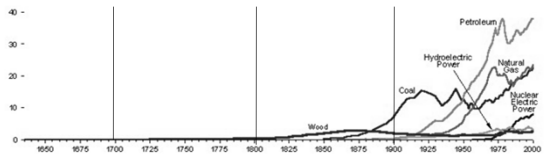
FORM FOLLOWS ENERGY

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

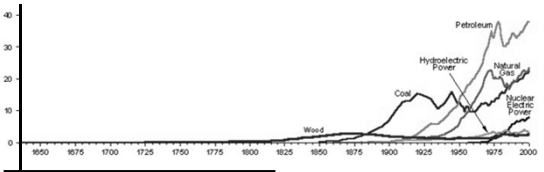
2011 UMass Wood Structures Symposium
Amherst, Massachusetts
September 8-9, 2011

History of Energy Consumption by Source in USA 1630 to Present



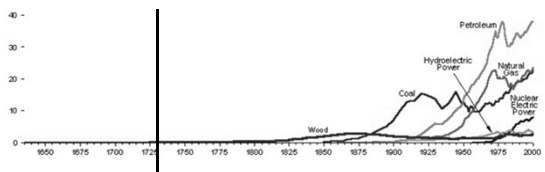
FORM FOLLOWS ENERGY

House 1630



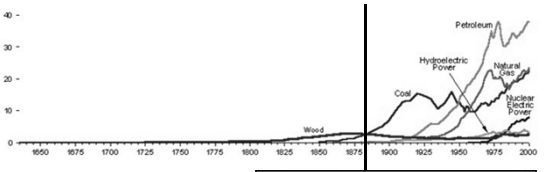
George Soule House 1630s, Plymouth, MA

House 1732



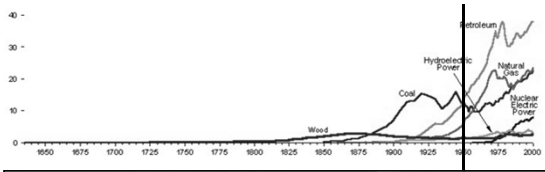
Hartwell Tavern, Concord, MA, 1732

House1880



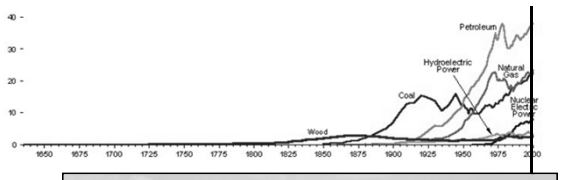
Drew House 1882, Sandwich MA

House 1950



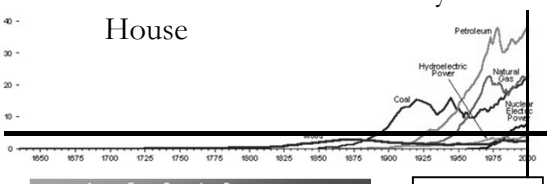
Farnsworth House, Mies van der Rohe 1951, Plano, IL

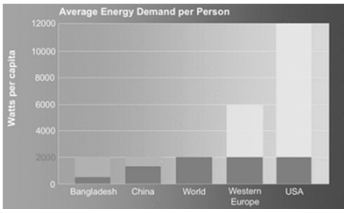
House 1995



Anywhere USA

House Now – 21st Century House





Passive House Energy Standard

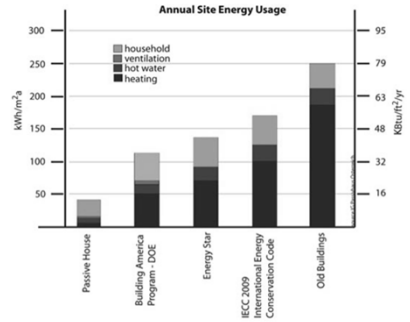
A Green Building Standard
built on an
Energy Budget
For the 21st Century
Energy Context

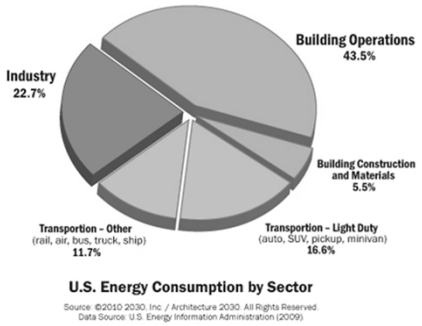
Passive House Energy Standard

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)

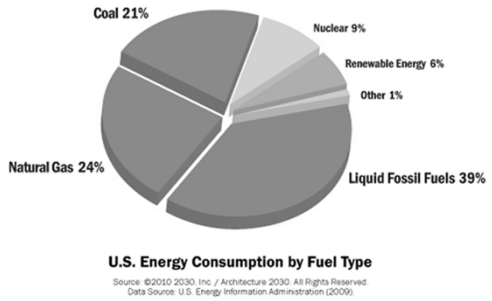
Standards Comparison





U.S. Energy Consumption by Sector

Data Source: U.S. Energy Information Administration (2009).



