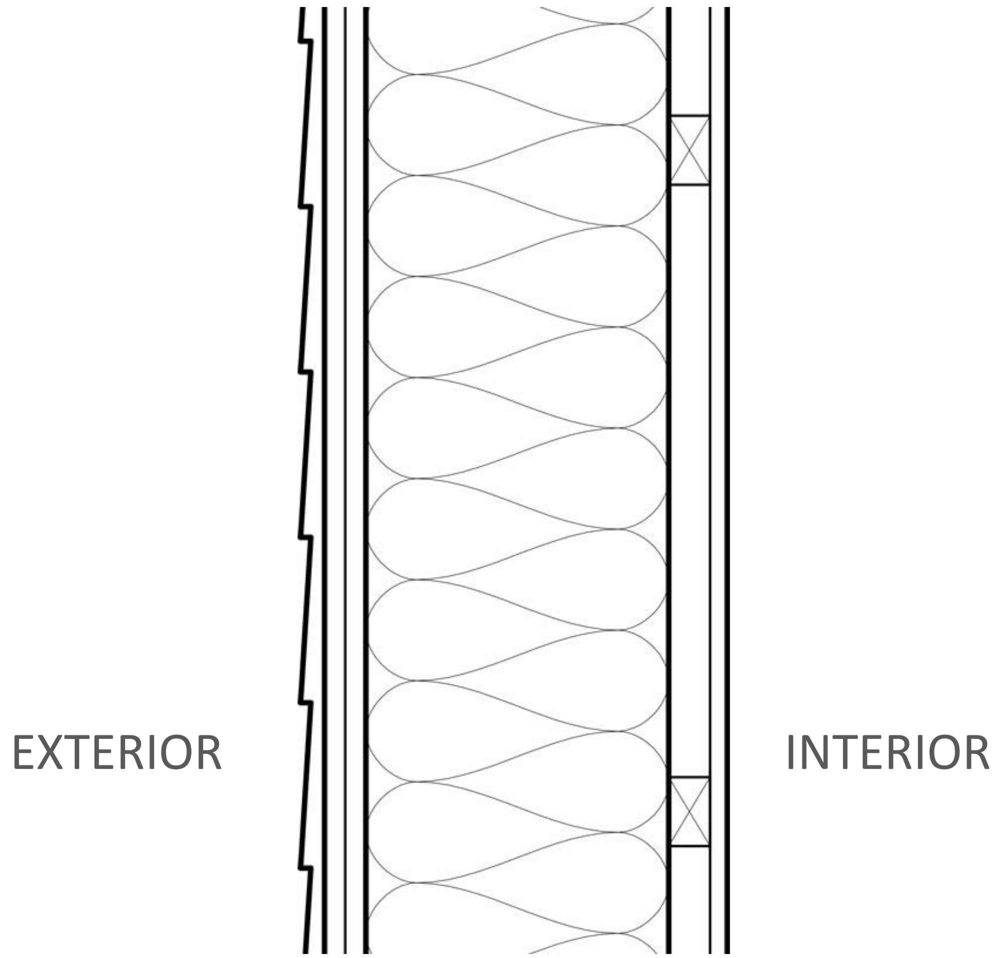
Airtight

Let’s start with a generic building:



Airtight

With generic walls, roof and floor

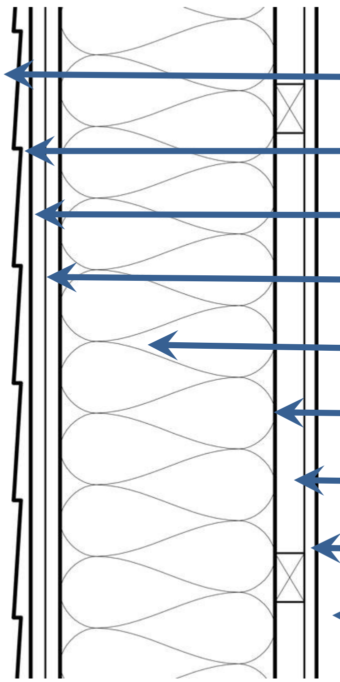


CTPH
CONNECTICUT PASSIVE HOUSE

Airtight

For this example:
The walls, roof and floor will be the same R-Value

EXTERIOR



INTERIOR

	R-VALUES
AIR FILM	.17
SIDING	.79
BUILDING WRAP	.06
SHEATHING	.63
STRUCTURE / INSULATION	46.30
AIR BARRIER	.00
SERVICE CAVITY	.92
SHEETROCK	.45
AIR FILM	.68

R-VALUE = 50

CTPH
CONNECTICUT PASSIVE HOUSE

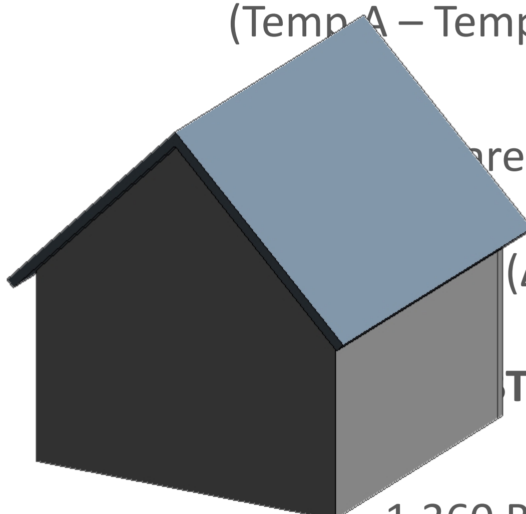
Airtight

Heat Transferred Through the Envelope / hour:

Surface Area

x

(Temp A – Temp B) / R Value of Assembly



re foot (Surface Area)

x

(ΔT) / 50 (R Value)

=

TUs per hour / Sq Ft

1.360 BTUs / hour / Sq Ft

x

5,288 Sq Ft of Surface Area

=

7,192 BTUs per hour through enclosure

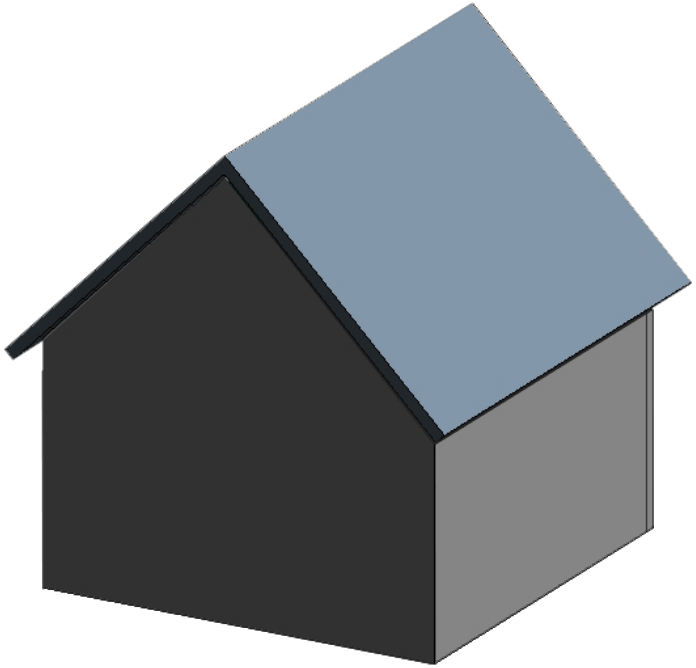
CTPH
CONNECTICUT PASSIVE HOUSE

Airtight

But what about infiltration?

