# Form Follows Energy:

## Achieving the Passive House Standard for Habitat for Humanity

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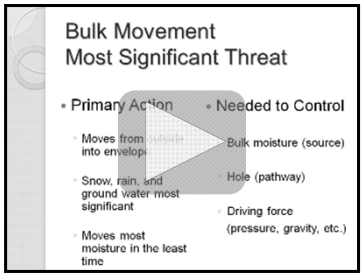


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# Course Description

This webinar focuses the design and construction of a Passive House in northern Vermont. This house was the first Certified Passive House in the U.S. for Habitat for Humanity, the first Passive House in Vermont and the first to be built modular.

The webinar will discuss the principles of Passive House design: Envelope specifications; insulation, air sealing, and thermal bridge free details; mechanical systems; and modeling in the PHPP. The webinar will then walk you through the construction of the Passive House. The webinar will also review the monitored data on energy consumption, temperature and indoor air quality. Lastly we will review lessons learned and think about what is to come.

# Learning Objectives

1. Participants will be able to identify the core principles and design techniques of the Passive House energy standard.
2. Participants will be able to evaluate the benefits of low load homes including: reduced operating costs; increased comfort, durability, and health; and as the best path to net zero.
3. Participants will review the design and construction of Vermont's first Passive House.
4. Participants will review measured data and reflect on the design and specification choices made.

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**J.B. Clancy, AIA**
Albert, Righter & Tittman Architects, Inc.

Submit a question to the moderator via the Chat box. They will be answered as time allows.

**Stephen Schreiber FAIA**
Professor and Architecture+Design Program Director
Department of Art, Architecture, and Art History
University of Massachusetts Amherst
Moderator

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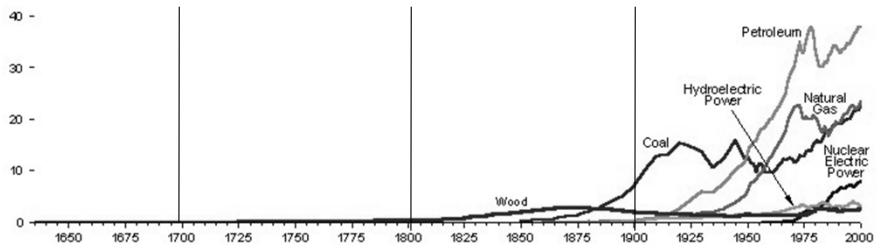
# FORM FOLLOWS ENERGY

J.B. Clancy, AIA
**CERTIFIED PASSIVE HOUSE CONSULTANT**
**ALBERT, RIGHTER & TITTMANN ARCHITECTS**

AIA Webinar
June 4, 2012

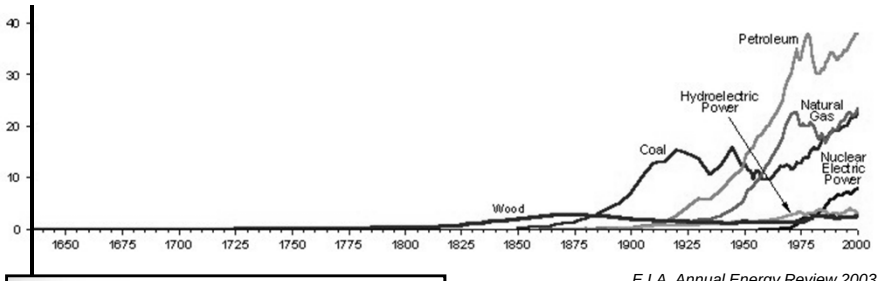
History of Energy Consumption by Source in USA 1630 to Present




*E.I.A. Annual Energy Review 2003*

# FORM FOLLOWS ENERGY

# House 1630

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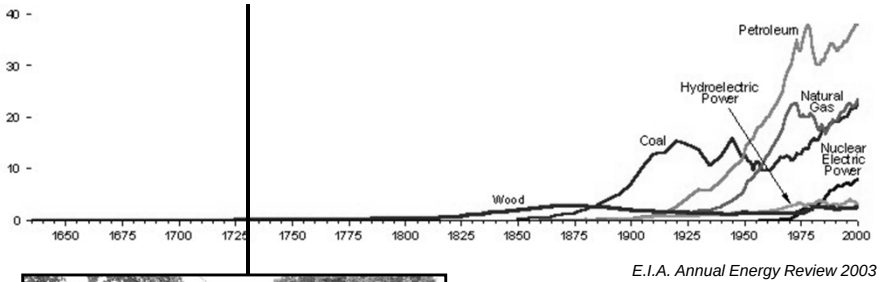
George Soule House, Plymouth, MA 1630s

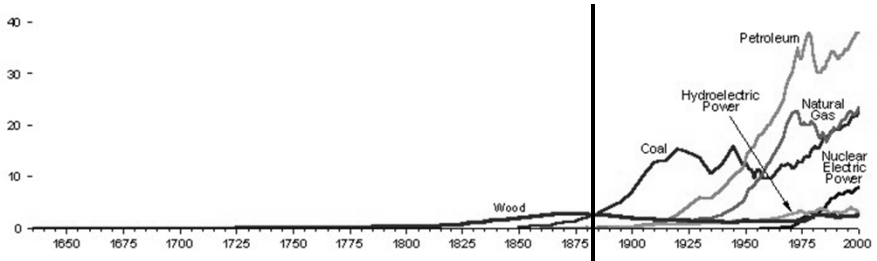
# House 1732




*E.I.A. Annual Energy Review 2003*

Hartwell Tavern, Concord, MA 1732

# House1882

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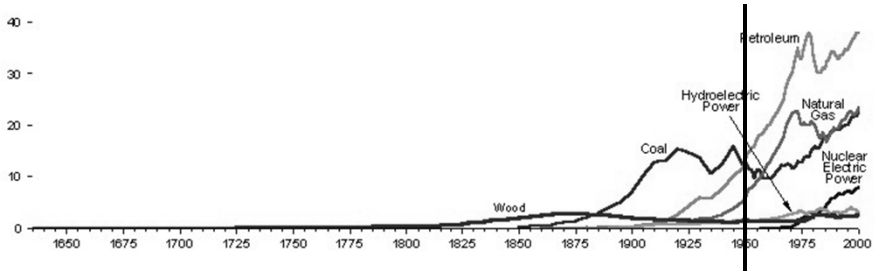
Drew House , Sandwich MA 1882

# House 1951

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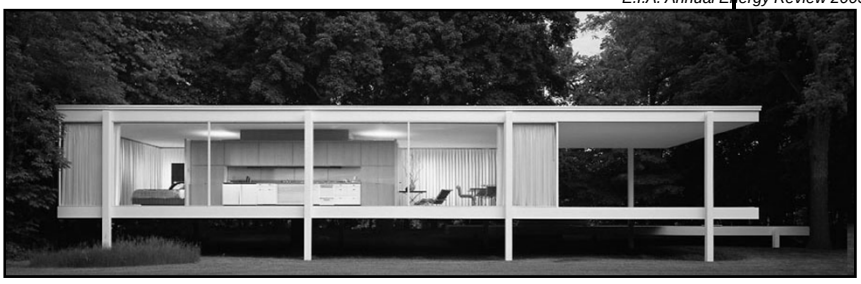
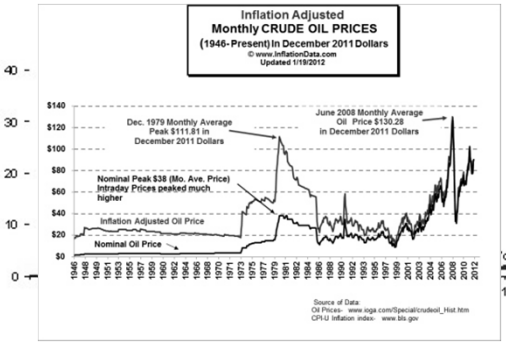
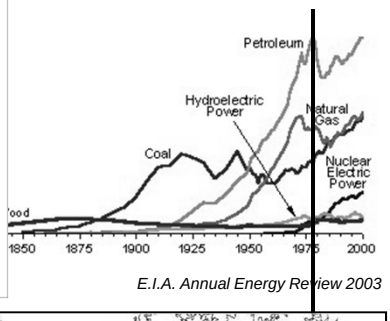


Farnsworth House, Mies van der Rohe , Plano, IL 1951

# House 1976

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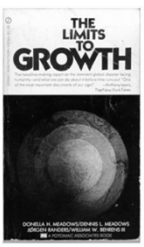
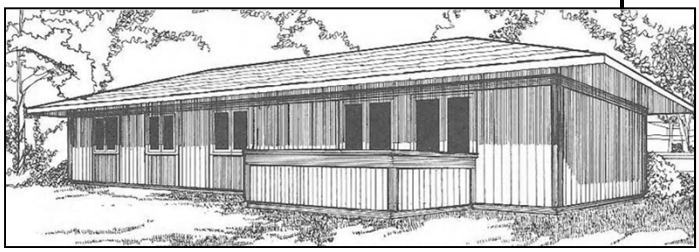
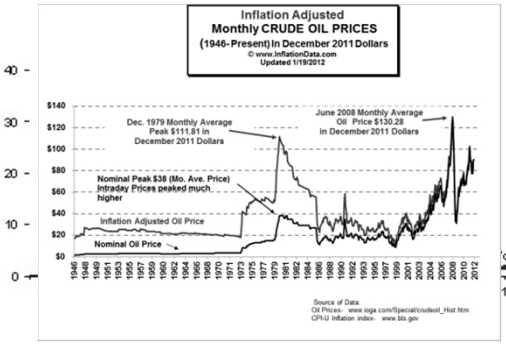
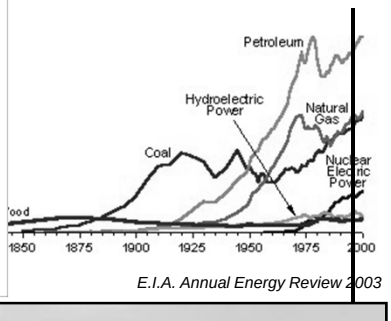


Lo-Cal House, University of Illinois at Urbana-Champaign 1976
Wayne Schick

# House 1995

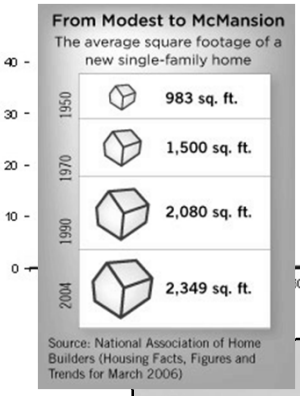



*E.I.A. Annual Energy Review 2003*

Anywhere USA

# House 1995







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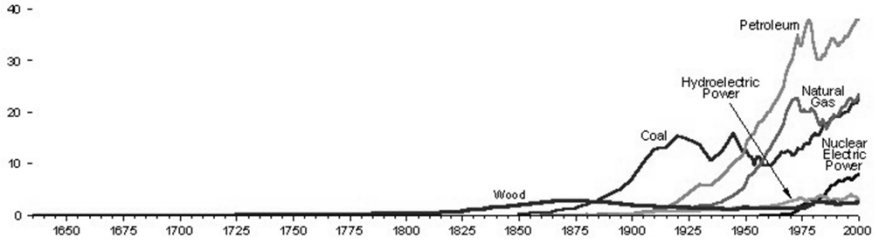
Anywhere USA

# House 21st Century

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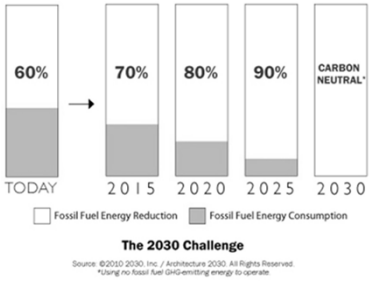



*Architecture 2030*

## Passive House Energy Standard

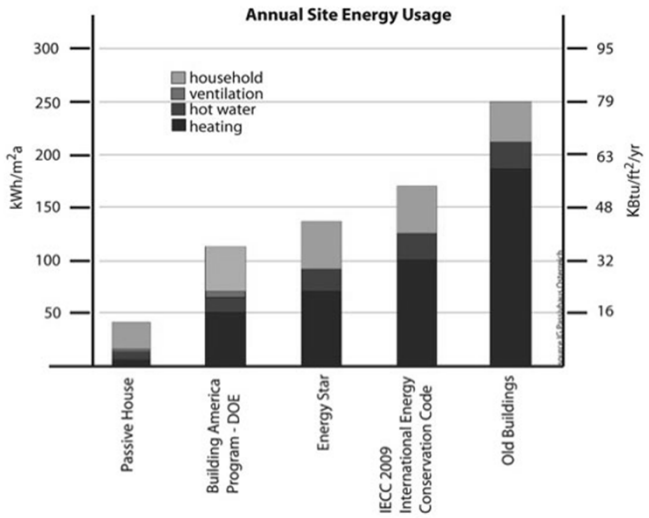
A Green Building Standard
built on an
Energy Budget
for the 21st Century