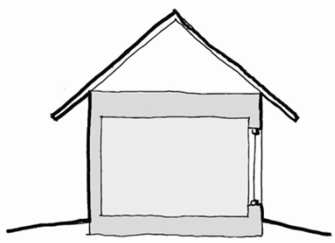
U.S. Energy Consumption by Fuel Type

Data Source: U.S. Energy Information Administration (2009)

THE PASSIVE HOUSE STRATEGY

Passive House Concept

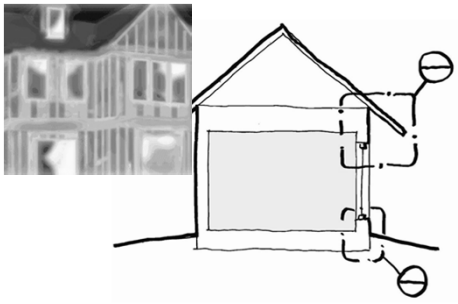
Controlling Heat Loss… INSULATION



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

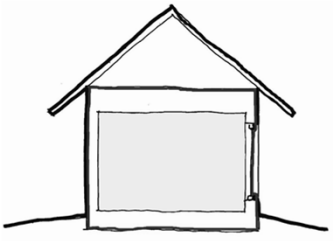
Passive House Concept

Controlling Heat Loss… ELIMINATE THERMAL BRIDGES



Passive House Concept

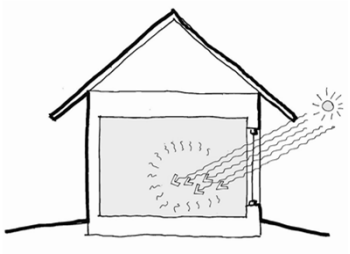
Controlling Heat Loss… REDUCE AIR INFILTRATION



.6 ACH @ 50 PA

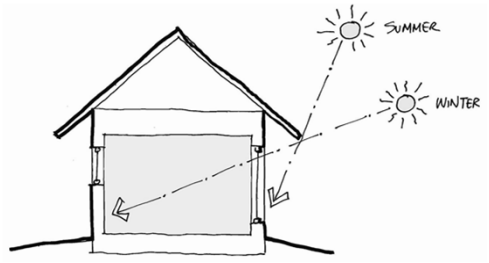
Passive House Concept

Capturing Heat Gains… SOLAR ENERGY



Passive House Concept

Controlling Gains Seasonally… WINDOWS & ORIENTATION



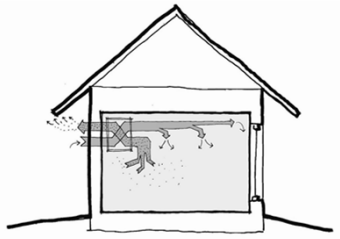
U VALUE .10: TRIPLE GLAZED: >.5 SHGC ON SOUTH WINDOWS

Passive House Concept

Controlling Gains Seasonally… SOLAR THERMAL

Passive House Concept

Providing Fresh Air… HEAT RECOVERY VENTILATION

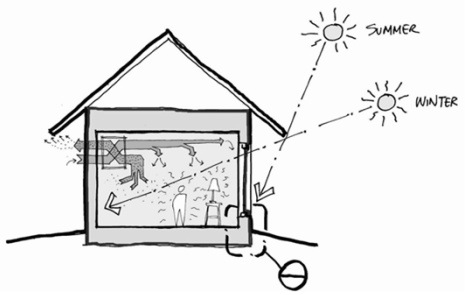


MINIMUM .35 ACH

Passive House Concept

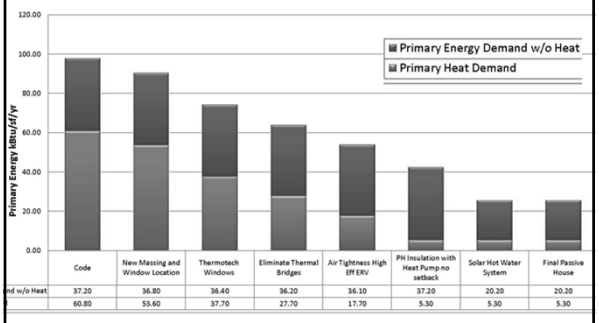
INTEGRATED

"Let the architecture do the work"