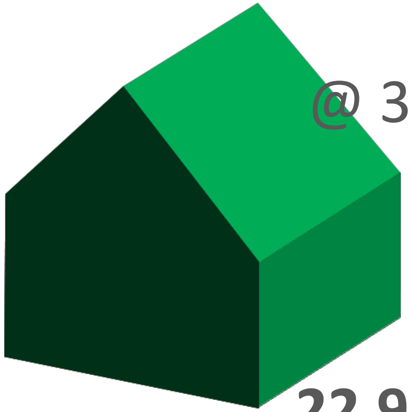
CTPH
CONNECTICUT PASSIVE HOUSE

Airtight



Airtight

VOLUME OF AIR:



@ 32’ x 32’ x 18’

\+

ATTIC

=

22,950 cubic feet

CTPH
CONNECTICUT PASSIVE HOUSE

Airtight

Assumptions:

- Specific Heat of Air (Cp): 0.240 BTU / pound (of air) / degree Fahrenheit
- Specific Density: 0.075 Pounds per cubic foot
- Air Density is determined @ Sea Level / 70°F
- BTU = British Thermal Unit
- Heat travels from warm to less warm

CTPH
CONNECTICUT PASSIVE HOUSE

Airtight

So,

The amount of heat to raise 1 cubic foot of air 1°F:

0.018 BTU / Cubic Foot / 1°F

x

ΔT of 68°F (0°F outside, 68°F inside)

=

1.224 BTUs / Cubic Foot Infiltration

CTPH CONNECTICUT PASSIVE HOUSE

Airtight

One Air Change Each Hour:

22,950 Cubic Feet

x

1.224 BTUs / Cubic Foot

=

28,091 BTUs / Hour

CTPH
CONNECTICUT PASSIVE HOUSE

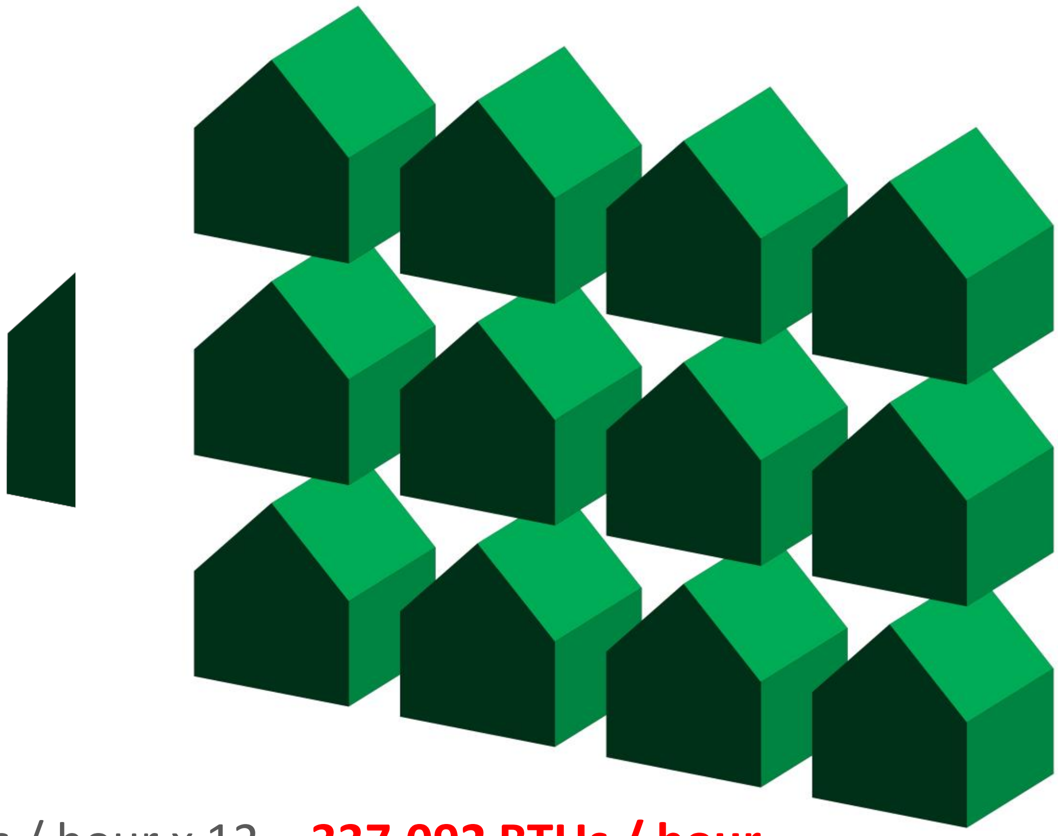
Airtight

Consider an old New England house:

Airtight

Consider an old New England house:

12 air changes per hour is not unusual.



28,091 BTUs / hour x 12 = **337,092 BTUs / hour**

(That's a lot!)

CTPH CONNECTICUT PASSIVE HOUSE

Airtight

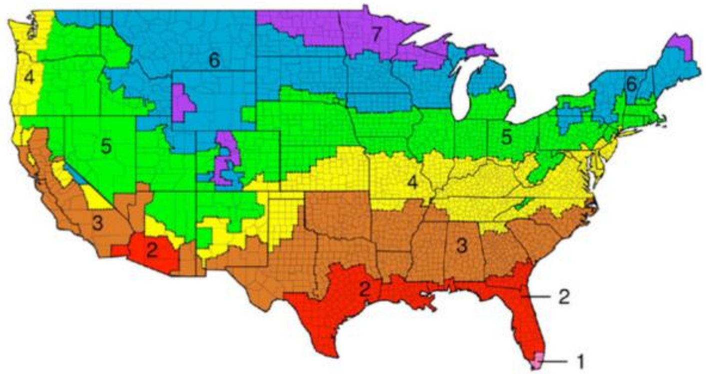
In 2009, the IECC introduced requirements for air changes.

BUILDING TECHNOLOGIES PROGRAM | **AIR LEAKAGE GUIDE**

DEFINITIONS
As defined according to 2012 IECC:

BUILDING
Any structure used or intended for supporting or sheltering any use or occupancy, including any mechanical systems, service water heating systems and electric power and lighting systems located on the building site and supporting the building.

BUILDING THERMAL ENVELOPE
The basement walls, exterior walls, floor, roof, and any other building elements that enclose *conditioned space* or provide a boundary between *conditioned space* and exempt or unconditioned space.



All of Alaska in Zone 7
except for the following buroughs in Zone 8:

- Bethel
- Dellingham
- Fairbanks N.Star
- Nome
- North Slope
- Northwest Arctic
- Southeast Fairbanks
- Wade Hampton
- Yukon-Koyukuk

Zone 1 includes:

- Hawaii
- Guam
- Puerto Rico
- Virgin Islands

Figure 2: Climate zones (by county) for the 2012 IECC

We are Climate Zone 5

Climate Zone	2009 IECC	2012 IECC
1 - 2	< 7 ACH	≤ 5 ACH @ 50 pascals
3 - 8	< 7 ACH @ 50 pascals	≤ 3 ACH @ 50 pascals