## Passive House Energy Standard

| | |
|---|---|
| Heating Demand (Site): | 4.75 kBTU/SF/YR |
| Cooling Demand (Site): | 4.75 kBTU/SF/YR |
| Total Energy Demand (Source): | 38 kBTU/SF/YR |
| Air Tightness: | .6 ACH @ 50pa |

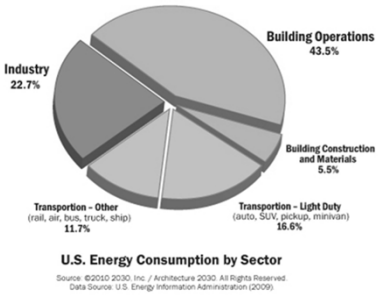
As modeled in the PHPP
(Passive House Planning Package)

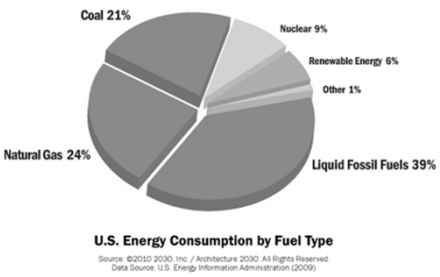
# Standards Comparison




# Passive House Energy Standard

## Why an <u>Energy Budget?</u>



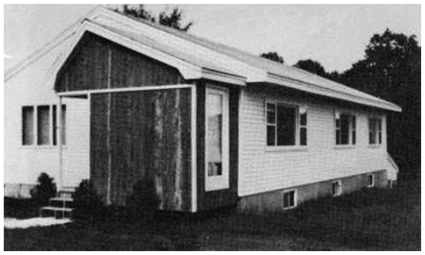




*Architecture 2030*

# THE PASSIVE HOUSE CONCEPT

## Passive House History

### North American Roots



*Leger House, Pepperell, MA*

*Lovins House, Snowmass, CO*

**A whole series of North American developments ("super-insulated houses") in the 70s and 80s were very close to the Passive House. William A. Shurcliff (1981) authored many publications on this subject.**

**This work was an important basis for low-energy houses and Passive Houses in Europe.**

**A. B. Lovins visited the Passive House in Darmstadt Kranichstein in 1995. It was he who suggested that the Passive House should be considered not just as a research project, but also as the energy standard of the future.**

*PASSIVE HOUSE INSTITUTE*

# Passive House Concept

## Functional Definition

### The Passive House: The Functional Definition

**Although the designs of Passive Houses may appear quite different, the principle remains the same. The principle behind a Passive House is based on the concept by Amory Lovins of reducing investment through energy efficient design. By dramatically increasing the energy efficiency of a building, the HVAC systems can be radically simplified upon reaching a certain level of efficiency.**

**Consider the example of building a house for a cold climate. The heat demand for heating the house in the cold season is the major energy consuming service. If the heat demand is reduced by means of insulation, heat recovery, superwindows, passive solar gains and other measures, the heating system can be simplified step-by-step. But the most significant threshold appears when the peak heating load reaches**

**10 W/m².**

**When the peak heating load is less than 10 W/m², independent of climate, the ventilation system can easily be used for space heating, and a separate heating system is no longer required.**

**The primary function of the ventilation system is to maintain excellent indoor air quality.**

**If the maximum load is lower than 10 W/m², the ventilation system can distribute all heat needed throughout the building as well. The definition of a Passive House is therefore that the peak heating load should be projected to a lower level than 10 W/m². In warmer climates, this value may be easy to achieve, however in colder climates, careful planning is required.**

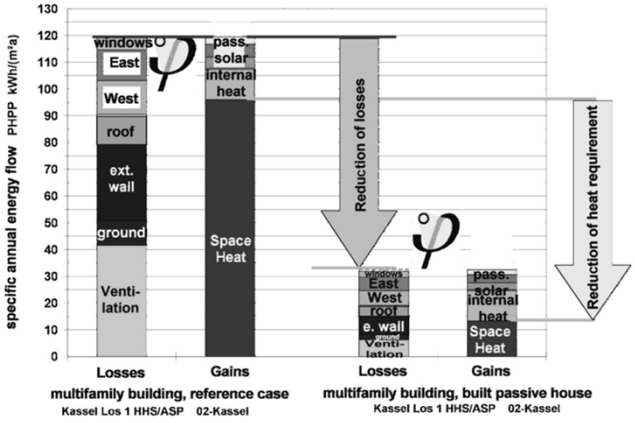
1. The Passive House: A Method Rather than a Building Style

*First Steps: What Can be a Passive House in Your Region with Your Climate?*
*Dr. Wolfgang Feist*

# Passive House Concept

## ENERGY BALANCE

## Reduce Losses – Reduce Heat Requirement

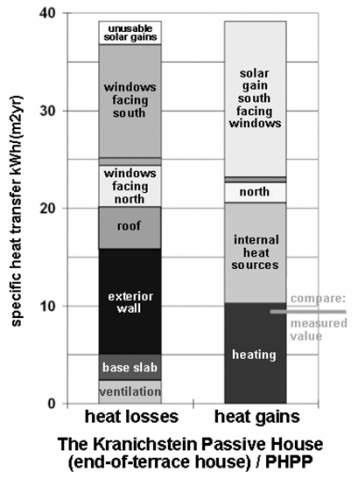



*First Steps: What Can be a Passive House in Your Region with Your Climate?*
*Dr. Wolfgang Feist*

# Passive House Concept

ENERGY BALANCE

Minimize Losses and Maximize Gains

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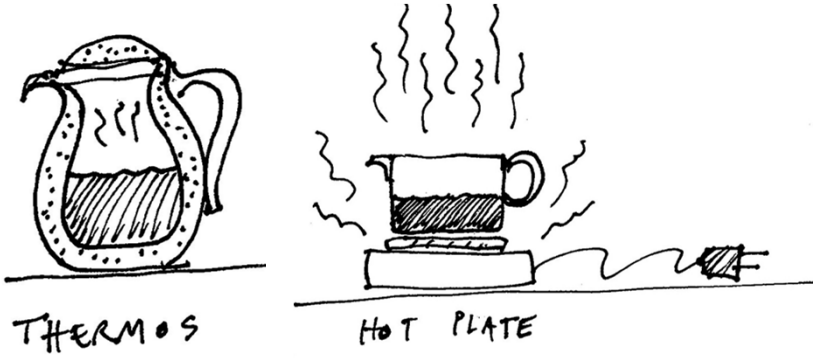
# Passive House Concept

Maintain temperature using the envelope,
rather than by using energy.



# Passive House (Passivhaus)

Passivhaus Institut
Darmstadt, Germany

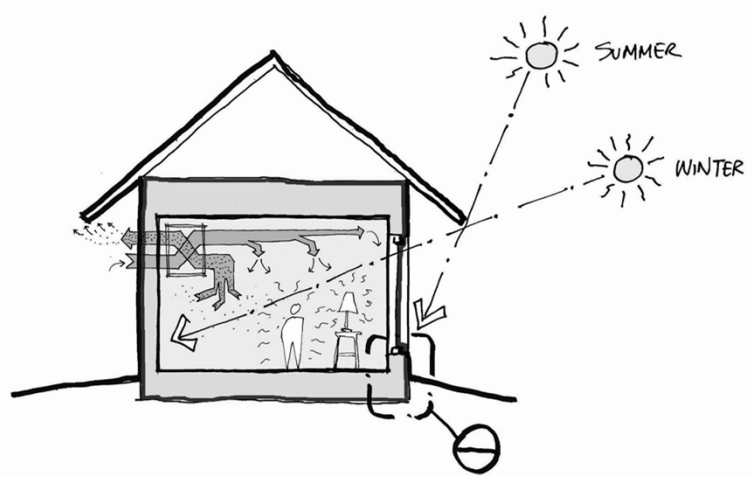
PHIUS
Passive House Institute US

Passive House Institute US
Urbana, Illinois

# Passive House Concept

**INTEGRATED**

**"Let the architecture do the work"**

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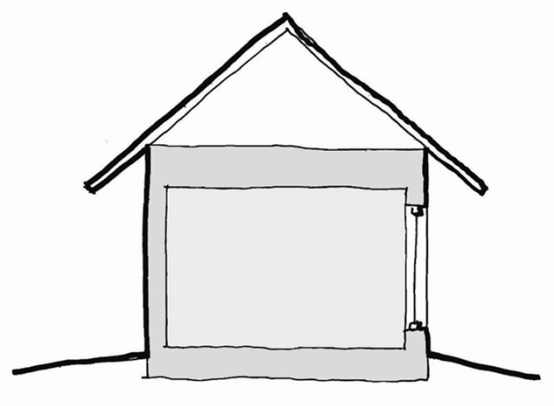
# Passive House Concept

**Controlling Heat Loss… INSULATION**



R58 WALLS: R90 CEILING: R60 SLAB
High Performance WINDOWS U value 0.16

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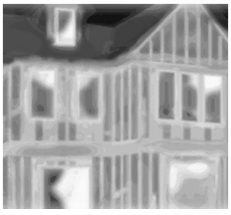
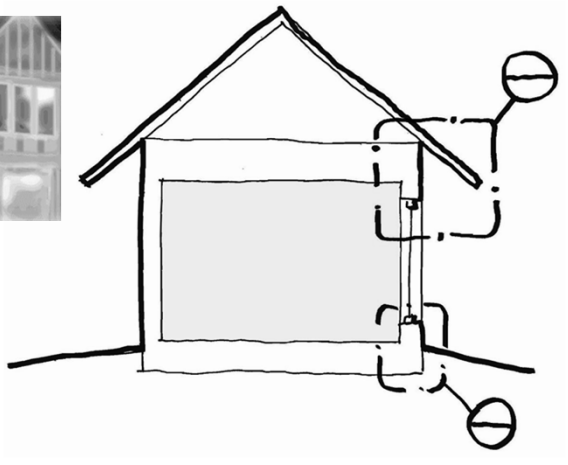
# Passive House Concept

**Controlling Heat Loss… ELIMINATE THERMAL BRIDGES**





**Ψ ≤ 0.01 W/(mK)**

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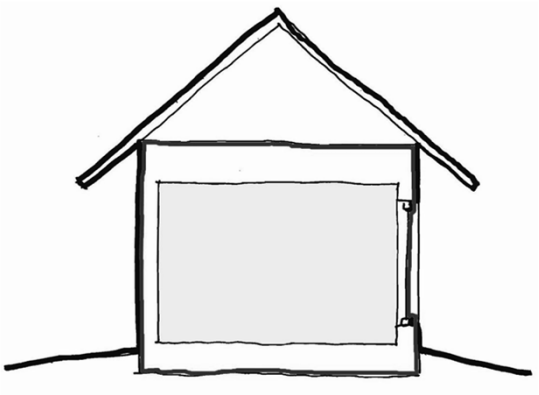
# Passive House Concept

**Controlling Heat Loss… REDUCE AIR INFILTRATION**



.6 ACH @ 50 PA

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# Passive House Concept

**Capturing Heat Gains… PEOPLE**

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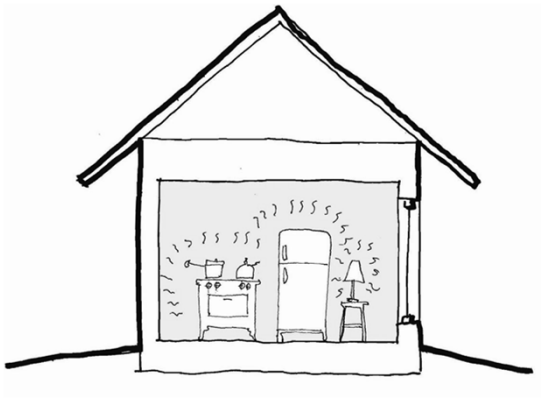
# Passive House Concept

**Capturing Heat Gains… EQUIPMENT**



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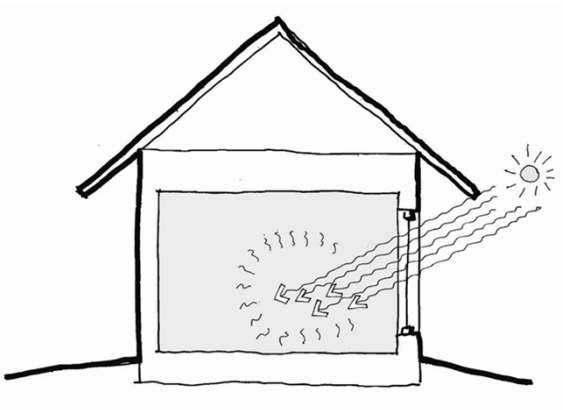
# Passive House Concept

