Buildings XV Conference
December 5-8, 2022 | Clearwater Beach, FL

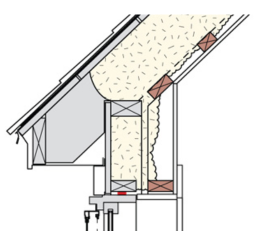
ASHRAE | OAK RIDGE National Laboratory

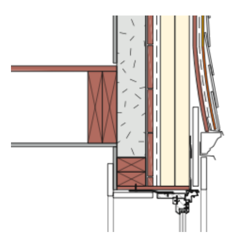
*Deep Energy Retrofit of a Sears Roebuck House: A Home for the Next 100 Years**……

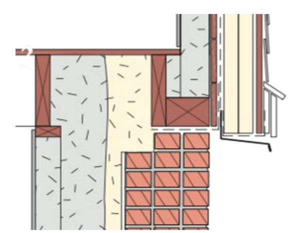
13 Years Later

*published by HIGH PERFORMING BUILDINGS Spring 2009

Betsy Pettit, FAIA, President
Building Science Corporation
betsy@buildingscience.com







Building Science Corporation

Acknowledgements

- **All of us**– who support building research because we believe in energy security and resource efficiency, and reducing our dependence on fossil fuel use

- **The U.S. Department of Energy - Energy Efficiency & Renewable Energy -**

who support building research through public/private partnerships and through review and management of specific projects

- **The National Laboratories -** who support research teams, provided research results and have created outreach opportunities to share the research results

National Renewable Energy Laboratory – Ren Anderson, Achilles Karagiozis and many more

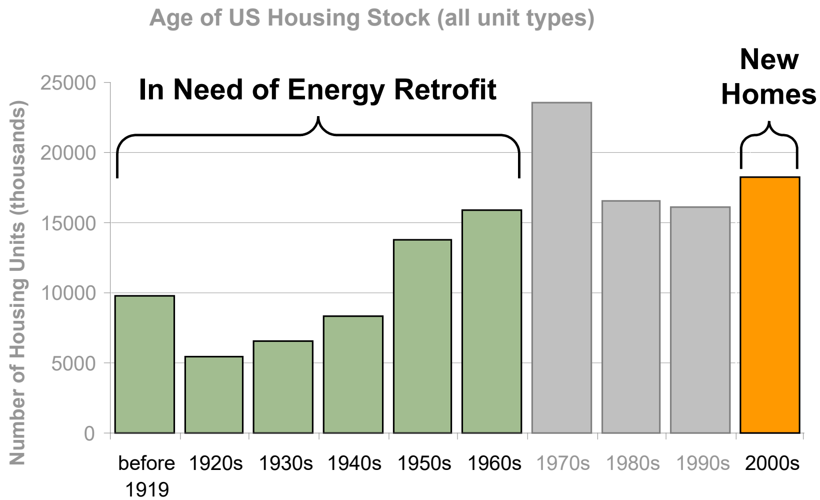
Oak Ridge Nation Laboratory - Andre Desjarlais and many more

Pacific Northwest National Laboratory - Cheryn Metzger, Theresa Gilbride, and many more

- **The Partners and Associates of Building Science Corporation**

Joseph Lstiburek, Kohta Ueno, and Peter Baker

Deep Energy Retrofits Applied Research



- Practices - it is important to follow up on the goals of practical research to see if you met them.

- Lessons – what was learned through the original research? What impact did it have? What mistakes were made?

- Goals change – how have goals changed since the practical research was completed and what would be done differently today?

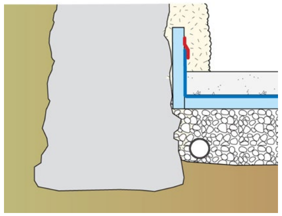
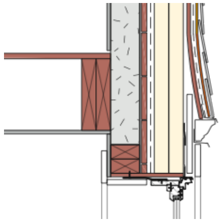
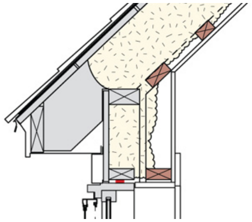
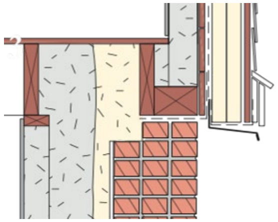
Goals - The Whole Building Approach

Performance Issues driving Retrofit:

- Increasing comfort
- Improving indoor air quality
- More efficient use of enclosed space
- Improving long term durability
- Reducing operating costs
- Increasing energy efficiency