Passive House Strategies

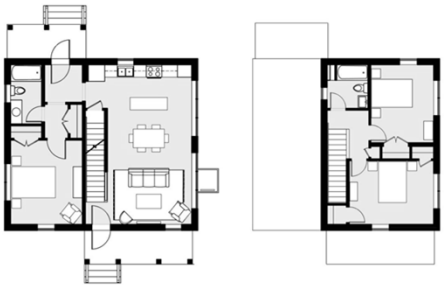
TO GET FROM CODE TO PASSIVE HOUSE



THE FIRST CERTIFIED PASSIVE HOUSE IN VERMONT

CONSTRUCTED 2010

Habitat for Humanity Passive House

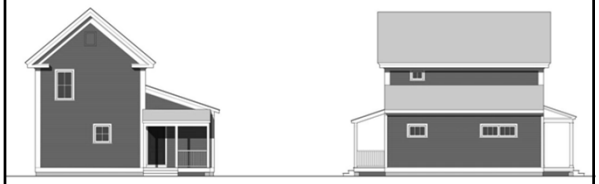


Habitat for Humanity Passive House

WEST ELEVATION

SOUTH ELEVATION

Habitat for Humanity Passive House

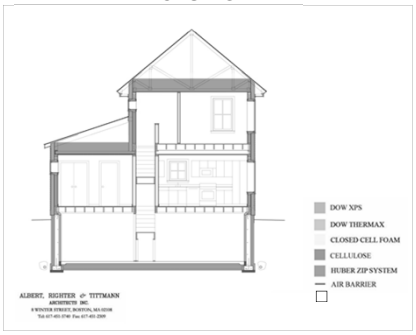


EAST ELEVATION

NORTH ELEVATION

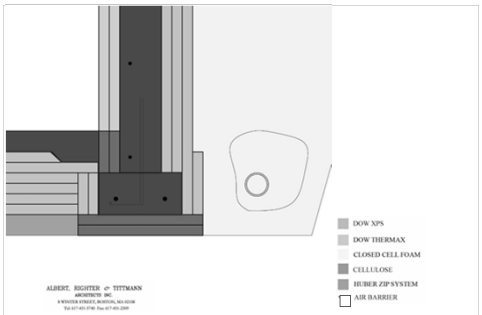
Habitat for Humanity Passive House

SECTION



Habitat for Humanity Passive House

FOOTING DETAIL



Code vs. Passive House

THERM MODELS OF FOUNDATION DETAILS

CODE INSULATION–
2" XPS Under Slab & on Wall

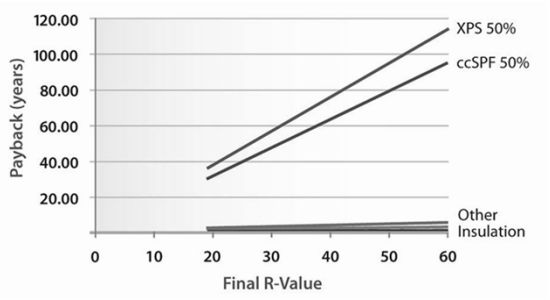
PASSIVE HOUSE INSULATION– 12" XPS Under Slab & 10" on Wall

Global Warming Potential of Insulation Materials

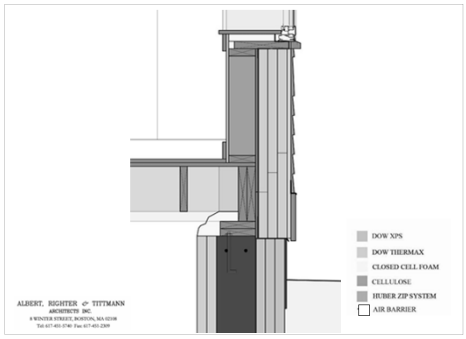
Insulation Material	R-value R/inch	Density lb/ft³	Emb. E MJ/kg	Emb. Carbon $kgCO_2/kg$	Emb. Carbon $kgCO_2/ft^2$•R	Blowing Agent (GWP)	Bl. Agent kg/kg foam	Blowing Agent GWP/ bd-ft	Lifetime GWP/ ft²•R
Cellulose (dense-pack)	3.7	3.0	2.1	0.106	0.0033	None	0	N/A	0.0033
Fiberglass batt	3.3	1.0	28	1.44	0.0165	None	0	N/A	0.0165
Rigid mineral wool	4.0	4.0	17	1.2	0.0455	None	0	N/A	0.0455
Polyisocyanurate	6.0	1.5	72	3.0	0.0284	Pentane (GWP=7)	0.05	0.02	0.0317
Spray polyure-thane foam (SPF) – closed-cell (HFC-blown)	6.0	2.0	72	3.0	0.0379	HFC-245fa (GWP=1,030)	0.11	8.68	1.48
SPF – closed-cell (water-blown)	5.0	2.0	72	3.0	0.0455	Water (CO_2) (GWP=1)	0	0	0.0455
SPF – open-cell (water-blown)	3.7	0.5	72	3.0	0.0154	Water (CO_2) (GWP=1)	0	0	0.0154
Expanded polystyrene (EPS)	3.9	1.0	89	2.5	0.0307	Pentane (GWP=7)	0.06	0.02	0.036
Extruded polystyrene (XPS)	5.0	2.0	89	2.5	0.0379	HFC-134a[1] (GWP=1,430)	0.08	8.67	1.77

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

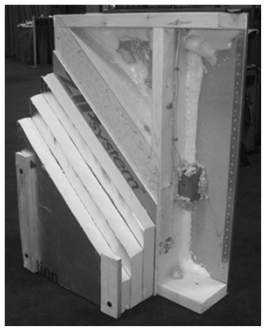
Payback of XPS Insulation



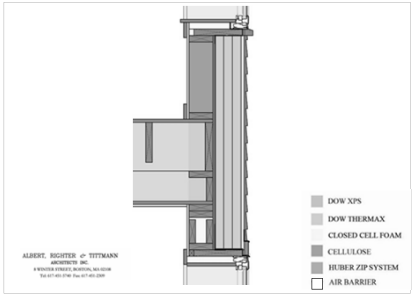
Habitat for Humanity Passive House
SILL DETAIL