Table 1: 2009 vs. 2012 IECC Comparisons

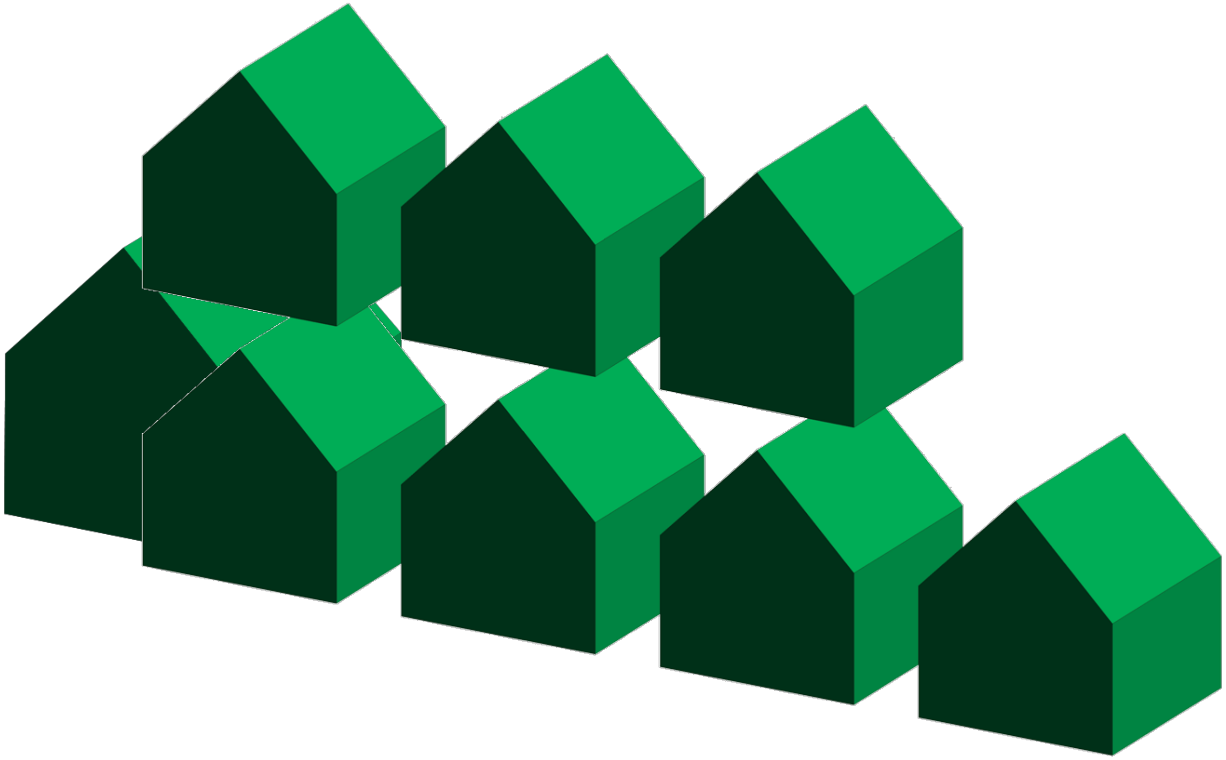
R402.4 Air leakage (Mandatory)
The building thermal envelope shall be constructed to limit air leakage in accordance with the requirements of Sections R402.4.1 through R402.4.4.

CTPH
CONNECTICUT PASSIVE HOUSE

Airtight

In 2009, the IECC introduced requirements for air changes.

The magic number was < 7 air changes / hour



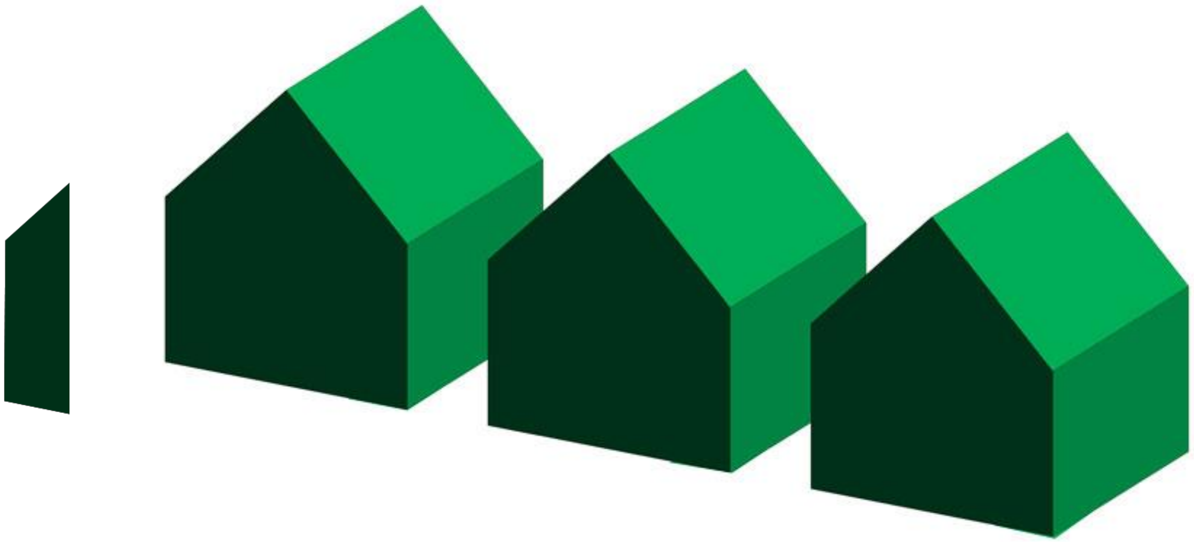
28,091 BTUs / hour x 7 = **196,637 BTUs / hour**

A little bit better.

CTPH
CONNECTICUT PASSIVE HOUSE

Airtight

In 2012, the IECC reduced the number to 3 air changes / hour.



28,091 BTUs / hour x 3 = **86,703 BTUs / hour**

Better still - but still not good enough.

CTPH
CONNECTICUT PASSIVE HOUSE

Airtight

86,703 BTUs / hour is a big number.

Compared to the amount of
Heat lost through the envelope:
7,192 BTUs / hour

To get control of this
we need even fewer air changes per hour

CTPH
CONNECTICUT PASSIVE HOUSE

Airtight

The maximum allowed air changes per hour
for Passive House is
0.6 air changes per hour

(even less is better)

16,854 BTUs / hour
This amount appears manageable

CTPH
CONNECTICUT PASSIVE HOUSE

Airtight

CONSIDER:

high R Value walls, roof & floor

+

very little infiltration

=

very small heating & cooling load

=

very small heating & cooling equipment

=

significant cost, space and energy savings…

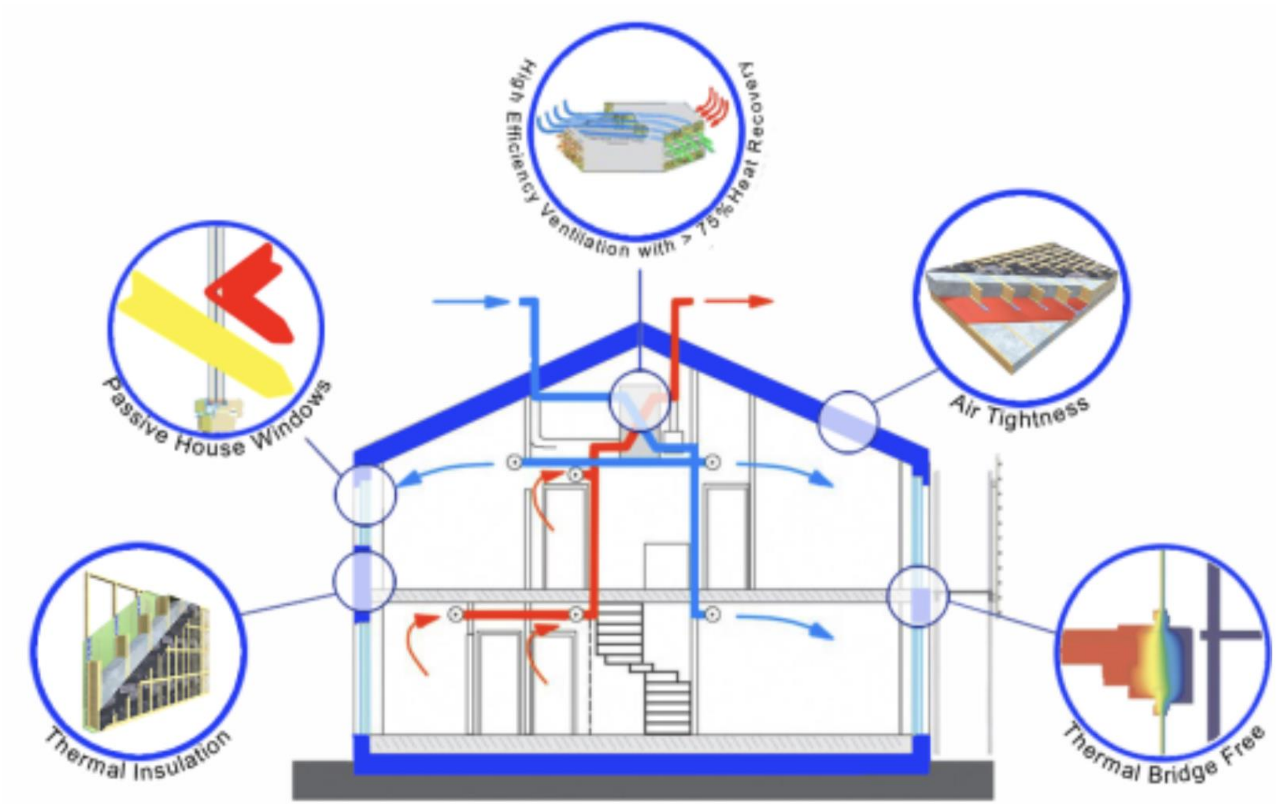
CTPH
CONNECTICUT PASSIVE HOUSE

5 Principles of Passive House

1. Insulation
2. Thermal Bridge Free
3. High-Performance Windows
4. Airtight
5. HVAC

HVAC

EXTERNAL LOADS:	ENVELOPE	LOSS (W)	GAIN (S)
	VENTILATION	LOSS (W)	GAIN (S)
INTERNAL LOADS:	APPLIANCES	GAIN (W)	GAIN (S)
	EQUIPMENT	GAIN (W)	GAIN (S)
	PEOPLE	GAIN (W)	GAIN (S)

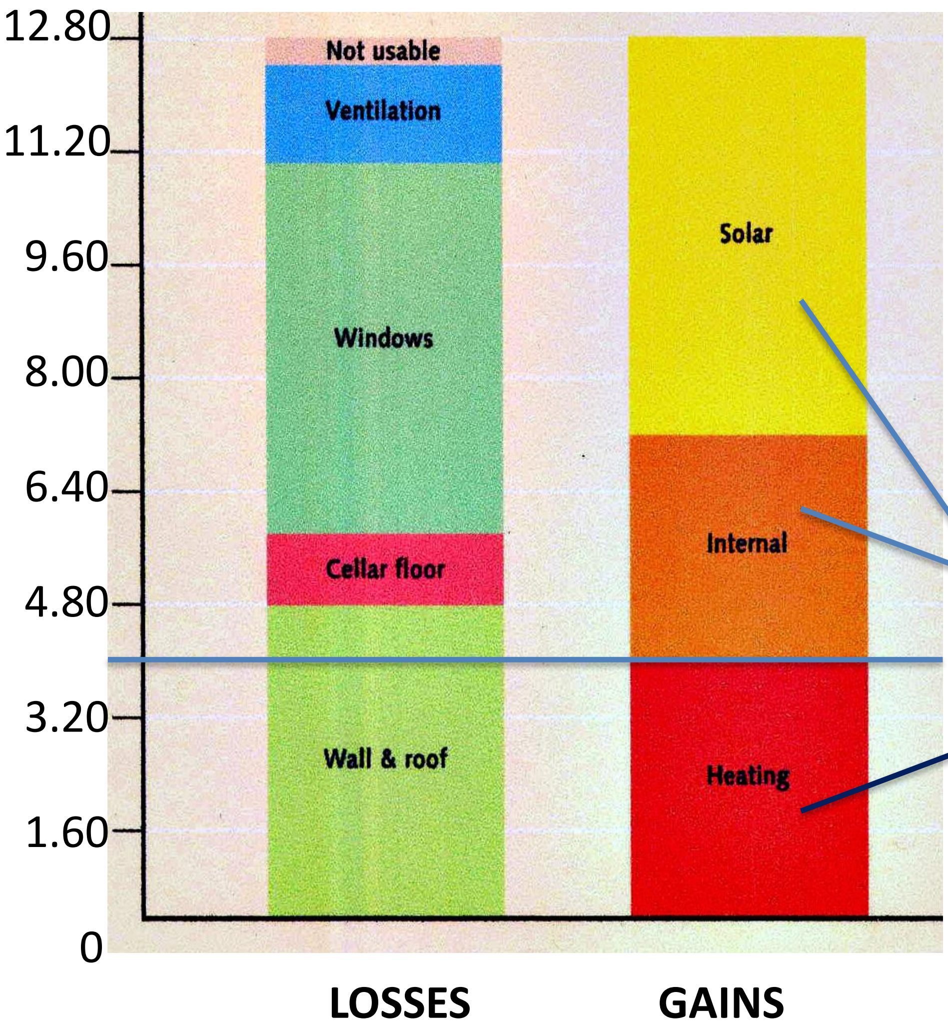


CREDIT: PHI

CTPH
CONNECTICUT PASSIVE HOUSE

HVAC

k BTU THERMAL BALANCE IN PASSIVEHOUSES



PASSIVEHOUSE THRESHOLDS:

- HEATING DEMAND: 4.75 kBTU/SF/Yr
- COOLING DEMAND: 4.75 kBTU/SF/Yr
- Overheating Frequency (>77 F): <10%
- Excessive Humidity:0.2 OZ/LB
- AIR TIGHTNESS: 0.6 ACH @ n50
- PRIMARY ENERGY /RENEWABLE