Deep Energy Retrofits

- > 50% reduction in energy use
- Secure buildings future

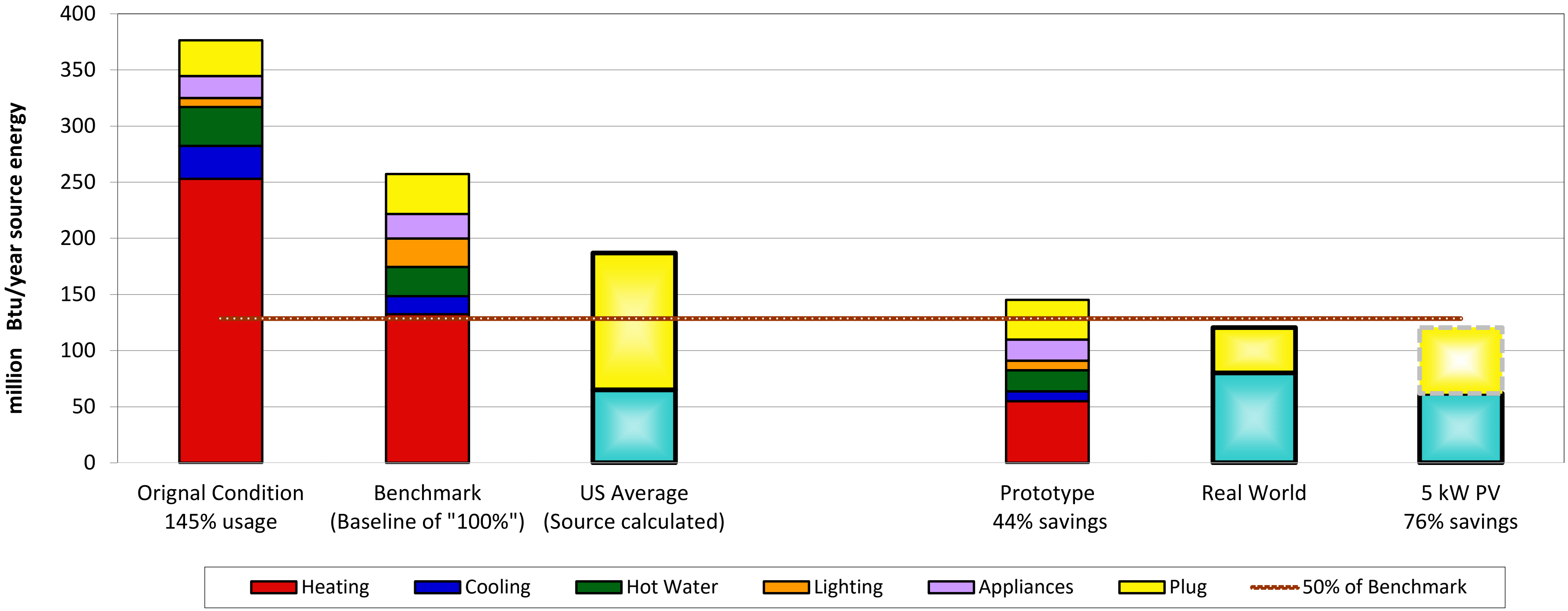





Enclosure Retrofit - Goals

- Airtightness 2 ACH @50 Pascals
- Windows R-2
- Insulation
  - Roof R-60
  - Walls R-40
  - Basement R-20
  - Slabs R-10