**Capturing Heat Gains… SOLAR ENERGY**



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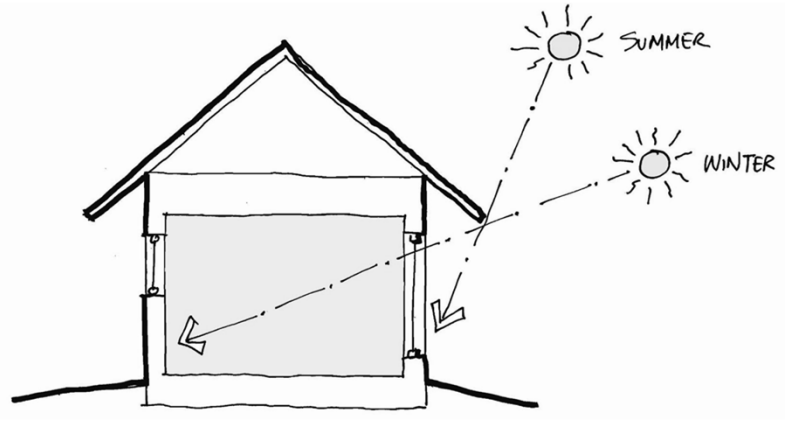
# Passive House Concept

**Controlling Gains Seasonally… WINDOWS & ORIENTATION**




TRIPLE GLAZED: >.5 SHGC ON SOUTH WINDOWS

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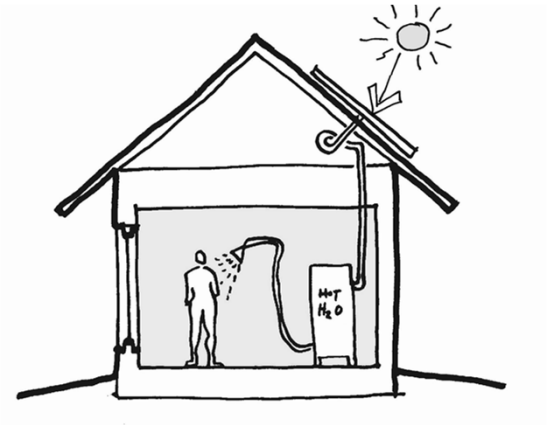
# Passive House Concept

**SOLAR THERMAL**

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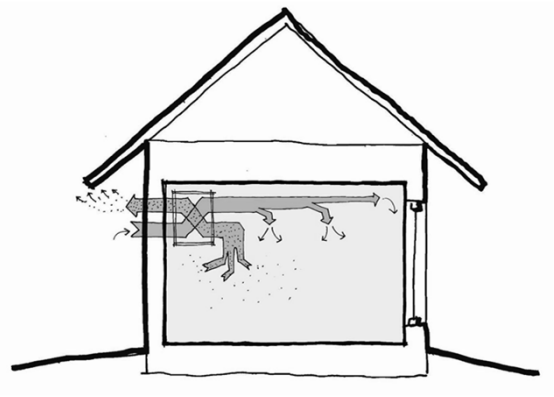
# Passive House Concept

**Providing Fresh Air… HEAT RECOVERY VENTILATION**



MINIMUM .30 ACH

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# Passive House Concept

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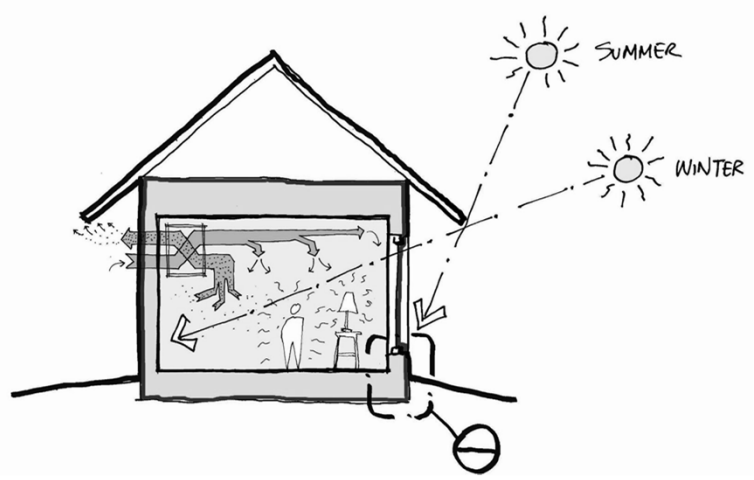
**“Let the architecture do the work”**

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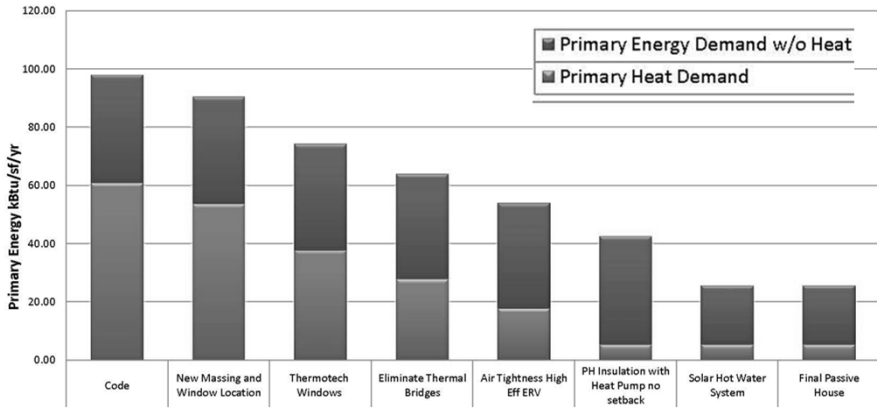
# Passive House Concept
## TO GET FROM CODE TO PASSIVE HOUSE




INTEGRATED

# Passive House Concept
## PHPP SOFTWARE

The PASSIVE HOUSE PLANNING PACKAGE (PHPP) is an important tool for designing Passive Houses consisting of a spreadsheet workbook and a manual.

The Passive House Planning Package (PHPP) provides everything needed to design a properly functioning Passive House including tools for:

- Calculating energy balances (including U-value calculation)
- Planning the windows
- Designing the comfort ventilation system
- Determining the heating load
- Estimating the summer comfort
- Design the heating and hot water supply

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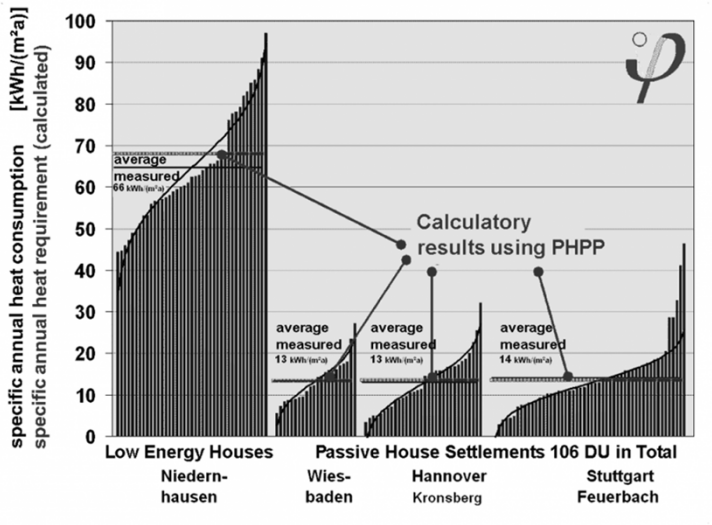
# Passive House Concept
## PHPP SOFTWARE

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# Passive House Concept
## RESULTS

- Dramatic reduction in energy consumption
- Superior indoor air quality
- Exceptional occupant comfort
- Lower annual energy costs
- Smaller carbon footprint
- More durable construction details

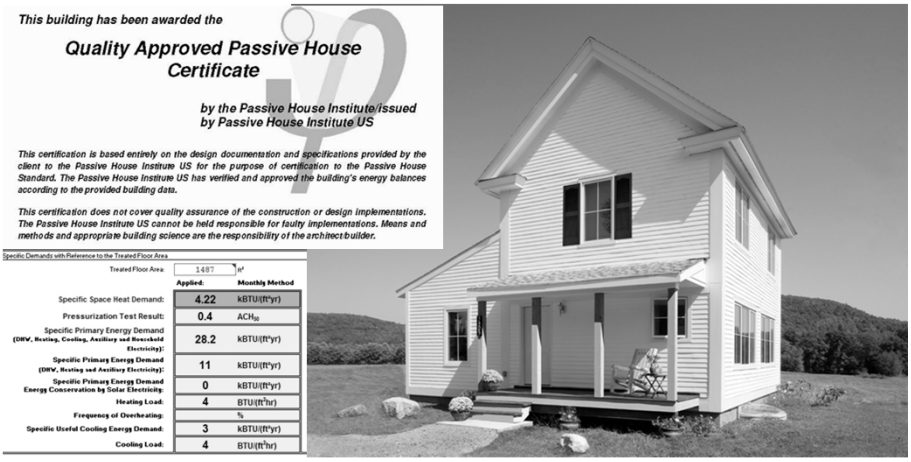
## Passive House Concept
**SUMMARY**

- Envelope focused: super insulation, high performance windows, no thermal bridging, air tight
- Ventilation with heat recovery
- Optimized through integrated design using energy modeling

## Passive House Concept
**SUMMARY**

- Focus on ENERGY conservation
- Do more with less ENERGY
- Minimize losses – Maximize gains
- Simple is better than complex
- Passive better than active
- Moving parts fail

## THE FIRST CERTIFIED PASSIVE HOUSE IN VERMONT



*This building has been awarded the*

***Quality Approved Passive House Certificate***

*by the Passive House Institute/issued by Passive House Institute US*

*This certification is based entirely on the design documentation and specifications provided by the client to the Passive House Institute US for the purpose of certification to the Passive House Standard. The Passive House Institute US has verified and approved the building's energy balances according to the provided building data.*

*This certification does not cover quality assurance of the construction or design implementations. The Passive House Institute US cannot be held responsible for faulty implementations. Means and methods and appropriate building science are the responsibility of the architect/builder.*

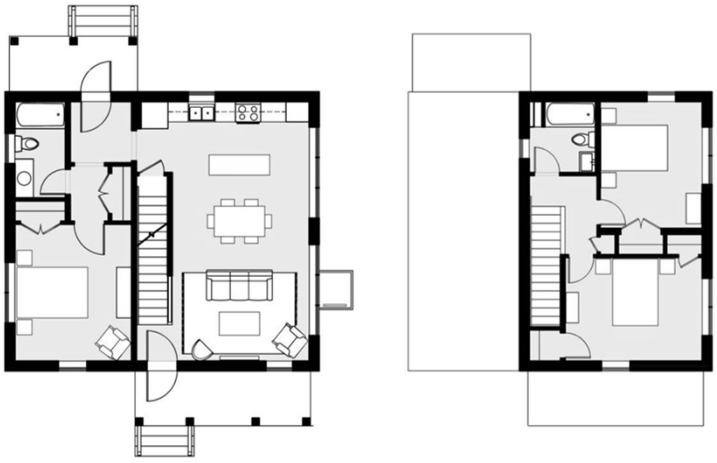
Specific Demands with Reference to the Treated Floor Area

| | Treated Floor Area: 1487 m² | Applied: | Monthly Method |
|---|---|---|---|
| Specific Space Heat Demand: | | 4.22 | kBTU/(ft²yr) |
| Pressurization Test Result: | | 0.4 | $ACH_{50}$ |
| Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity): | | 28.2 | kBTU/(ft²yr) |
| Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity): | | 11 | kBTU/(ft²yr) |
| Specific Primary Energy Demand Energy Conservation by Solar Electricity: | | 0 | kBTU/(ft²yr) |
| Heating Load: | | 4 | BTU/(ft²hr) |
| Frequency of Overheating: | | | % |
| Specific Useful Cooling Energy Demand: | | 3 | kBTU/(ft²yr) |
| Cooling Load: | | 4 | BTU/(ft²hr) |

*Philip Jensen-Carter*

**PROJECT TEAM**
**CLIENT:** Green Mountain Habitat for Humanity, David Mullin
**ARCHITECT:** J.B. Clancy, Albert, Righter & Tittmann Architects
**ENERGY CONSULTANT:** Peter Schneider, VEIC
**STRUCTURAL ENGINEER:** John Higgins, Artisan Engineering