PASSIVE GAINS

4.75 kBTU

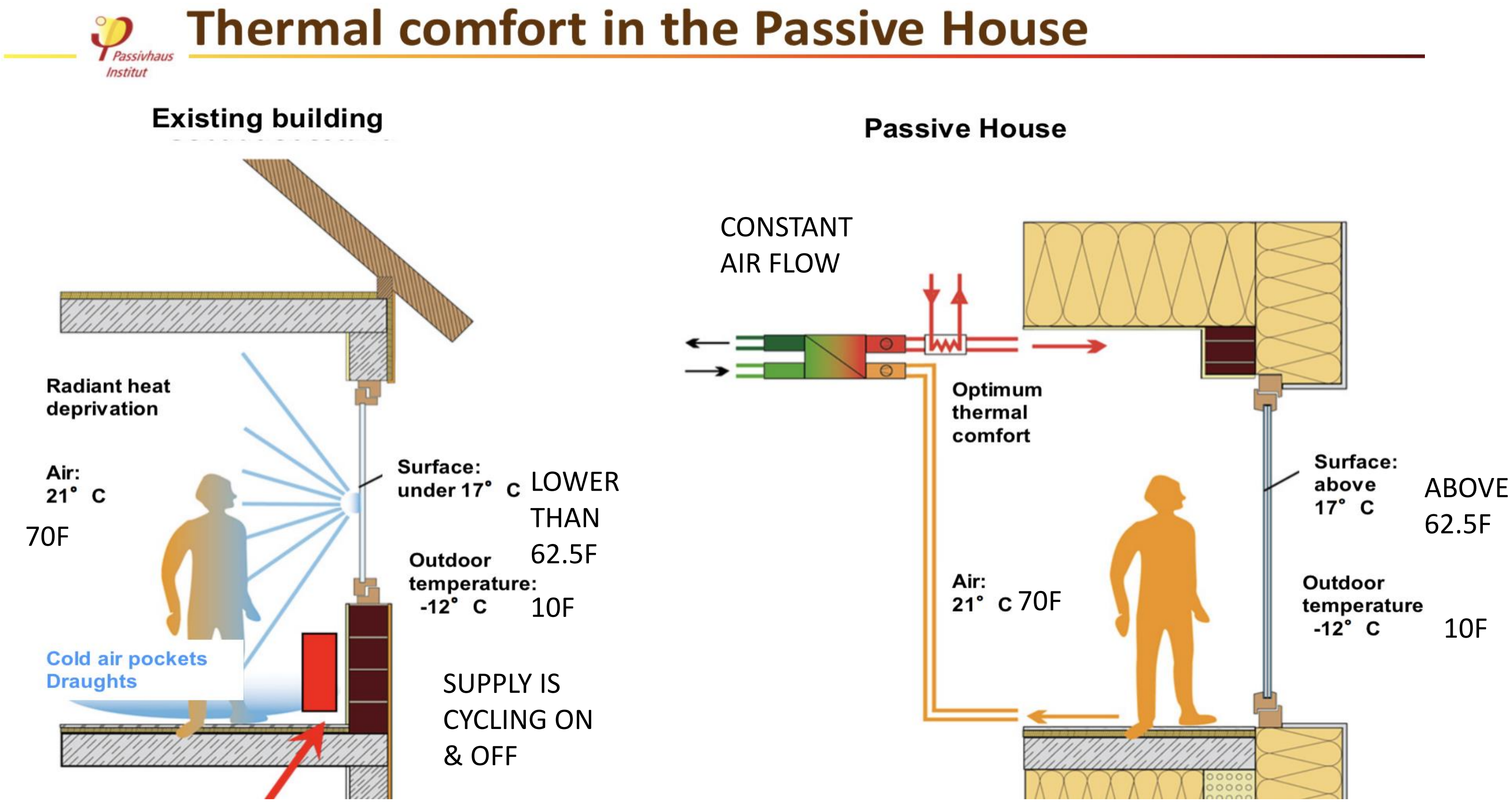
HEATING DEMAND

CREDIT: PHI

CTPH CONNECTICUT PASSIVE HOUSE

HVAC

THE PURPOSE OF HVAC IS TO MAINTAIN INTERIOR COMFORT ALL YEAR



LOCAL HEAT SUPPLY TO OFFSET LOW TEMPERATURE

IF WINDOW IS WITHIN 10% OF THE ROOM TEMPERATURE, NO COLD RADIATION

CTPH
CONNECTICUT PASSIVE HOUSE

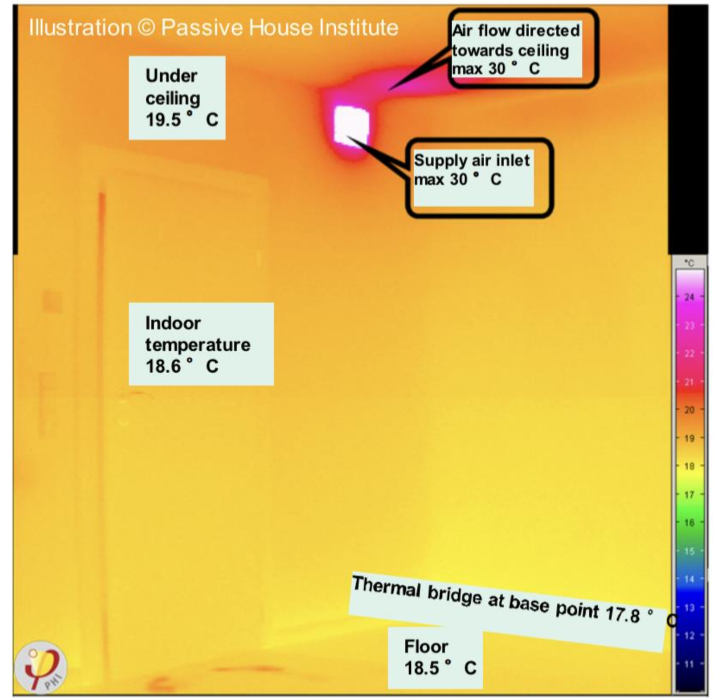
HVAC

4.75 kBTU/SF/Yr = VERY SMALL LOAD, COMPARED WITH A STANDARD HOUSE HEATING LOAD (>32 kBTU/SF/Yr

IN A 2,200 SF HOUSE, 4.75kBTU/SF/Yr = 20,000 BTU PEAK HEATING LOAD (LESS THAN 2 TONS)

HOW DO YOU MOVE SMALL AMOUNT OF AIR THROUGH A WHOLE HOUSE?

- LOW VELOCITY DUCT DESIGN
- GRILLES WITH COANDA EFFECT
- REDUCED DUCT LENGHTS



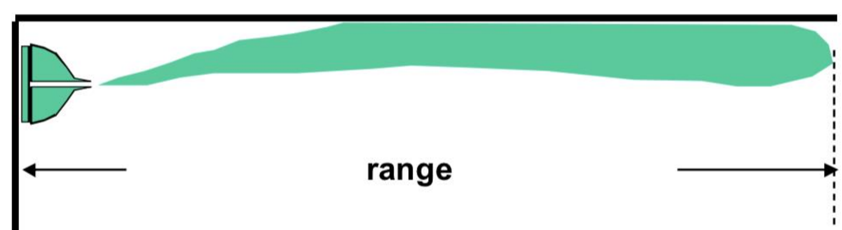


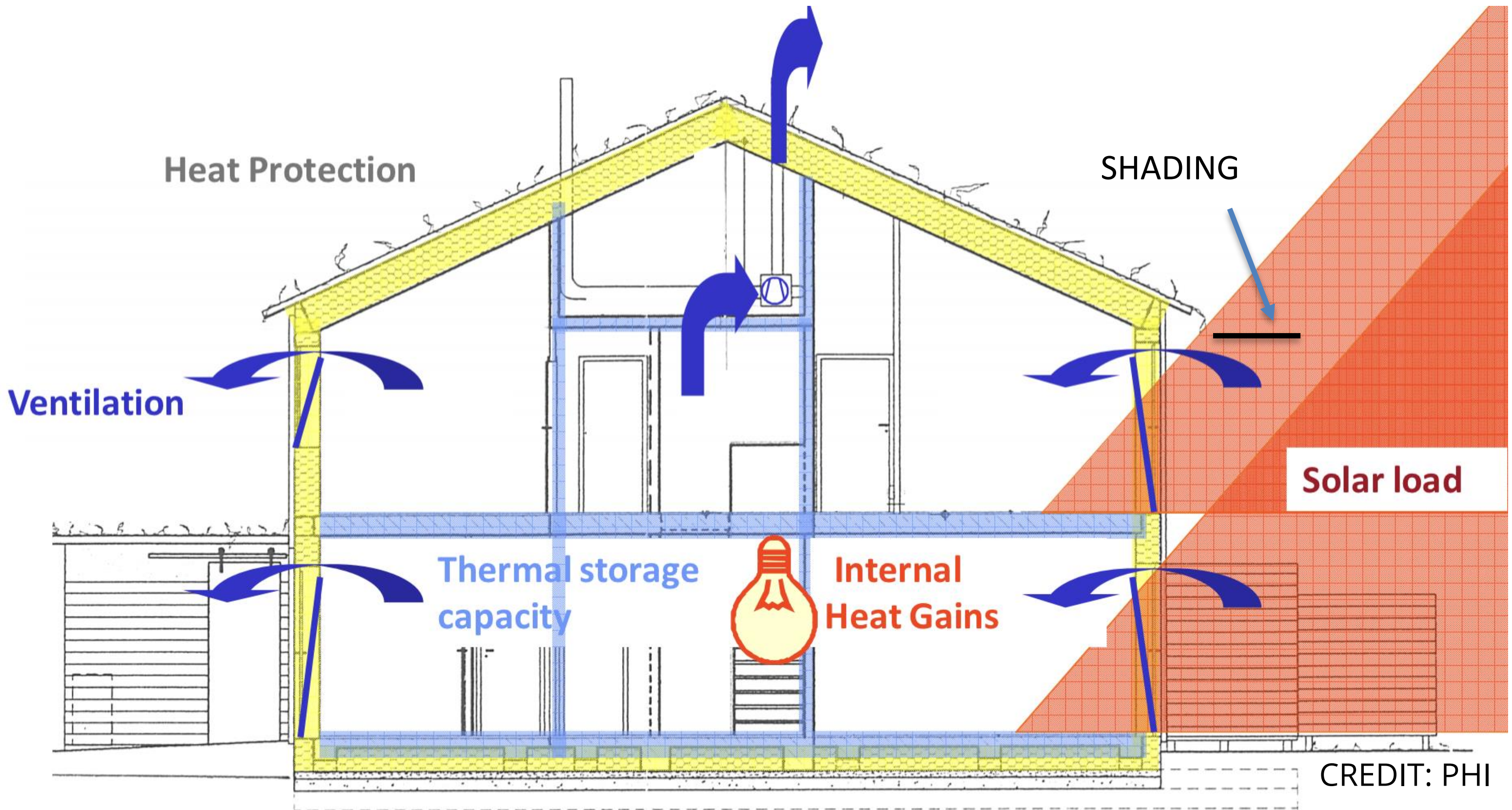
Illustration © Passive House Institute

CTPH
CONNECTICUT PASSIVE HOUSE

HVAC

COOLING & DEHIMIDIFICATION (INCLUDING VENTILATION AIR SUPPLY)