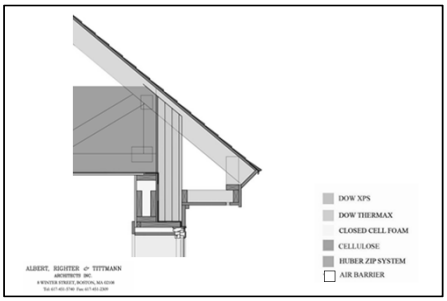
Habitat for Humanity Passive House
WALL SECTION



Habitat for Humanity Passive House
SECOND FLOOR PLATFORM DETAIL



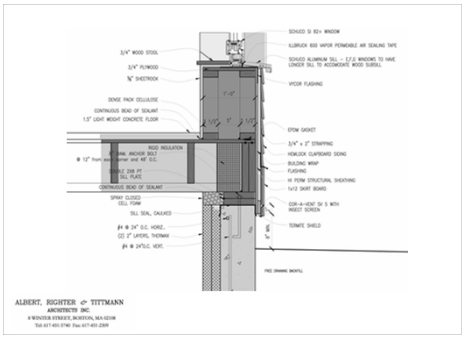
Habitat for Humanity Passive House
EAVE DETAIL



Habitat for Humanity Passive House

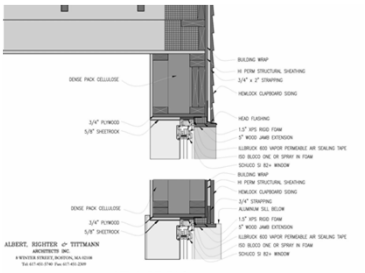
Habitat for Humanity Passive House

SILL DETAIL - ALTERNATE



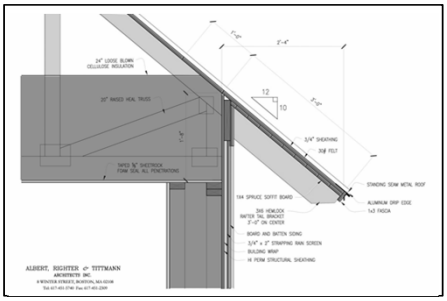
Habitat for Humanity Passive House

SECOND FLOOR PLATFORM DETAIL ALTERNATE



Habitat for Humanity Passive House

EAVE DETAIL - ALTERNATE



Habitat for Humanity Passive House

WINDOWS

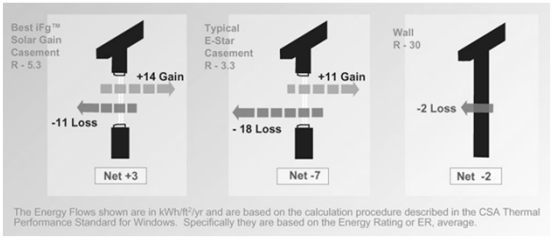
Thermotech
322 Gain+

.64 SHGC (solar heat gain coefficient)

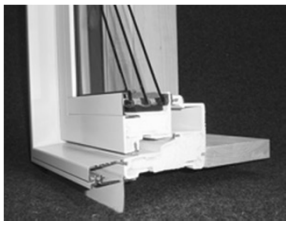
Glazing U-value .16
Frame U-value .16

Habitat for Humanity Passive House

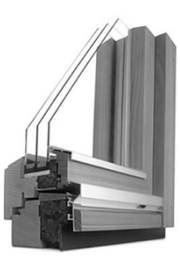
THERMOTECH WINDOWS

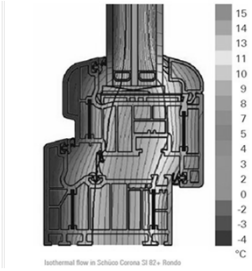


Habitat for Humanity Passive House
WINDOWS – NORTH AMERICAN CASEMENT



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

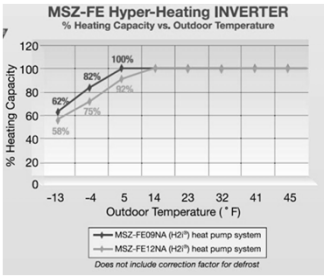
HRV
Zender ComfoAir 350 HRV

Soil heat exchange system
Two 125' loops of 1" pex around the base of the footings filled with water/glycol mix & tied to Laing 30W AC Pump & water-to-air coil (~40F Temp Rise)