## Habitat for Humanity Passive House



*Albert, Righter & Tittmann Architects*

# Habitat for Humanity Passive House

**WEST ELEVATION** **SOUTH ELEVATION**

**Glazing percentage % TFA: 1:1:8:2 (N:E:S:W)**

*Albert, Righter & Tittmann Architects*

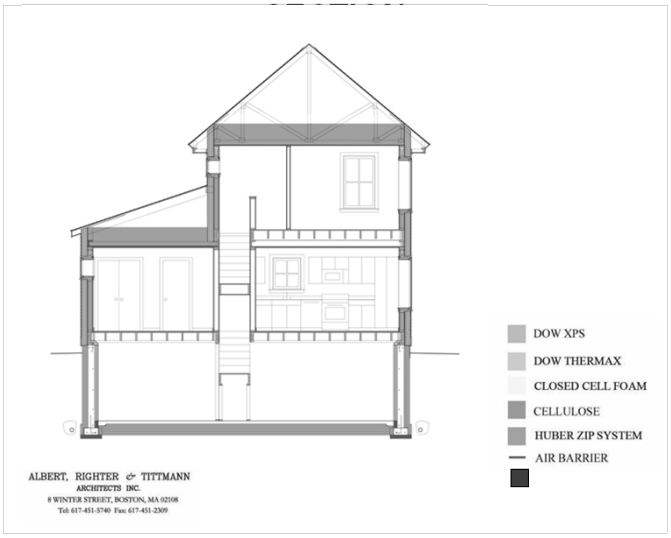
# Habitat for Humanity Passive House

**EAST ELEVATION** **NORTH ELEVATION**

**Glazing percentage % TFA: 1:1:8:2 (N:E:S:W)**

*Albert, Righter & Tittmann Architects*

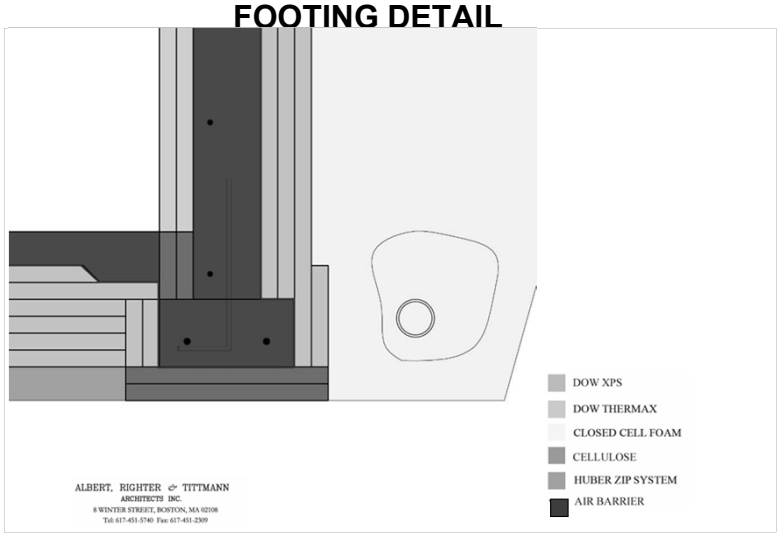
# Habitat for Humanity Passive House




*Albert, Righter & Tittmann Architects*

# Habitat for Humanity Passive House

**FOOTING DETAIL**




**SLAB: R61** **FDN WALLS: R57**

# Habitat for Humanity Passive House

**FOOTING DETAIL**

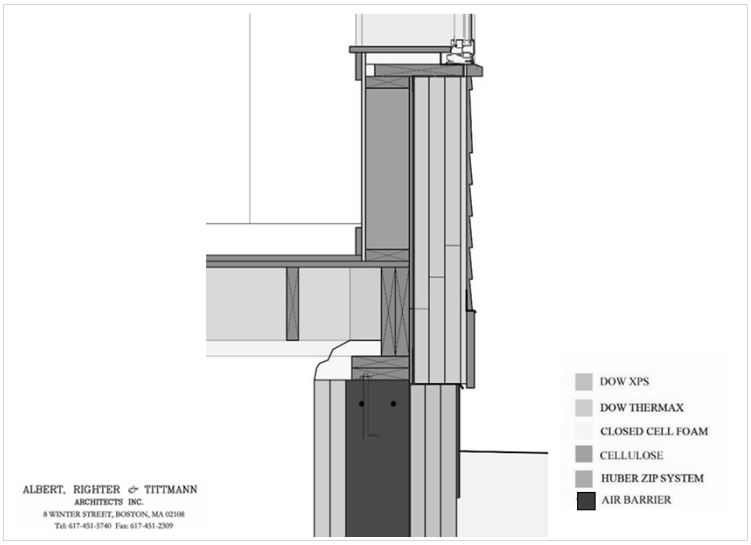


**CODE INSULATION**– 2” XPS Under Slab & on Wall

**PASSIVE HOUSE INSULATION**– 12” XPS Under Slab & 10” on Wall

**THERM MODELS OF FOUNDATION DETAILS**

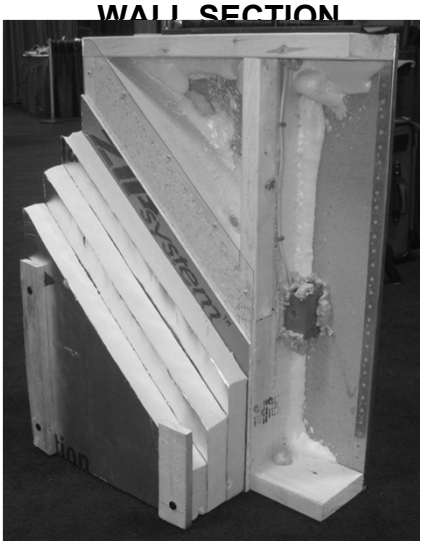
# Habitat for Humanity Passive House




**EXTERIOR WALL: R59**

# Habitat for Humanity Passive House

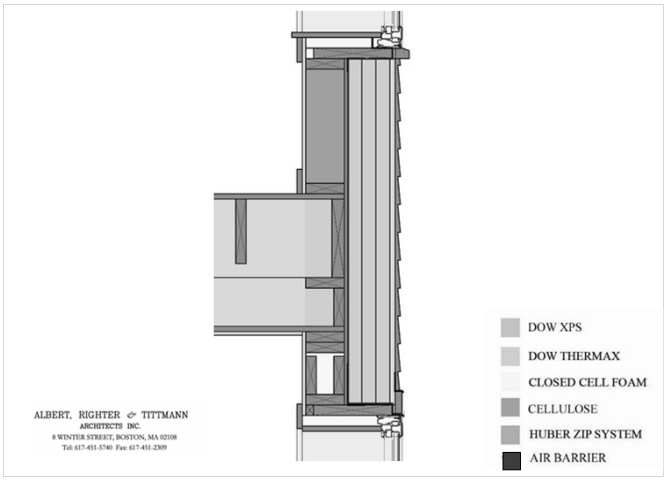
**WALL SECTION**



**EXTERIOR WALL: R59**

# Habitat for Humanity Passive House

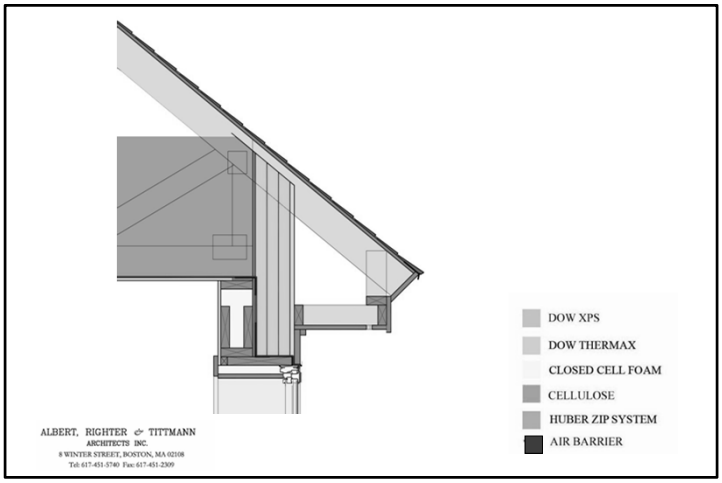
**SECOND FLOOR PLATFORM DETAIL**




**EXTERIOR WALL: R59**

## Habitat for Humanity Passive House

**EAVE DETAIL**




**ROOF: R90**

## Habitat for Humanity Passive House

**WINDOWS**

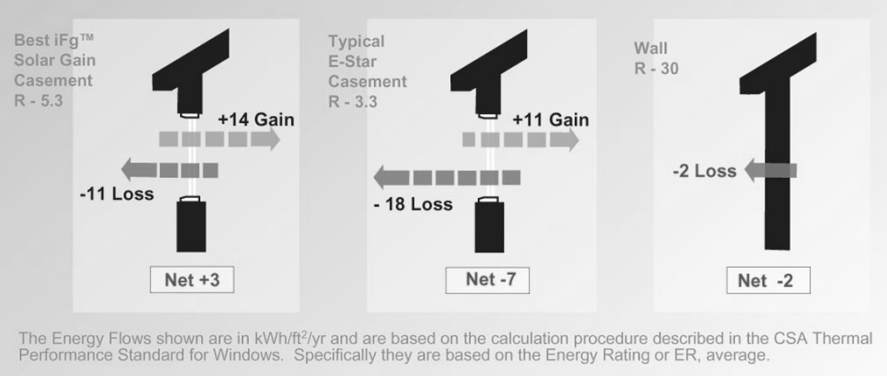
Thermotech
322 Gain+

.64 SHGC (solar heat gain coefficient)
COG U .16

NFRC whole window U .19 (R5.3)

# Habitat for Humanity Passive House

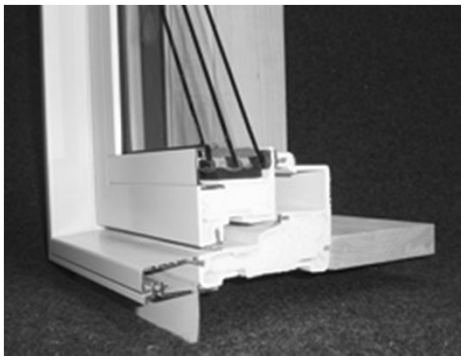
**THERMOTECH WINDOWS**




*Thermotech Windows*

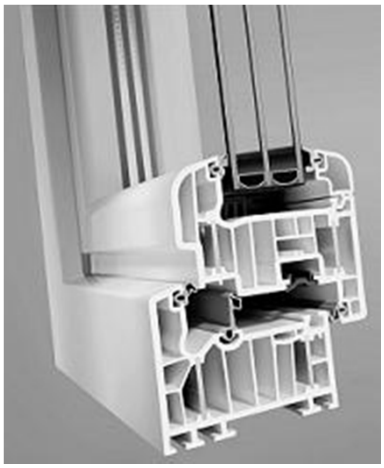
# Habitat for Humanity Passive House

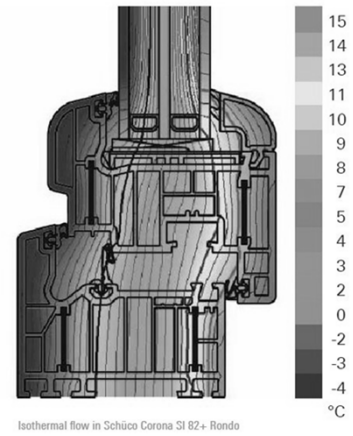
**WINDOWS – NORTH AMERICAN CASEMENT**



# Habitat for Humanity Passive House

**WINDOWS – EUROPEAN TILT-TURN**






# Habitat for Humanity Passive House

**HVAC SYSTEM**

**Air Source Heat Pump**
Mitsubishi Hyper-heat MSZ-MUZ FE 12

**HRV**
Zender ComfoAir 350 HRV

**Soil heat exchange system**
Two 125' loops of 1" pex around the base of the footings filled with water/glycol mix & tied to Zehnder ComfoFond (~30F Temp Rise and 80% efficiency)

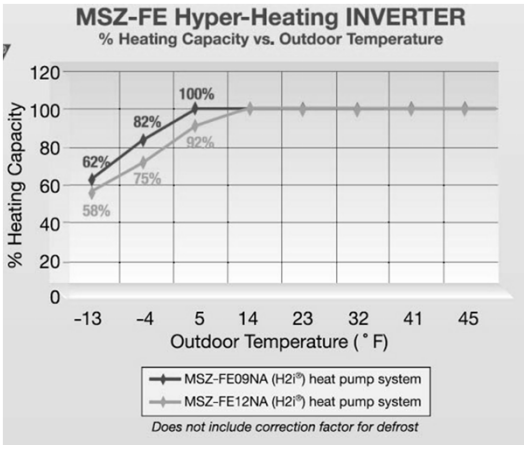
**Solar Hot Water**
Sunward Solar water heating system mounted on roof with 40g electric hot water heater as back-up