- EXTERNAL LOADS: TEMPERATURE AND SOLAR HEAT GAINS
- VENTILATION AIR SUPPLY CONDITIONING
- INTERNAL LOADS



CREDIT: PHI

CTPH
CONNECTICUT PASSIVE HOUSE

HVAC

SYSTEM DESIGN CONSIDERATIONS (small loads)

ISSUES:

- EFFICIENCY: LOW STATIC PRESSURE (aerodynamic duct design) & EFFICIENT MOTORS + GOOD FILTERS
- NOISE : QUIET (5’ of Flex Ducts as sound damper)
- COMFORT: CORRECT AIRFLOW, GRILLE SIZES & LOCATION, & PROPER AIR MIXING

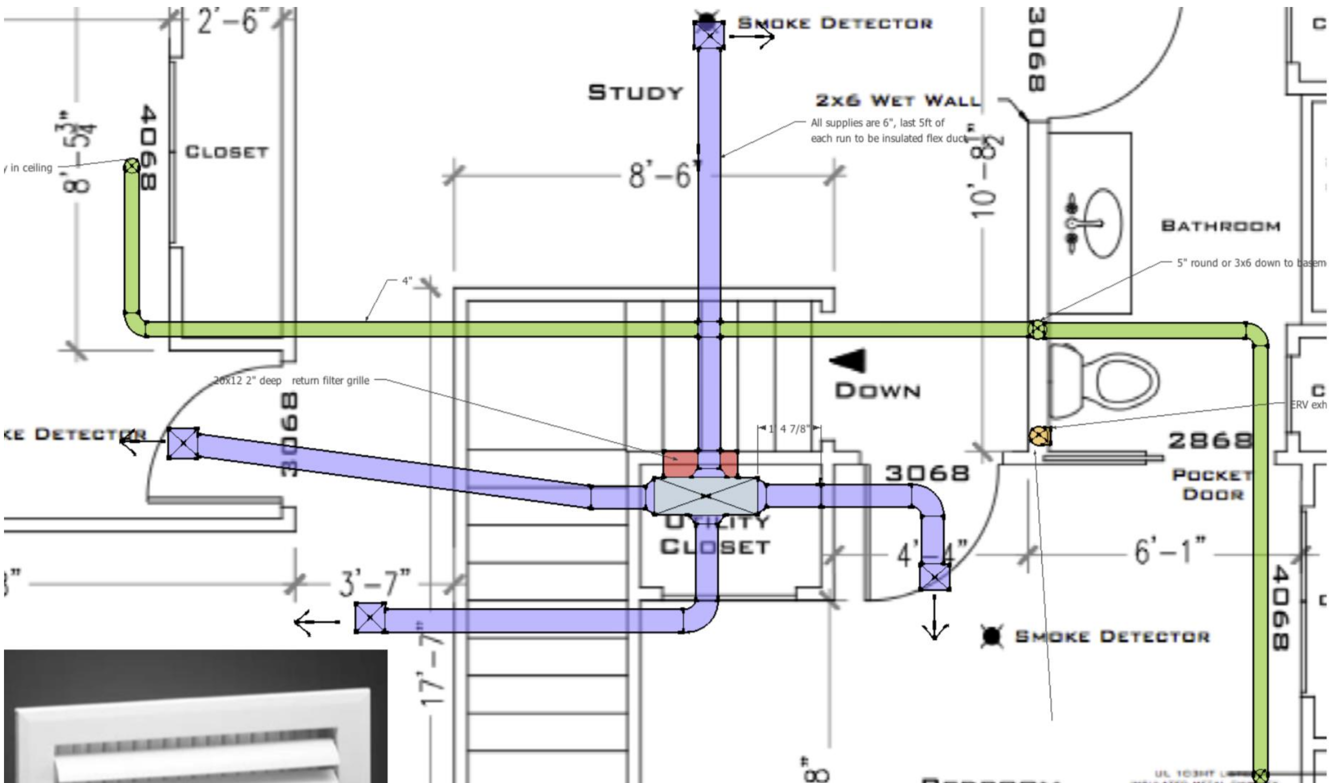


ILLUSTRATION CREDIT:
John Semmelhack

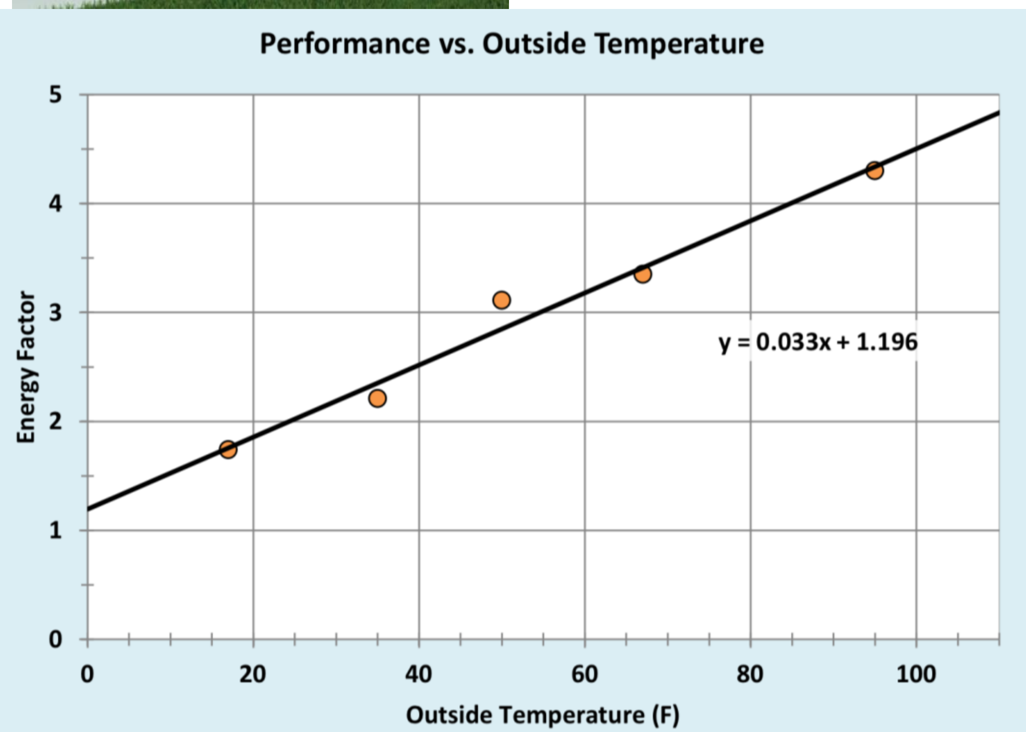
CTPH
CONNECTICUT PASSIVE HOUSE

HVAC

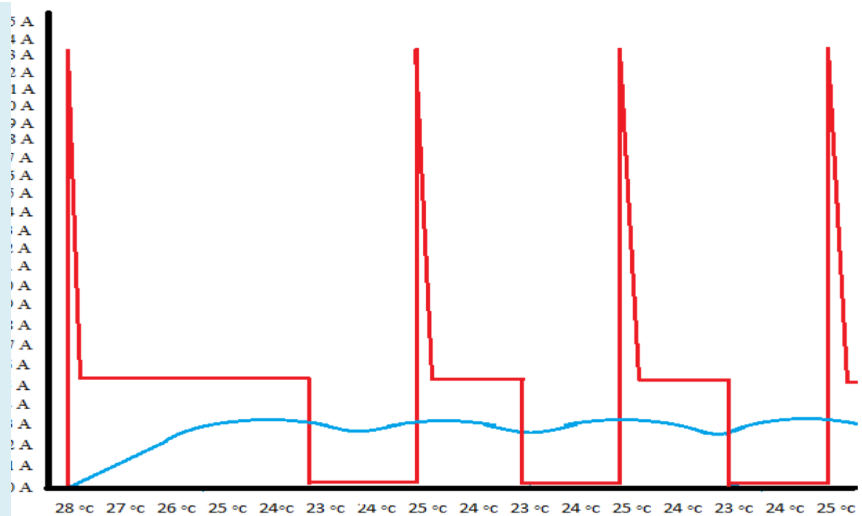
EQUIPMENT SELECTION PLAYS A BIG ROLE IN PASSIVEHOUSES

INTEGRATION WITH RENEABLE POWER:

- STARTUP LOAD MANAGEMENT



Current Differences Graph, between an Inverter- and a Non-Inverter Unit



CREDIT:
MITSUBISHI

CREDIT:
SANDEN

CONNECTICUT PASSIVE HOUSE

HVAC

BALANCED VENTILATION (1)

EXHAUST ONLY: DEPRESSURIZES
INTAKE ONLY: PRESSURIZES
DUAL FLUX: (intake & exhaust) BALANCED

PASSIVE HOUSE: SUPPLY 18 CFM/PERSON
EXHAUST: ACTIVITY BASED

KITCHEN :	35 CFM
BATHROOM:	24 CFM
BATH W/SHOWER:	12 CFM
LAUNDRY:	12 CFM

MINIMUM VENTILATION REQUIRED: 0.3 ACH

EXHAUST IN RESIDENTIAL

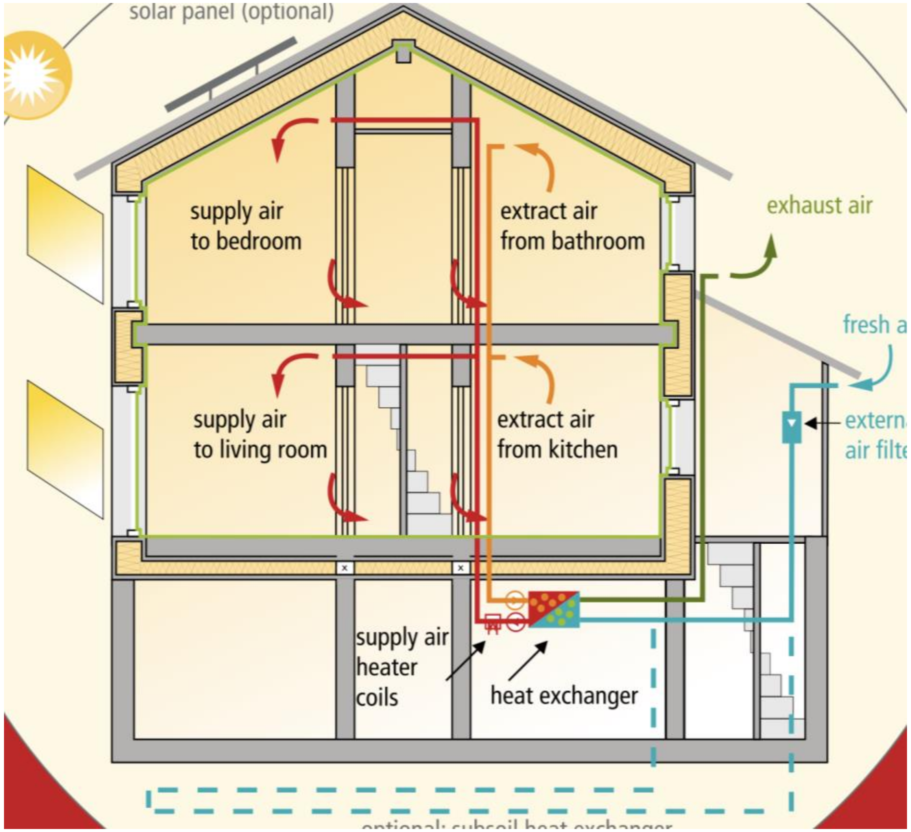


ILLUSTRATION FROM PHI MANUAL

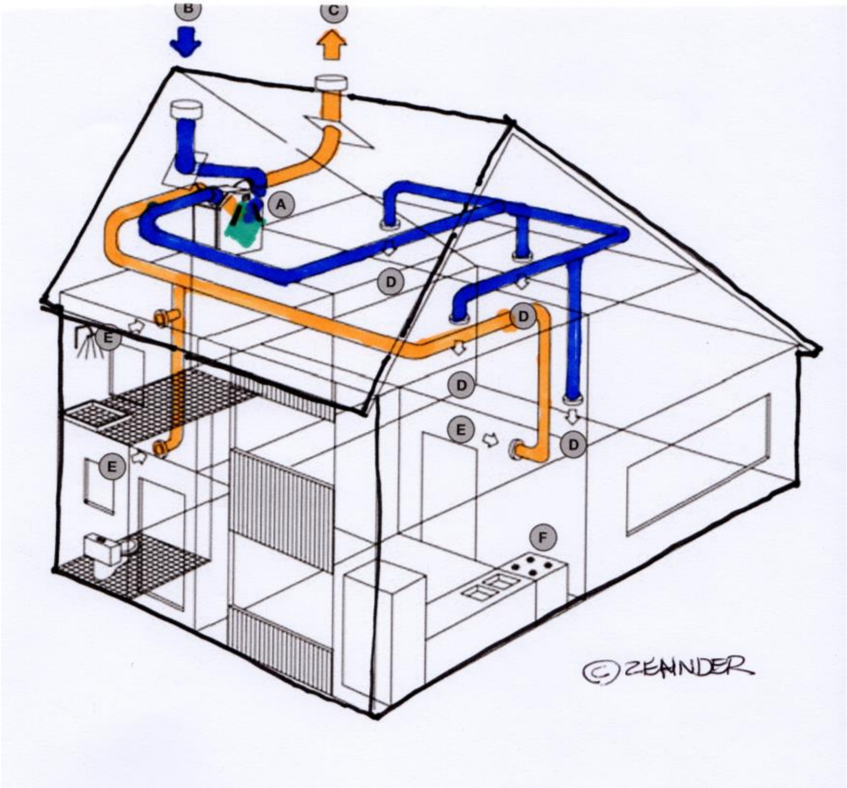
CTPH
CONNECTICUT PASSIVE HOUSE

HVAC

BALANCED VENTILATION (2)

HEALTH & COMFORT FROM A HRV/ERV:

- REQUIRED IN AIRTIGHT BUILDINGS
- 24 HR CONSTANT OPERATION
- FILTERS & CONDITIONS OUTSIDE AIR
- HRV: HEAT RECOVERY VENTILATION (SUITABLE FOR HEAT ONLY CLIMATE)
- ERV: ENTHALPY ENERGY RECOVERY –FOR HUMID CLIMATE W/ ACTIVE COOLING
- HIGH SPEED BOOST MODE (ON TIMER) FOR BATHROOM & LAUNDRY EXHAUST
- FROST PROTECTION IN COLD CLIMATES
- NOT SUFFICIENT FOR KITCHEN HOOD SUBSTITUTE
- OPTIONAL PRE-HEAT & PRE-COOL OF AIR INTAKE



CTPH
CONNECTICUT PASSIVE HOUSE

HVAC

MORE VENTILATION: INTERMITTENT USE

USES WHICH REQUIRE MAKEUP AIR WITH MOTORIZED AIRTIGHT DAMPER:
(energy code: make up air required if exhaust > 400 cfm)

KITCHEN EXHAUST HOOD : OVERSIZED HOOD FANS COMPOUND PROBLEM
(both air intake and hood exhaust ducts require a damper controlled by hood switch)
WOOD BURNING FIREPLACE: 1ST, YOU NEED AN AIRTIGHT FIREPLACE BOX!
LAUNDRY : PASSIVE AIRTIGHT EXHAUST DAMPERS
CLOTHES DRYERS (OR CONDENSING DRYER- NO VENT REQUIRED)

HVAC DESIGN IS A TEAM EFFORT

HVAC DESIGN STARTS WITH THE ENRGY MODELING
(PHPP) IN THE DESIGN PHASE.