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

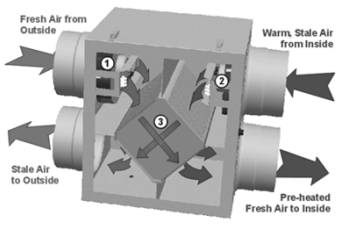


Habitat for Humanity Passive House
HEAT RECOVERY VENTILATION

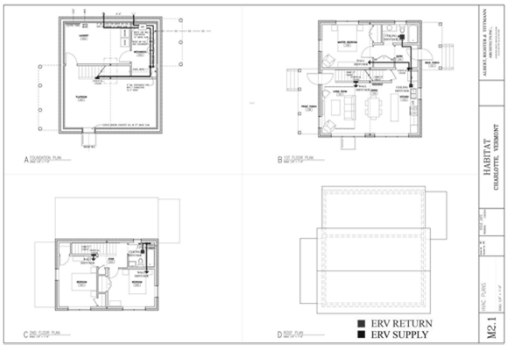
MINIMUM .35 ACH

Habitat for Humanity Passive House
HVAC SYSTEM

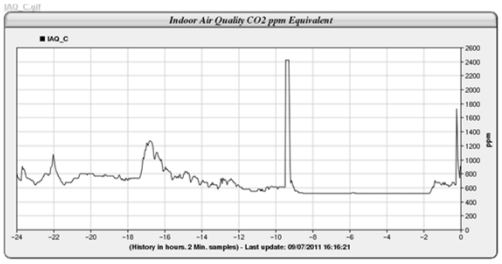
HRV
Zender ComfoAir 350 HRV



Habitat for Humanity Passive House
HVAC SYSTEM – DUCT LAYOUT



Habitat for Humanity Passive House
HVAC SYSTEM - IAQ



Habitat for Humanity Passive House
HVAC SYSTEM - 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.

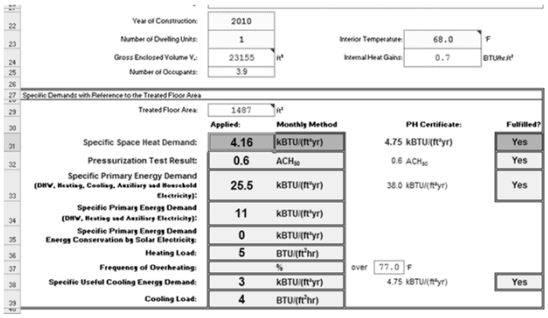
1,000 – 2,000 ppm - level associated with complaints of drowsiness and poor air.

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

PHPP Model
VERIFICATION



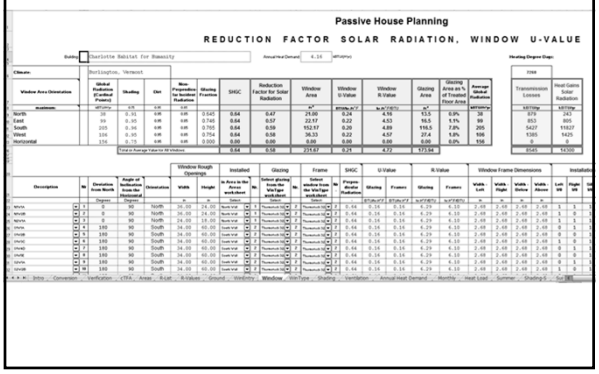
Year of Construction:	2010			
Number of Dwelling Units:	1		Interior Temperature:	68.0 °F
Gross Enclosed Volume V_e:	23155 ft³		Internal Heat Gains:	0.7 BTU/hr·ft²
Number of Occupants:	3.9			

Specific Demands with Reference to the Treated Floor Area

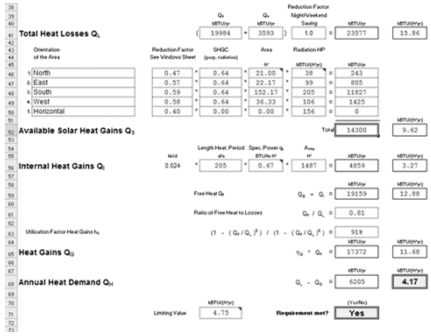
Treated Floor Area: 1487 ft²

	Applied:	Monthly Method	PH Certificate:	Fulfilled?
Specific Space Heat Demand:	4.16	kBTU/(ft²yr)	4.75 kBTU/(ft²yr)	Yes
Pressurization Test Result:	0.6	ACH_{50}	0.6 ACH_{50}	Yes
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	25.5	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:	5	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 Model
WINDOWS



PHPP Model
HEAT DEMAND

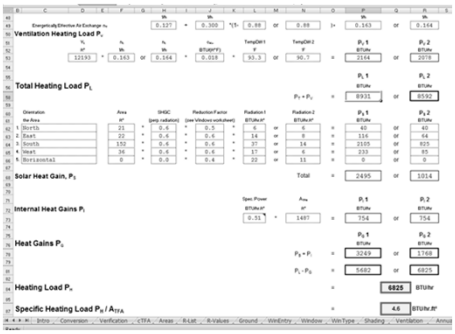


Total Heat Losses Q_L					19984	3593	23577 / 15.86
Available Solar Heat Gains Q_S							14300 / 9.62
Internal Heat Gains Q_I							4859 / 3.27
						Free Heat Q_F	19159 / 12.88
						Ratio of Free Heat to Losses	0.81
						Utilisation Factor Heat Gains η_G	918
Heat Gains Q_G							17372 / 11.68
Annual Heat Demand Q_H							6205 / 4.17