# Habitat for Humanity Passive House

## HVAC SYSTEM

**Air Source Heat Pump**

Mitsubishi Hyper-heat MSZ-MUZ FE 12

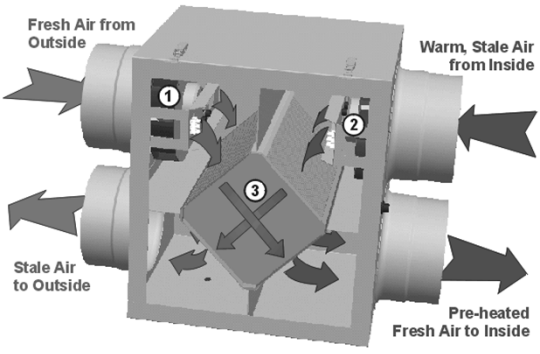



# Habitat for Humanity Passive House

## HVAC SYSTEM

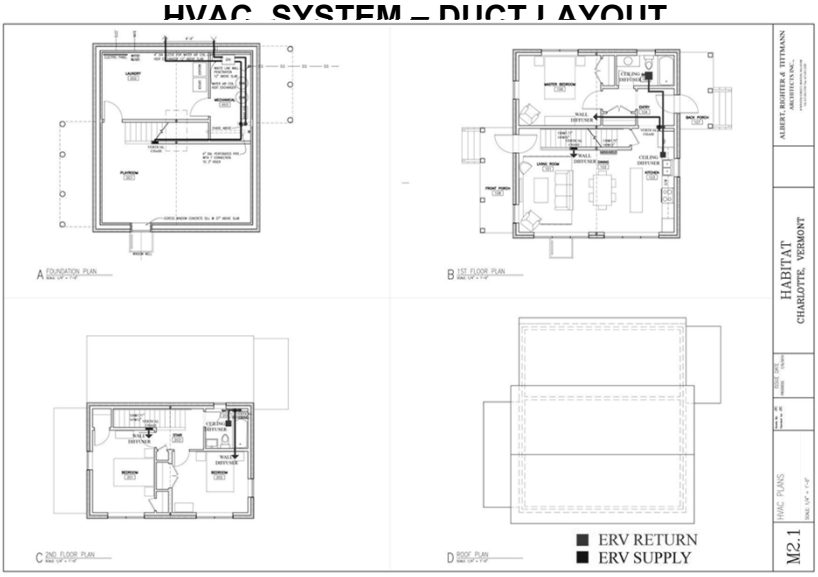
**HRV**

Zender ComfoAir 350 HRV




# Habitat for Humanity Passive House

## HVAC SYSTEM – DUCT LAYOUT




*Albert, Righter & Tittmann Architects*

# Habitat for Humanity Passive House

## ENERGY STAR - TIER III APPLIANCES

Refrigerator

| Brand | Model | KWH/ Year | % Less Energy |
|---|---|---|---|
| Whirlpool | W9RXXMF2*0 | 343 | 30% |

Dishwasher

| Brand | Model | KWH/ Year | Energy Factor |
|---|---|---|---|
| Whirlpool | GU3100XTV* | 270 | 0.82 |

Washer
Dryer

| Brand | Model | KWH/ Year | MEF Energy |
|---|---|---|---|
| Bosch | WFVC844*UC | 130 | 2.55 |

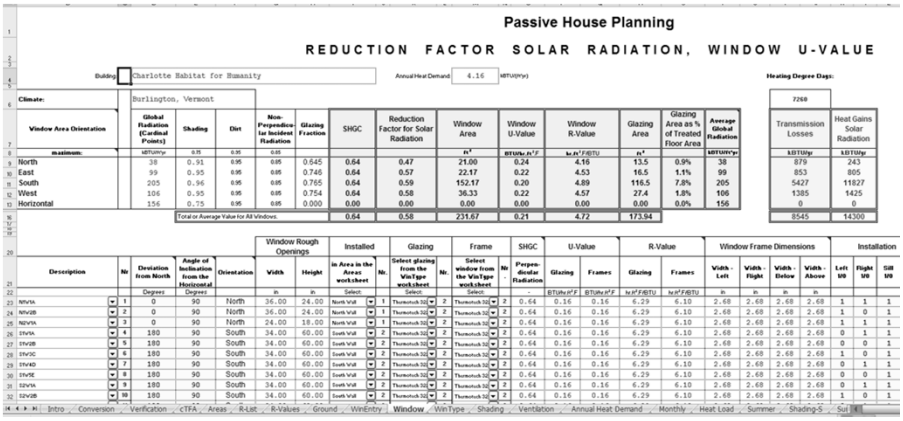
# PHPP Energy Model
## VERIFICATION PAGE

Specific Demands with Reference to the Treated Floor Area

Treated Floor Area: 1487 ft²

| | Applied: | Monthly Method | PH Certificate: | Fulfilled? |
|---|---|---|---|---|
| Specific Space Heat Demand: | 4.22 | kBTU/(ft²yr) | 4.75 kBTU/(ft²yr) | Yes |
| Pressurization Test Result: | 0.4 | $ACH_{50}$ | 0.6 $ACH_{50}$ | Yes |
| Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity): | 28.2 | kBTU/(ft²yr) | 38.0 kBTU/(ft²yr) | Yes |
| Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity): | 11 | kBTU/(ft²yr) | | |
| Specific Primary Energy Demand Energy Conservation by Solar Electricity: | 0 | kBTU/(ft²yr) | | |
| Heating Load: | 4 | BTU/(ft²hr) | | |
| Frequency of Overheating: | | % | over 77.0 °F | |
| Specific Useful Cooling Energy Demand: | 3 | kBTU/(ft²yr) | 4.75 kBTU/(ft²yr) | Yes |
| Cooling Load: | 4 | BTU/(ft²hr) | | |

# PHPP Energy Model
## WINDOW ENTRY



# Post-Construction Performance Testing


**Airflow at 50 Pascals** — 50 Pa

102 cfm50 ( +/- 3.4 %)
0.41 ACH50
0.0685 cfm50/ft² Floor Area
0.0257 cfm50/ft² Surface Area

**Leakage Areas**

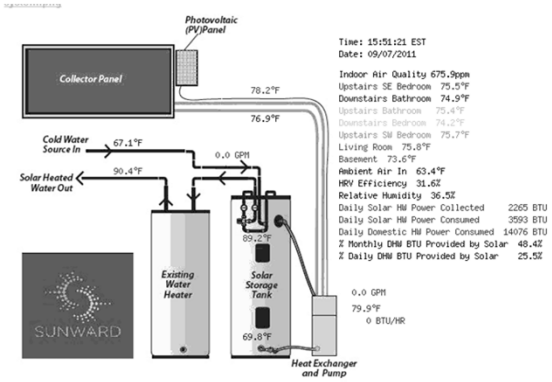
7.6 in² ( +/- 12.5 %) Canadian EqLA @ 10 Pa or 0.0019 in²/ft² Surface Area
3.4 in² ( +/- 19.7 %) LBL ELA @ 4 Pa or 0.0009 in²/ft² Surface Area

**Building Leakage Curve**

Flow Coefficient (C) = 3.7 ( +/- 30.7 %)
Exponent (n) = 0.849 ( +/- 0.080 )
Correlation Coefficient = 0.99107

VERMONT ENERGY INVESTMENT CORPORATION

# Post-Construction Performance Monitoring

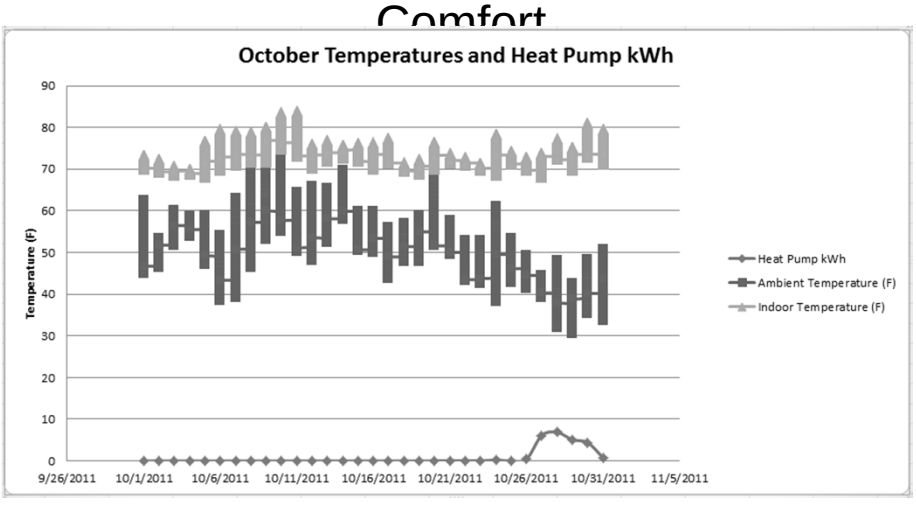



VERMONT ENERGY INVESTMENT CORPORATION

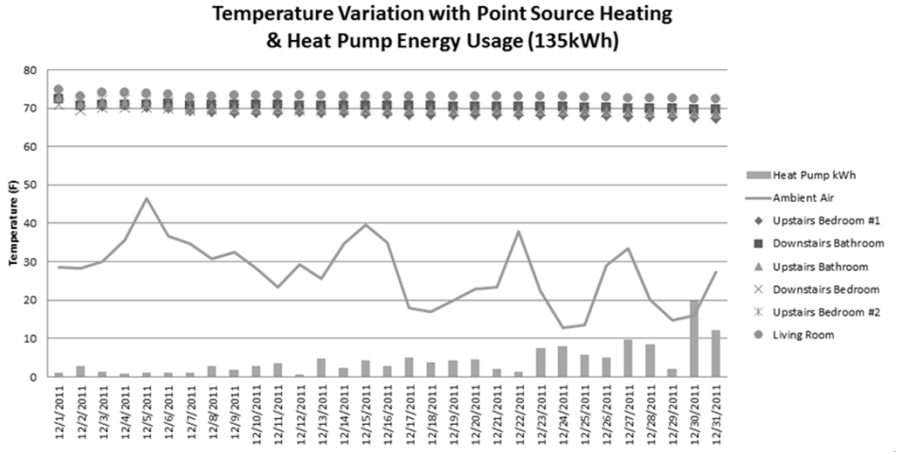
# Post-Construction Performance Monitoring


VERMONT ENERGY INVESTMENT CORPORATION

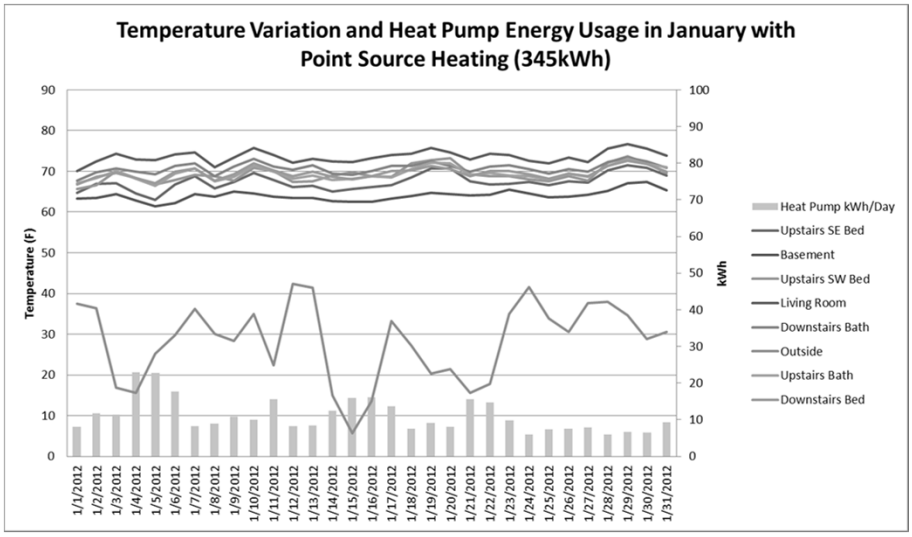
# Heating Energy Needed to Meet Comfort



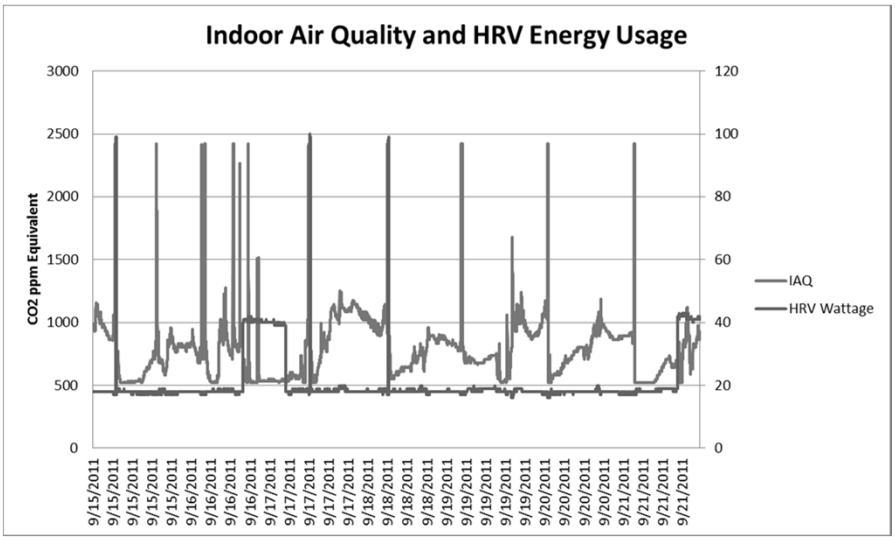
# Heating Energy Needed to Meet Comfort




# Heating Energy Needed to Meet



# IAQ




HRV Energy to Meet IAQ Needs

# IAQ

*The levels of CO2 in the air and potential health problems are:*

*250 - 350 ppm – background (normal) outdoor air level*

*350- 1,000 ppm - typical level found in occupied spaces with good air exchange.*