Specific Energy Reduction Targets

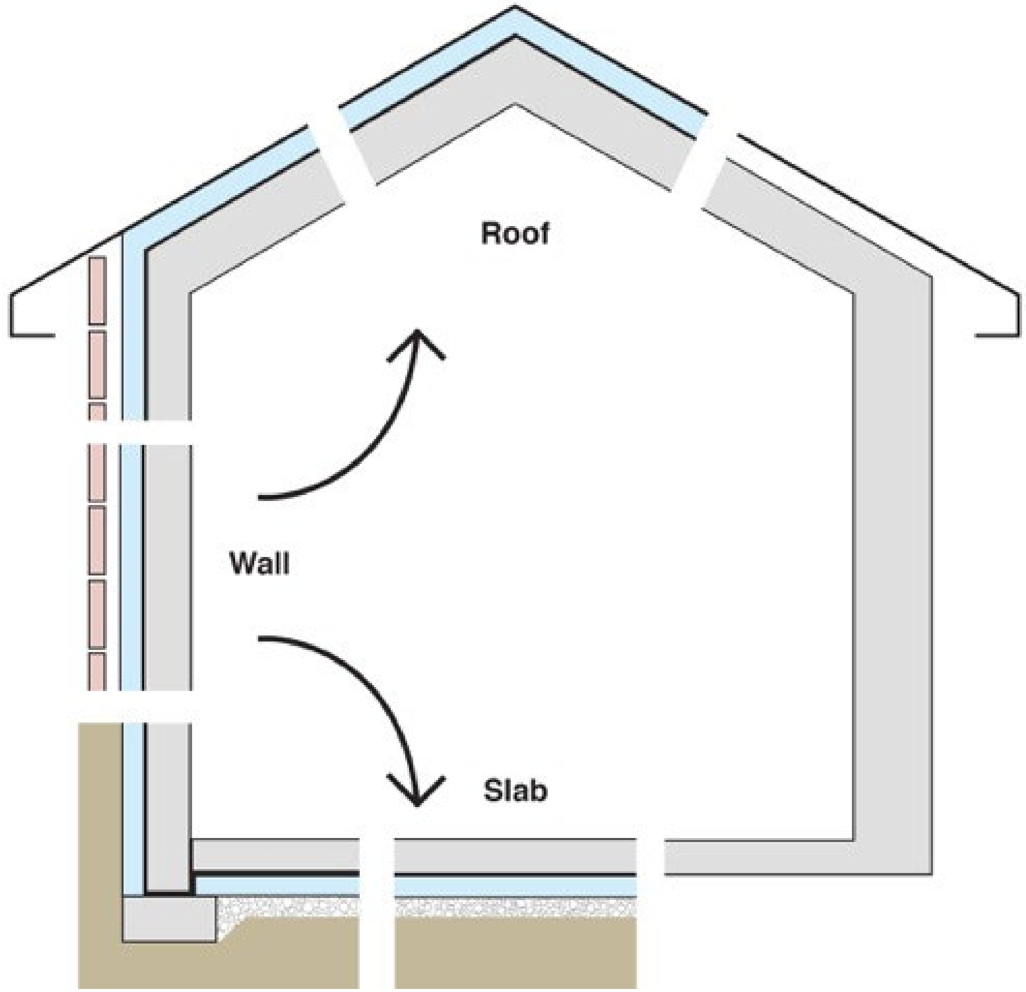
- To provide a 72% reduction in total energy use with respect to its original energy use.
- To provide a 44% reduction in total energy use with respect to the national average.
- With Photovoltaics, to provide an 76% reduction in total energy use with respect to the national average and to approach **Net Zero Energy**