CTPH
CONNECTICUT PASSIVE HOUSE

CONCLUSIONS

A WIN-WIN-WIN SOLUTION:

1) THE PASSIVEHOUSE STANDARD MAKES IT EASY TO DELIVER GREAT INDOOR COMFORT AND VERY GOOD IAQ LEVELS, YEAR ROUND

<u>ISSUES:</u>

OUTDOOR POLLUTANTS:

POLLENS, MOLDS & DUST

INDOOR POLUTANTS:

PET DANDERS, MOLD & BACTERIA

FORMALDEHYDES, RADON, VOC

UNCONTROLLED MOISTURE LEVELS

PERSISTENT ODORS

THIRD PARTY TESTING PROVIDES AN UNBIASED VERIFICATION OF BUILDING PERFORMANCE: NO GUESSWORK

<u>PASSIVEHOUSE:</u>

AIR TIGHTNESS: 0.6 ACH

24 HRS VENTILATION

FILTRATION

AIR FLOW: CLEAN TO DIRTY SPACES

PRE-CONDITIONING OF AIR SUPPLY

CTPH

CONNECTICUT PASSIVE HOUSE

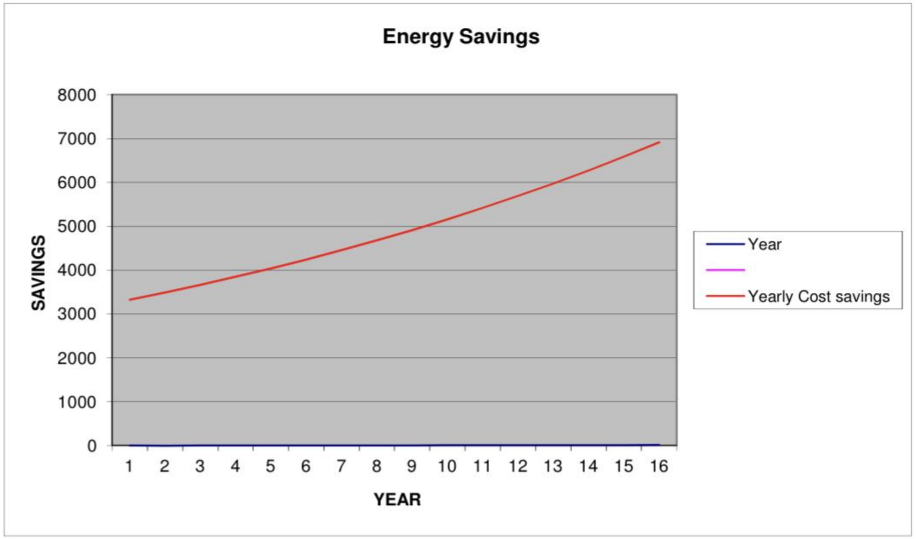
CONCLUSIONS

2) A SAFER INVESTMENT:

UPGRADING TO PASSIVEHOUSE ADDS VALUE TO THE ASSETS, AND A GUARANTEED RETURN ON THE INVESTMENTS (SAVINGS INCREASE WITH TIME)

ON THE OTHER HAND, REDUCING 1ST COSTS (BUILDING) LEADS TO EVER INCREASING OPERATING COSTS (NO REAL SAVINGS, BUT A DEFERRED EXPENSE)

PASSIVEHOUSE	Consumption BTU/Hr	BTU/Year	Oil- Gal	LPGas Gal	Electricity KW
HEATING:		13489840 Btu/Year	96.36	147.43	3952.488
Peak Load	18118				
Cost			**374.82**	**558.76**	**731.21**
COOLING		9735880			2852.587
Peak Load	7679.11				
Cost			527.73	**527.73**	**527.73**
TOTAL			**902.55**	**1086.49**	**1258.94**
Same house code complying insulation					
HEATING:		88440000 Btu/Year	670.00	1025.14	27483.15
Basement		5360000			
Peak Load	74052	93800000			
Cost			**2606.30**	**3885.27**	**5084.38**
COOLING		66000			
Basement		7704			19435.57
Peak Load	73704.00	66333600.00			
Cost			**3595.58**	**3595.58**	**3595.58**
TOTAL			**6201.88**	**7480.85**	**8679.96**
ANNUAL SAVINGS					



15 YEARS SAVINGS: $78,696.00 ; AS NET-ZERO:$107,443.00 (2014)

CTPH
CONNECTICUT PASSIVE HOUSE

CONCLUSIONS

3) A MEASURABLE STEP TOWARDS GREENHOUSE GASSES REDUCTION

<u>OTHER POSITIVE ASPECTS:</u>
DURABILITY IS BUILT INTO THE DETAILS
RESILIENCY- SURVIVAL IN PLACE
NET ZERO: A REDUCTION IN INFRASTRUCTURE

	PRE OIL EMBARGO	2003 ENERGY CODE	ABOVE ENEGY STAR	PASSIVE HOUSE
Heating energy demand of a typical one-family house	**kWh/m²a 300-250**	**kWh/m²a 150-100**	**kWh/m²a 50-40**	**kWh/m²a ≤ 15**
BUILDING STANDARD	**Completely insufficient thermal insulation** Structurally questionable, cost of heating no longer economical (typical of rural buildings, non-modernized old buildings).	**Insufficient thermal insulation** Thermal renovation is clearly worth the trouble (typical of residential houses built in the 50s to 70s of the last century).	**Low-energy houses**	**Very low energy houses** (passive houses need to meet this parameter as part of the requirement profile)
BUILDING ELEMENT	**Typical U-values and insulation thicknesses**			
External walls (massive wall of 25 cm) Insulation thickness	1.30 W/(m²K) 0 cm	0.40 W/(m²K) 6 cm	0.20 W/(m²K) 16 cm	0.13 W/(m²K) approx. 30 cm
Roof Insulation thickness	0.90 W/(m²K) 4 cm	0.22 W/(m²K) 22 cm	0.15 W/(m²K) 30 cm	0.10 W/(m²K) 40 cm
Floors to ground Insulation thickness	1.0 W/(m²K) 0 cm	0.40 W/(m²K) 6 cm	0.25 W/(m²K) 10 cm	0.15 W/(m²K) 26 cm
Windows	5.10 W/(m²K) Single glazing	2.80 W/(m²K) Double glazing, insulation glass (air-filled)	1.10 W/(m²K) Double glazing, thermal insulation glazing	0.80 W/(m²K) Triple glazing, thermal insulation glass, special frame
Ventilation	Leaky joints	Open the windows	Exhaust air unit	Comfort ventilation with heat recovery
CO_2 emission	**60 kg/m²a**	**30 kg/m²a**	**10 kg/m²a**	**2 kg/m²a**
Energy consumption in liters heating oil per m² living space and year	**30-25 liters**	**15-10 liters**	**4-5 liters**	**1.5 liters**
GAL OIL SF/YEAR	7.9 GAL	4 GAL	1.3 GAL	0.4 GAL
CO2/SF/Y	5.6kg	2.8kg	0.93 kg	0.19kg

CREDIT: ISOVER

CTPH
CONNECTICUT PASSIVE HOUSE

CTPH

CONNECTICUT PASSIVE HOUSE

www.ctpassivehouse.org

Connecticut Passive House is a community of like-minded professionals offering resources, education, and outreach using the broad knowledge base and skill-sets of our peers.