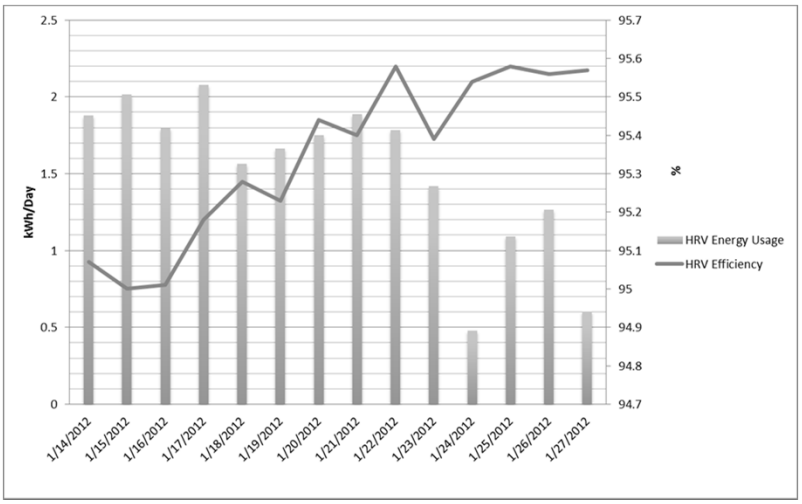
*1,000 – 2,000 ppm - level associated with complaints of drowsiness and poor air.*

*2,000 – 5,000 ppm – level associated with headaches, sleepiness, and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate and slight nausea may also be present.*

*>5,000 ppm – Exposure may lead to serious oxygen deprivation resulting in permanent brain damage, coma and even death.*

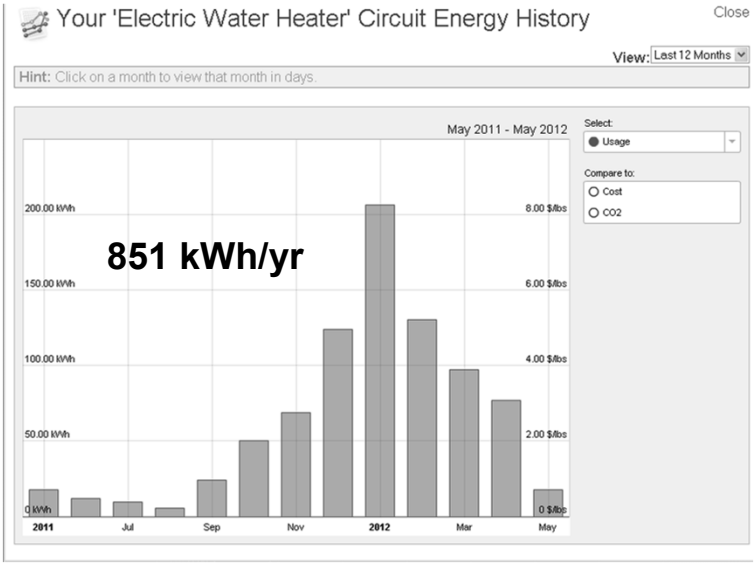
*Wisconsin's Department of Health*

# IAQ



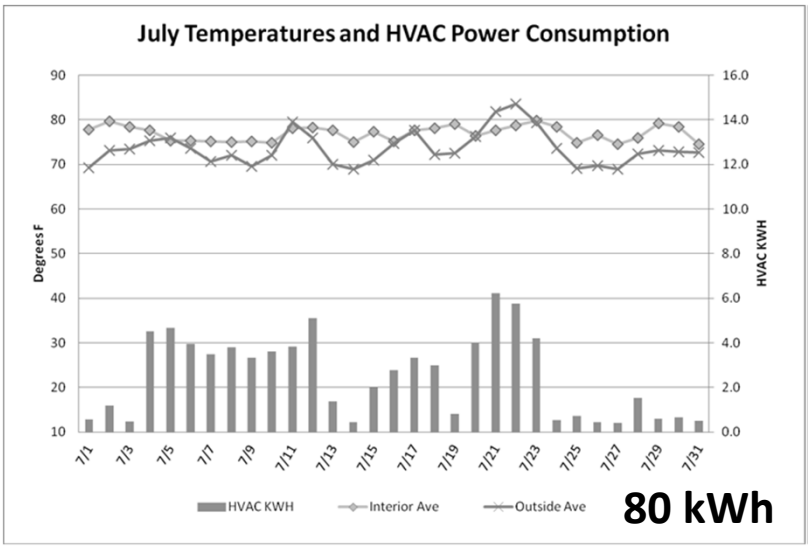

HRV Efficiency & Energy Use

# DHW




**Sunward Solar Thermal System**

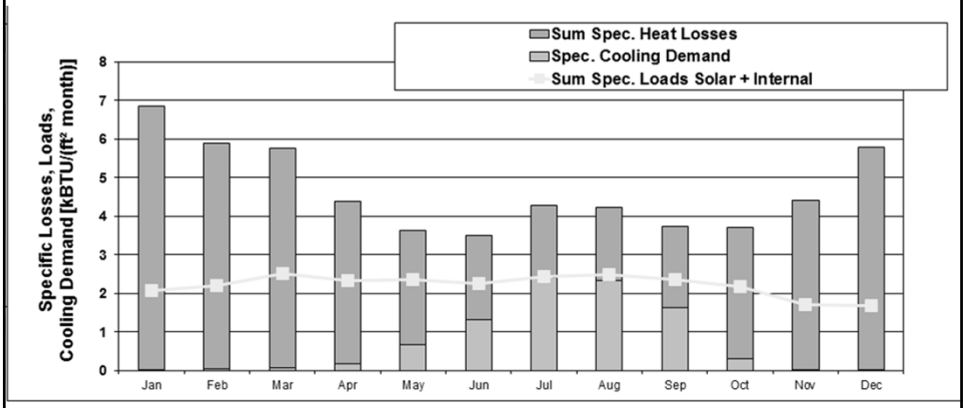
## Cooling Season




**80 kWh**

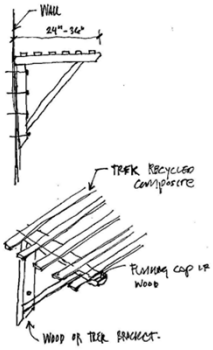
Cooling Energy Needed to Meet

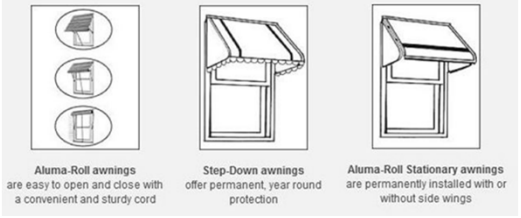
## Cooling Season




PHPP Predicted Cooling Demand

# Passive Houses need Shading



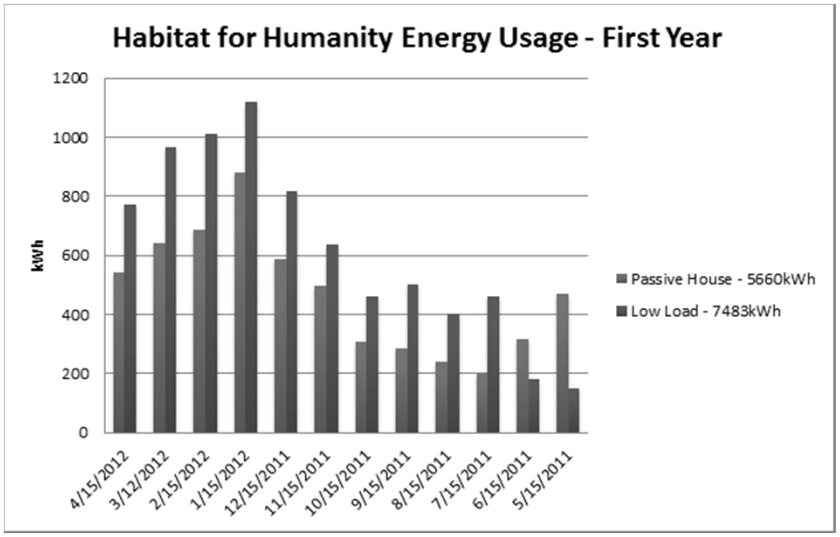



**Aluma-Roll awnings** are easy to open and close with a convenient and sturdy cord

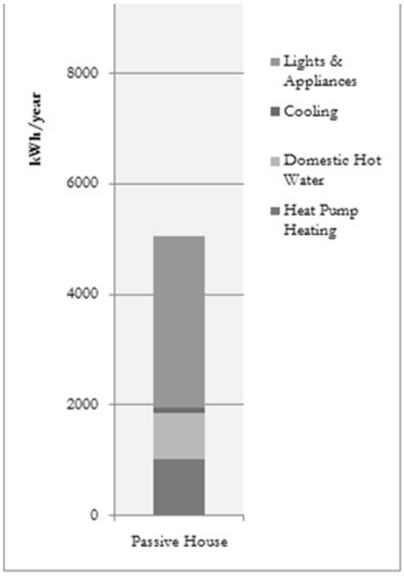
**Step-Down awnings** offer permanent, year round protection

**Aluma-Roll Stationary awnings** are permanently installed with or without side wings

# Total Energy

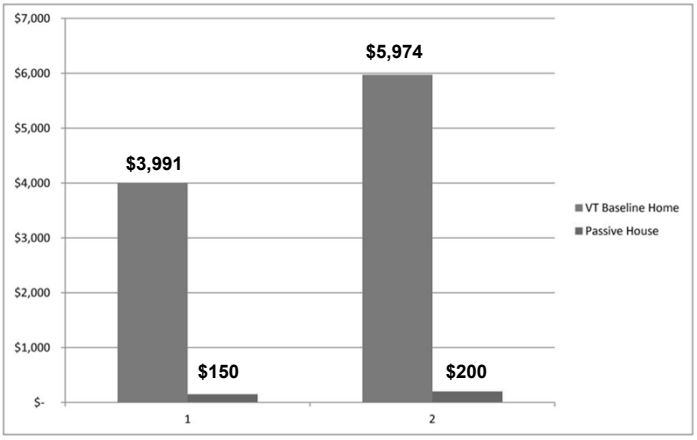


# Total Energy




# Comparison of Annual Heating Costs

## VT Baseline* : Passive House




Estimated monthly energy costs
$3.34/gal; elec $.15/kWh

Estimated monthly energy costs
$5/gal; elec $.20/kWh

*VT Baseline: VEIC Study of 300 new construction houses – Estimated heating costs based on REMRate models