Limiting Value: 4.75 kBTU/(ft²yr) — Requirement met? Yes

PHPP Model

HEAT LOAD



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

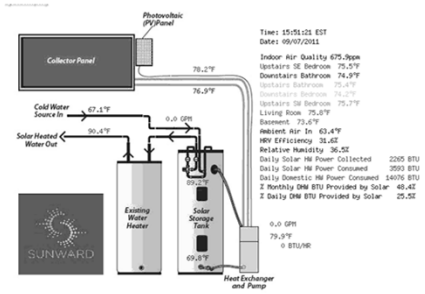
Leakage Areas

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

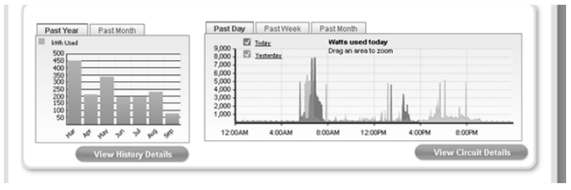
Flow Coefficient (C) = 3.7 (+/- 30.7 %)
Exponent (n) = 0.849 (+/- 0.080)
Correlation Coefficient = 0.99107

Post-Construction Performance Monitoring

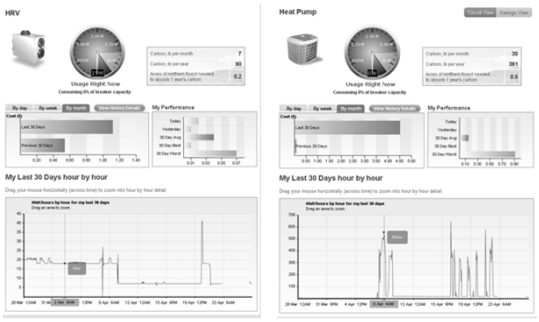


Post-Construction Performance Monitoring

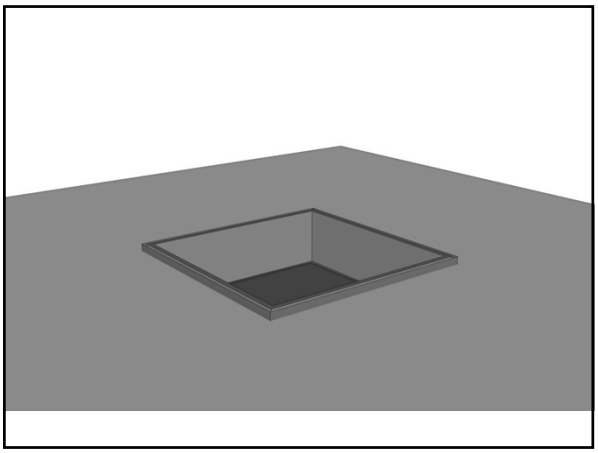
Post-Construction Performance Monitoring

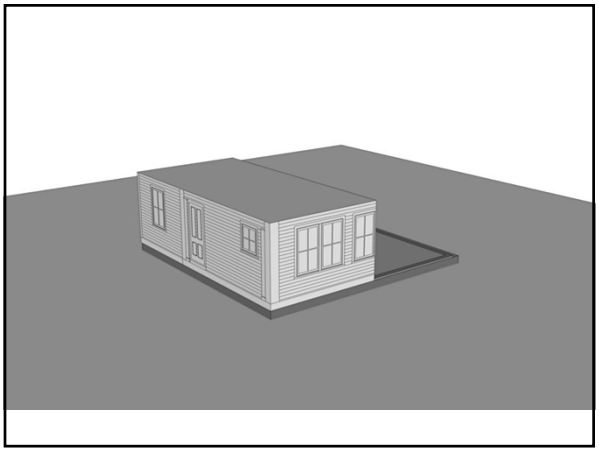


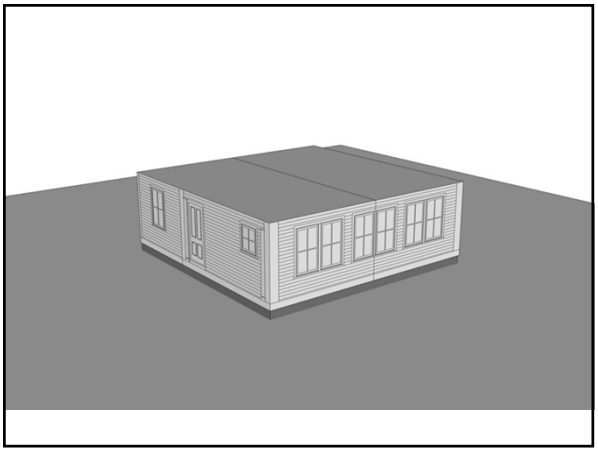
Post-Construction Performance Monitoring

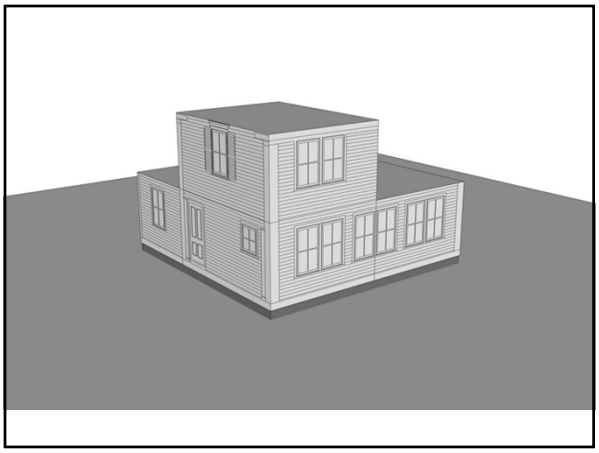


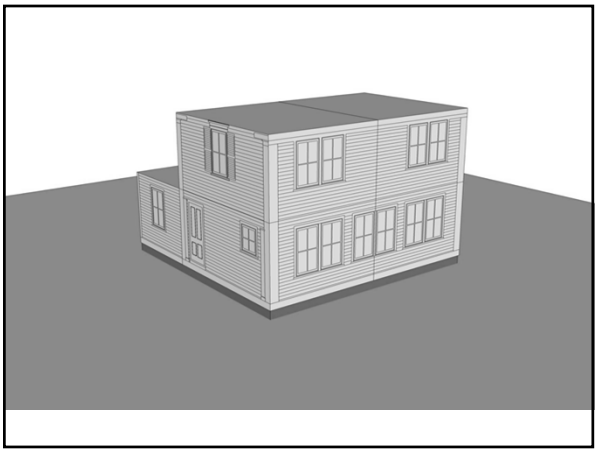
MODULAR CONSTRUCTION

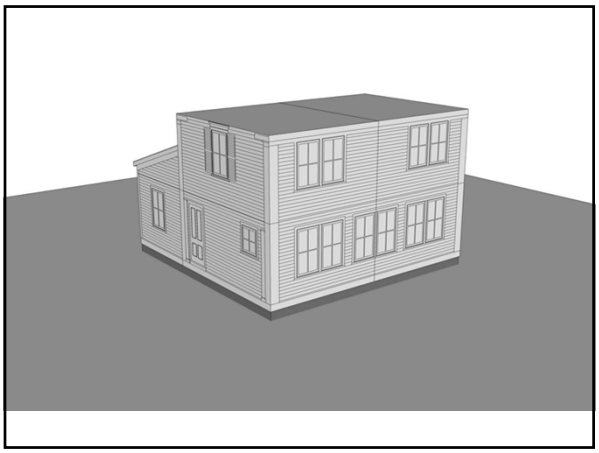


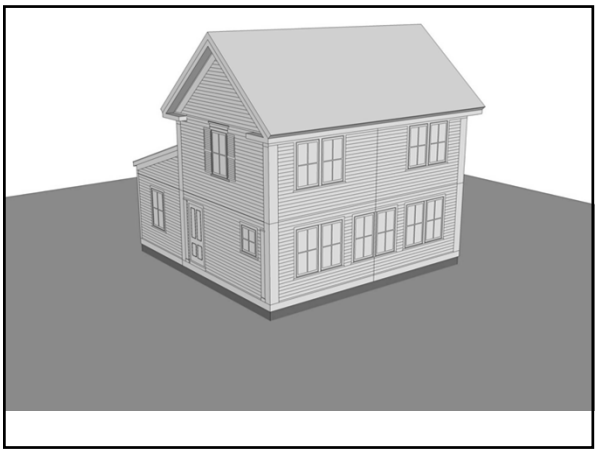


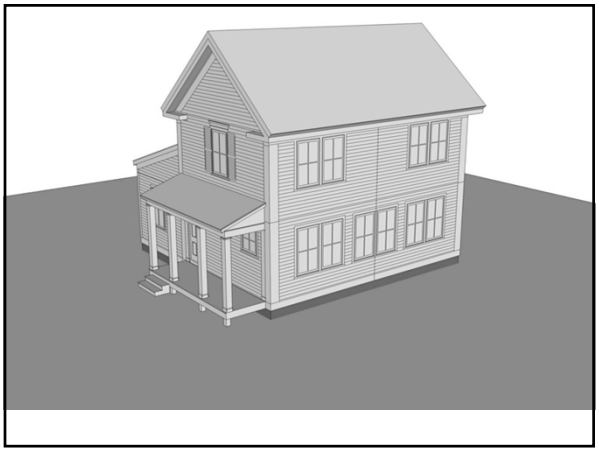








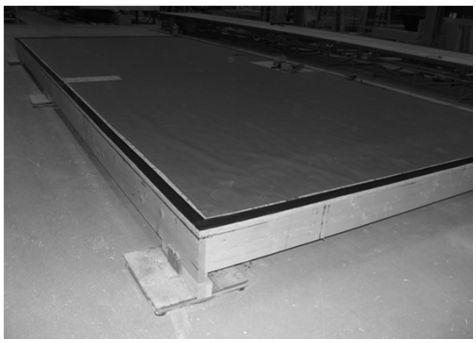




Beginning of floor system-open web joists, LVL to reduce columns in basement

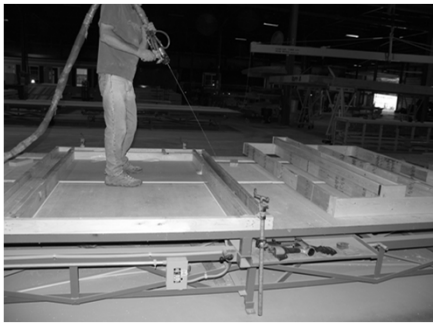
4"Foam blocking on outside perimeter of floors – open web joists – urethane adhesive on floors

EPDM gasket on floors.