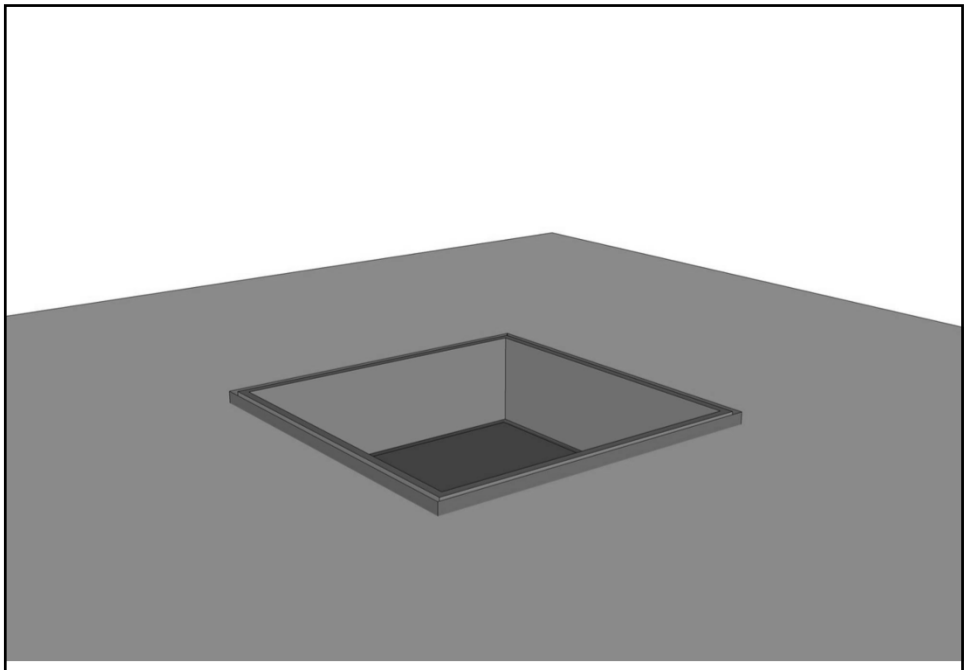
# Comparison of **Total Costs**

## VT Baseline* : Passive House

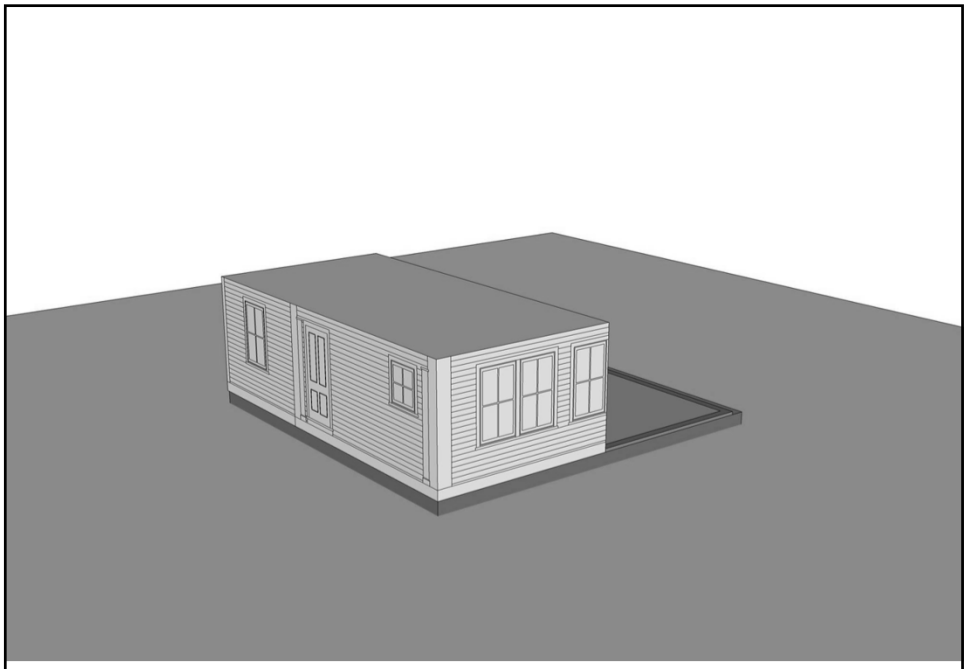
| | VT Baseline Home | Passive House |
|---|---|---|
| Total Cost of Home (Includes $200k for Land and Site Work) | **$375,000** | **$390,000** |
| Mortgage/month 30 year fixed @ 5% | $2,013 | $2,093 |
| Insurance | $50 | $50 |
| Property Taxes | $500 | $500 |
| Estimated monthly energy costs @ $3.34/gal; elec $.15/kWh | $438 | $42 |
| **Total Costs/month @ $3/gal; elec $.14/kWh** | **$3,001** | **$2,685** |
| | | |
| Estimated monthly energy costs @ $5/gal; elec $.20/kWh | $638 | $56 |
| **Total Costs/month @ $5/gal; elec $.20/kWh** | **$3,201** | **$2,699** |
| Passive House yearly savings @ $3.24/gal; elec $.15/kWh over energy code home = | | $3,792 |
| Passive House yearly savings @ $5/gal; elec $.20/kWh over energy code home = | | $6,024 |

*VT Baseline: VEIC Study of 300 new construction houses – Estimated heating costs based on REMRate Models. Models assume 4400 kWh for DHW and 4000 kWh for plugs

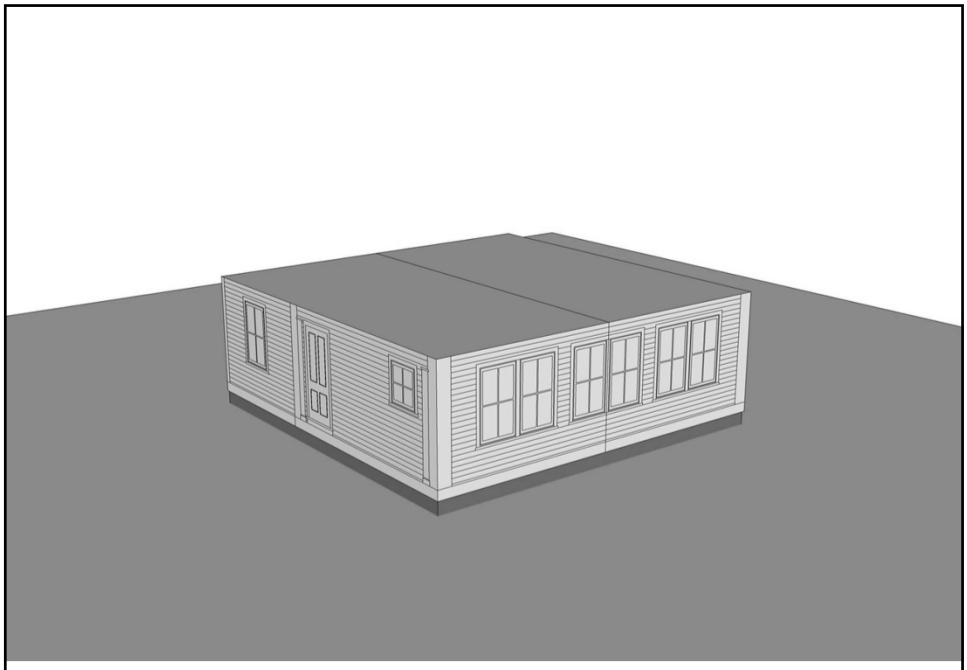
# MODULAR CONSTRUCTION



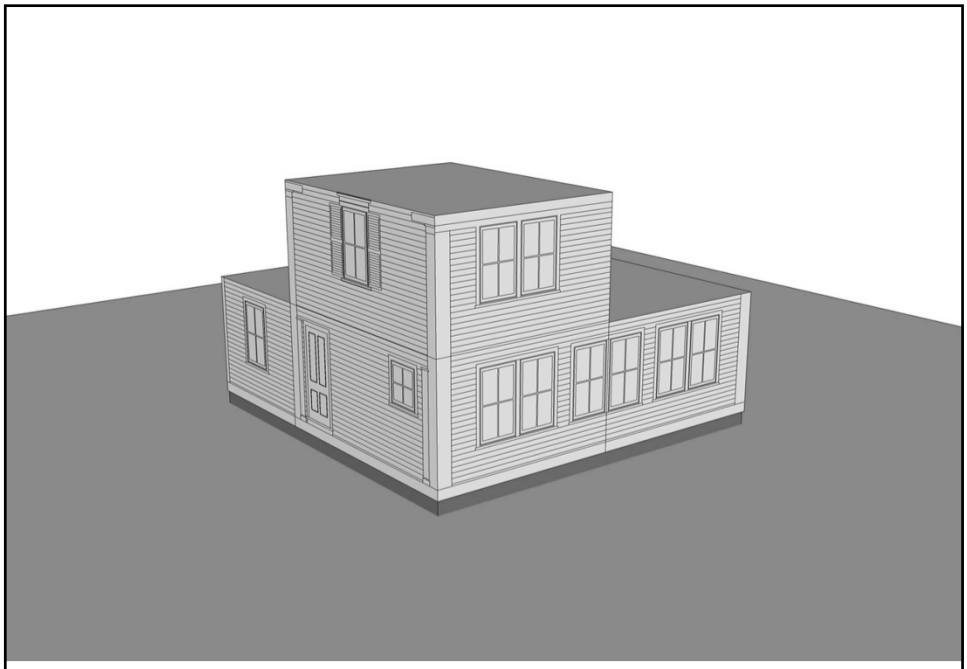
*Albert, Righter & Tittmann Architects*



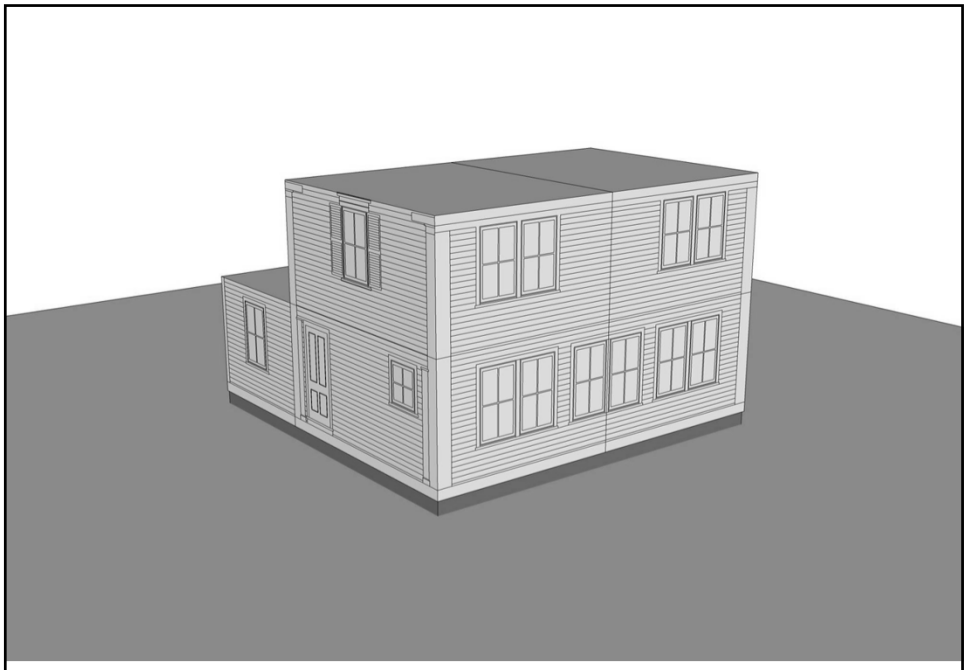
*Albert, Righter & Tittmann Architects*



*Albert, Righter & Tittmann Architects*



*Albert, Righter & Tittmann Architects*



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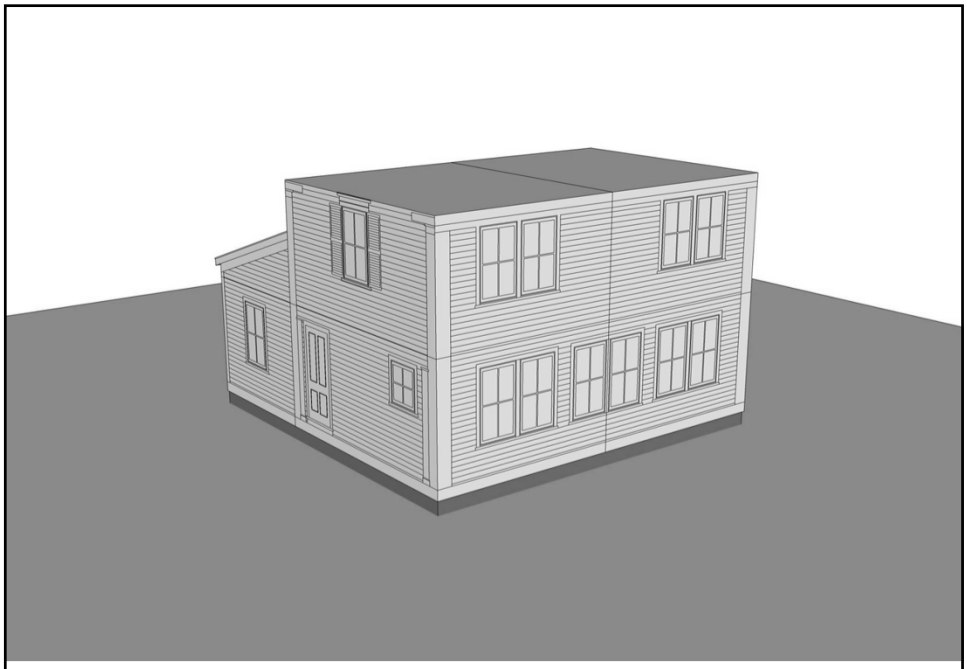
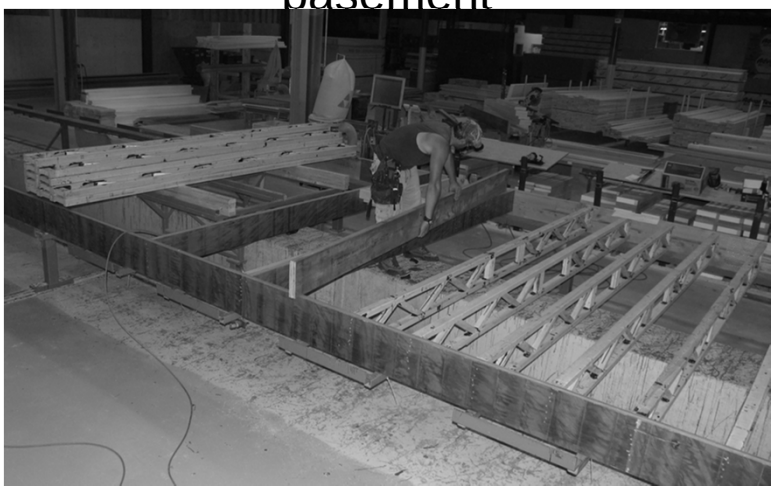