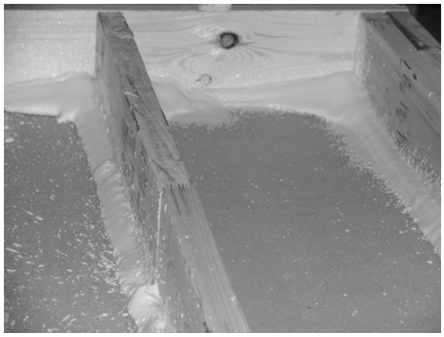


EPDM gasket at
floor and wall intersections

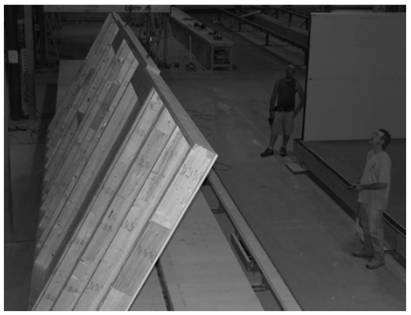
Spraying the foam seal - attaches the sheetrock to framing and makes air-tight assembly



Sheetrock air-sealed to framing

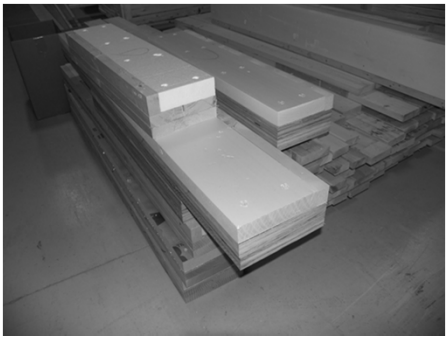


Lifting wall section off framing table



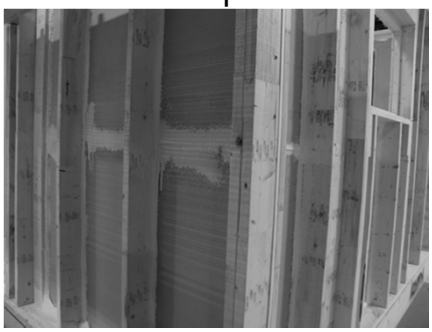
Assembled walls on floor for ½ of 1st floor

Insulated headers – built load specific

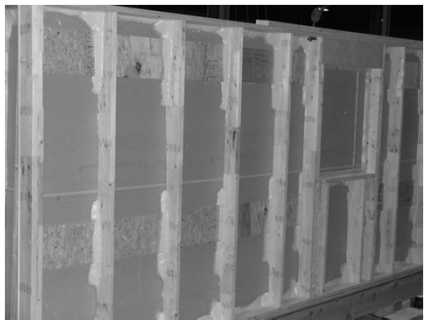


Full sheetrock air-seal behind tub

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

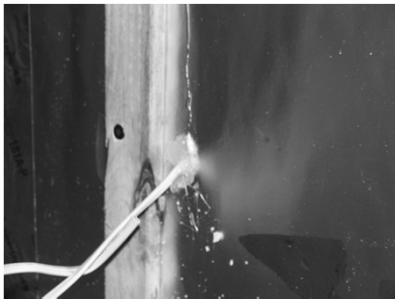
13 3/8" window buck
clapboard drainage under window

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

First Modular Passive House in USA

Habitat for Humanity Passive House

Habitat for Humanity Passive House

Habitat for Humanity Passive House

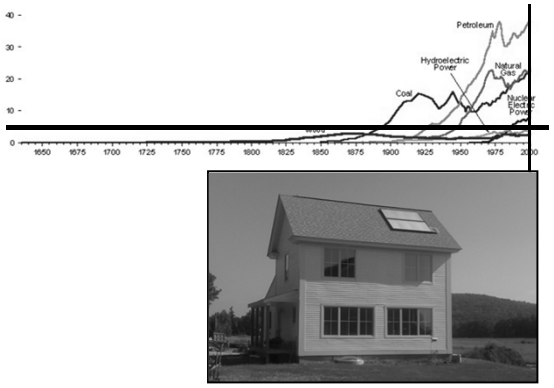
"Heating System"
$30 for January, average temp 72

Habitat for Humanity Passive House

Habitat for Humanity Passive House

Habitat for Humanity Passive House

House 2011



http://passipedia.passiv.de