*Albert, Righter & Tittmann Architects*

*Albert, Righter & Tittmann Architects*

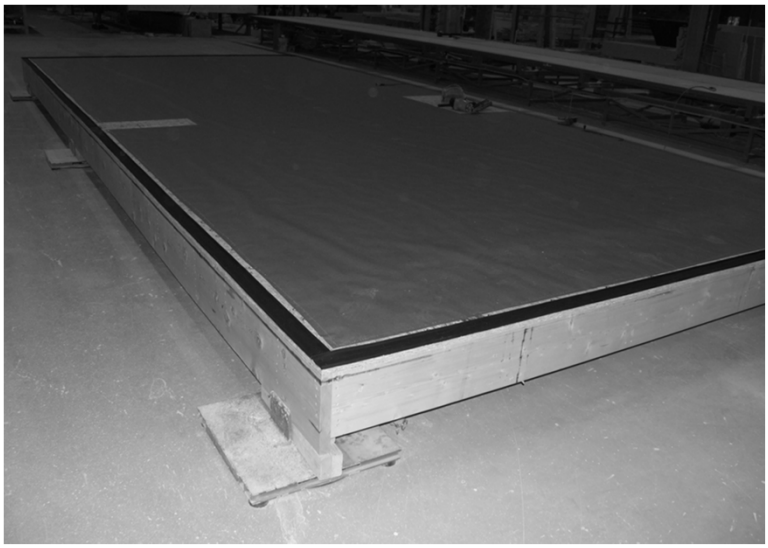
*Albert, Righter & Tittmann Architects*

Beginning of floor system-open web joists, LVL to reduce columns in basement



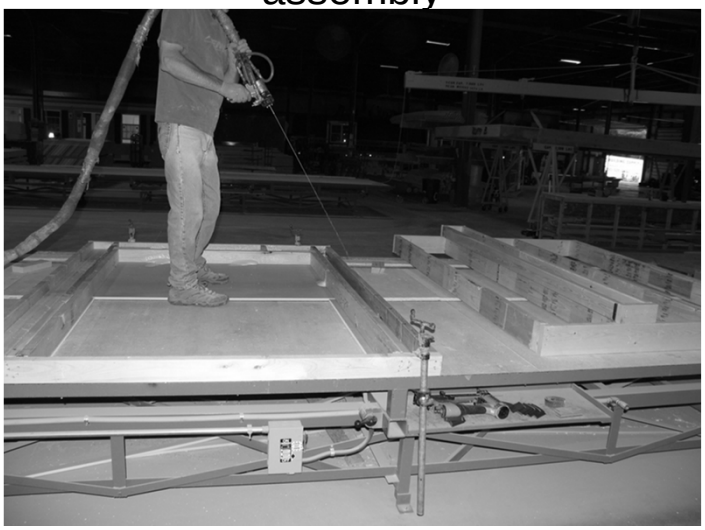
4”Foam blocking on outside perimeter of floors – open web joists – urethane adhesive on floors

## EPDM gasket on floors.

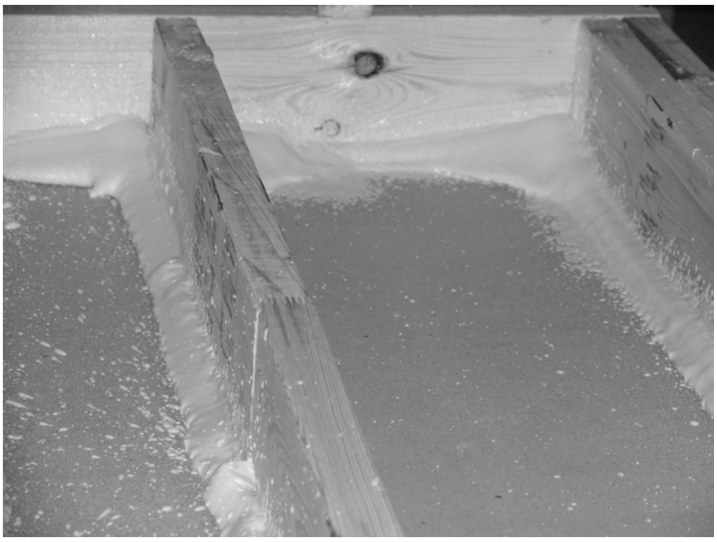


## EPDM gasket at floor and wall intersections

Spraying the foam seal - attaches the sheetrock to framing and makes air-tight assembly



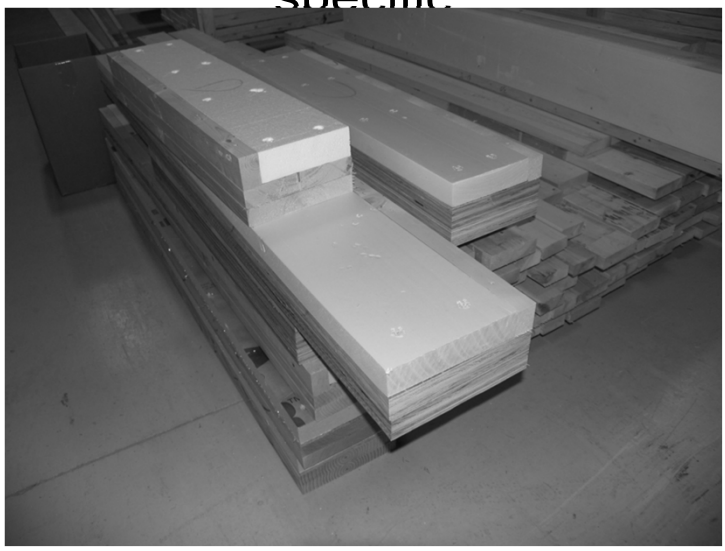
Sheetrock air-sealed to framing



## Lifting wall section off framing table

## Assembled walls on floor for ½ of 1st floor

## Insulated headers – built load specific

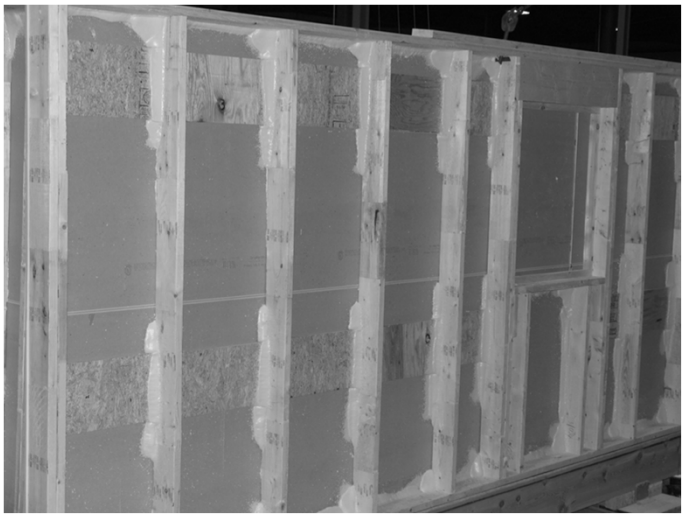


## Full sheetrock air-seal behind tub

## Foam sprayed on sheetrock joints at tub to complete air-seal

## OVE framing

(partial double plate is temporary for lifting)



20” raised Heel folding truss w/ EPDM gasket between walls and ceiling

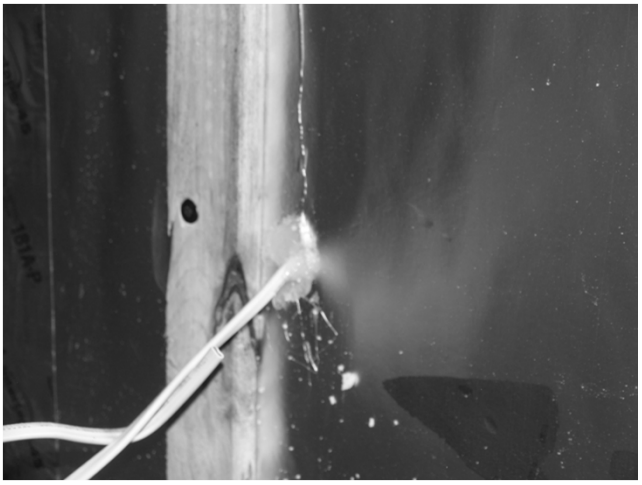
13 3/8” window buck
clapboard drainage under window

## Installed dense pack cellulose

## Air seal around plumbing vents

## Radon vent and ERV ducts


## Silicone sealing of wires penetrating exterior insulation



# Exterior insulation details

# Air sealing of wall sheathing

## Wide strapping on corners


## Folded shed roof

# Eave framing on shed roof

# Front door area

8.17.2010

10 working days

# On the launch pad Claremont, NH

6:30 AM 9.10.2010

# Section

## Foundation and wall insulation detail


# Coming in for landing



## Charlotte, VT

1:30 PM 9.10.2010

## Habitat for Humanity Passive House

## “Heating System”
## $30 for January, average temp 72

## Habitat for Humanity Passive House

## Habitat for Humanity Passive House

## Habitat for Humanity Passive House


## Habitat for Humanity Passive House

*Philip Jensen-Carter*

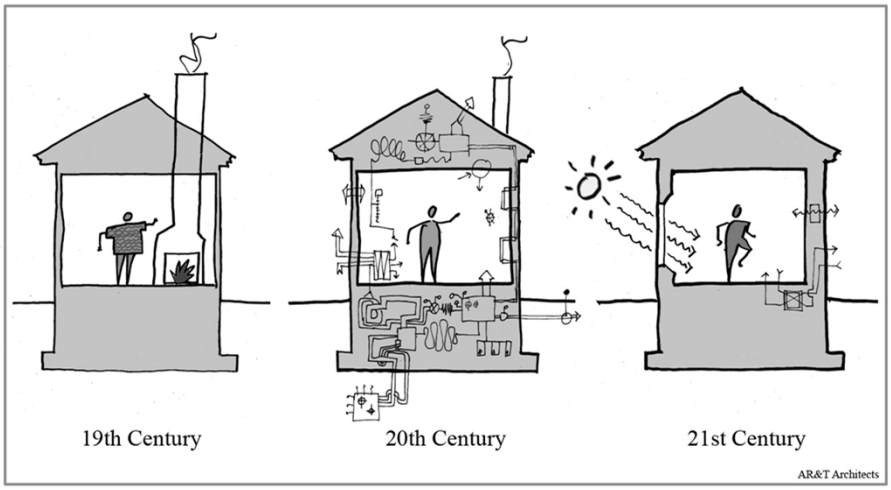
# Habitat for Humanity Passive House

*Philip Jensen-Carter*

# Habitat for Humanity Passive House

*Philip Jensen-Carter*

# Moving Towards Simplicity




*Albert, Righter & Tittmann Architects*

# Resources

*Philip Jensen-Carter*

- Passipedia: www.passipedia.passiv.de
- Passivhaus Institute Germany:  www.passiv.de
- PHIUS: www.passivehouse.us

**J.B. Clancy, AIA**
Albert, Righter & Tittman Architects, Inc.

Submit a question to the moderator via the Chat box. They will be answered as time allows.

**Stephen Schreiber FAIA**
Professor and Architecture+Design Program Director
Department of Art, Architecture, and Art History
University of Massachusetts Amherst
Moderator

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# Thank you for joining us!

This concludes the AIA/CES Course #H12005.

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