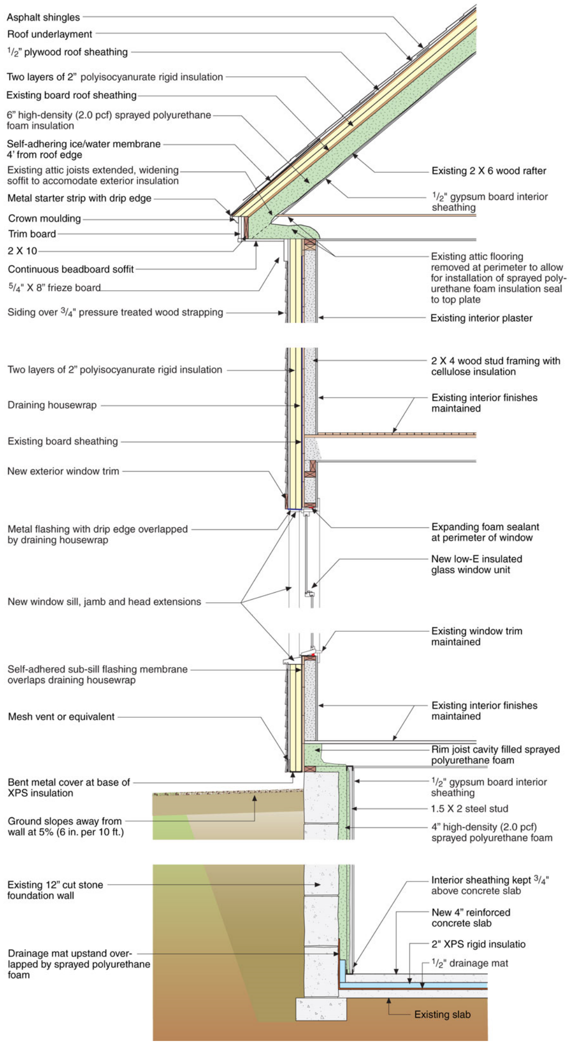
Foursquare – Concord, MA

The Perfect Enclosure

Adapted for Retrofits

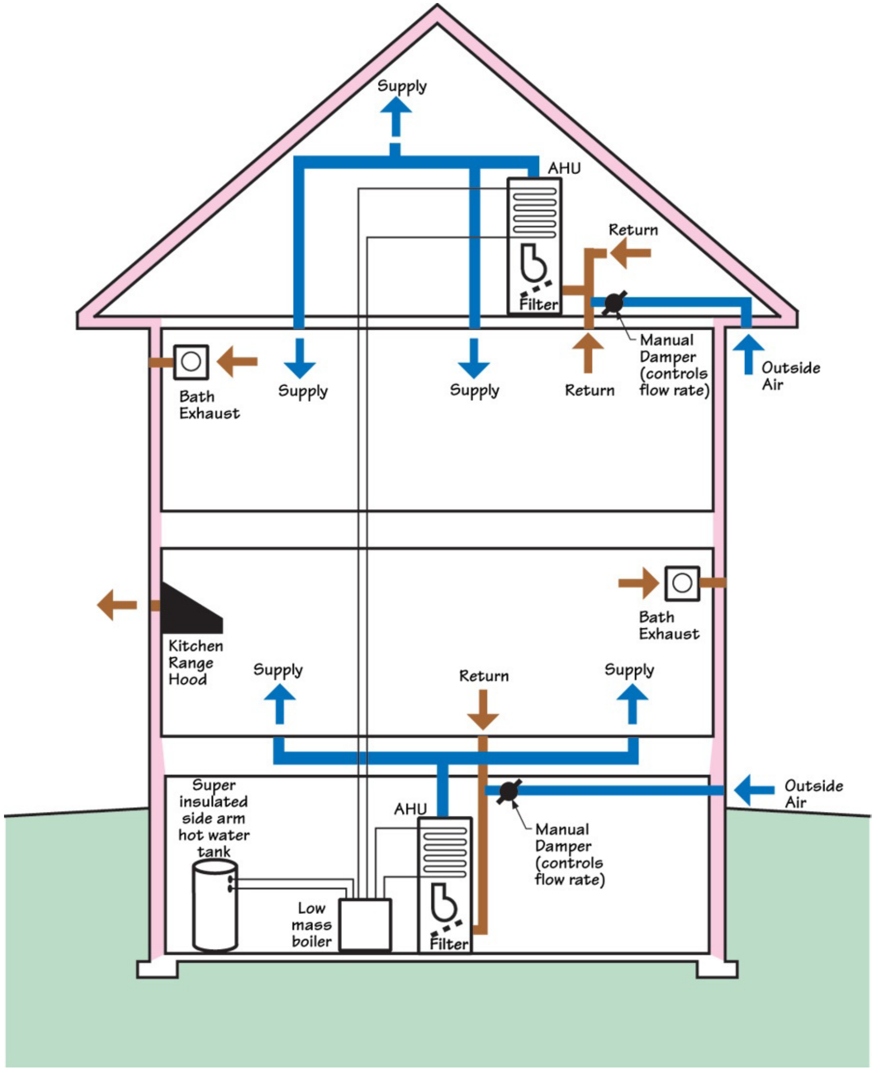


Enclosure Upgrades



MEASURE	PRERETROFIT	FINAL
Foundation walls (basement)	Uninsulated 12" cut stone	R-20; 4" high density (2.0 pcf) spray polyurethane foam
Slab insulation	None	R-10; 2" XPS insulating sheathing under slab
Above-grade walls	Some slag wool	R-41: blown cellulose cavity insulation and two layers of 2" polyisocyanurate rigid on the exterior
Siding	Aluminum siding over original shingles	Cedar siding over 3/4" wood strapping (rain-screen cavity)
Band joist areas	No insulation	Cavity filled with spray polyurethane foam
Cathedral ceilings	N/A	Two layers of 2" polyisocyanurate rigid insulation on top of roof sheathing with 6" high density (2.0 pcf) spray polyurethane foam in the existing 2x6 wood rafter
Flat ceilings	10" loose blown slag wool	N/A
Basement windows	Single-pane wood framed	Double-glazed, Low-E, argon-filled: U=33, SHGC=0.32; new window sill, jamb and head extensions, expanding foam sealant at window perimeter
Above-grade windows	Single-pane wood framed with aluminum storm windows	Double-glazed, Low-E, argon-filled: U=33, SHGC=0.32; new window sill, jamb and head extensions, expanding foam sealant at window perimeter
Exterior doors	Solid wood stile and rail	Kept existing front door

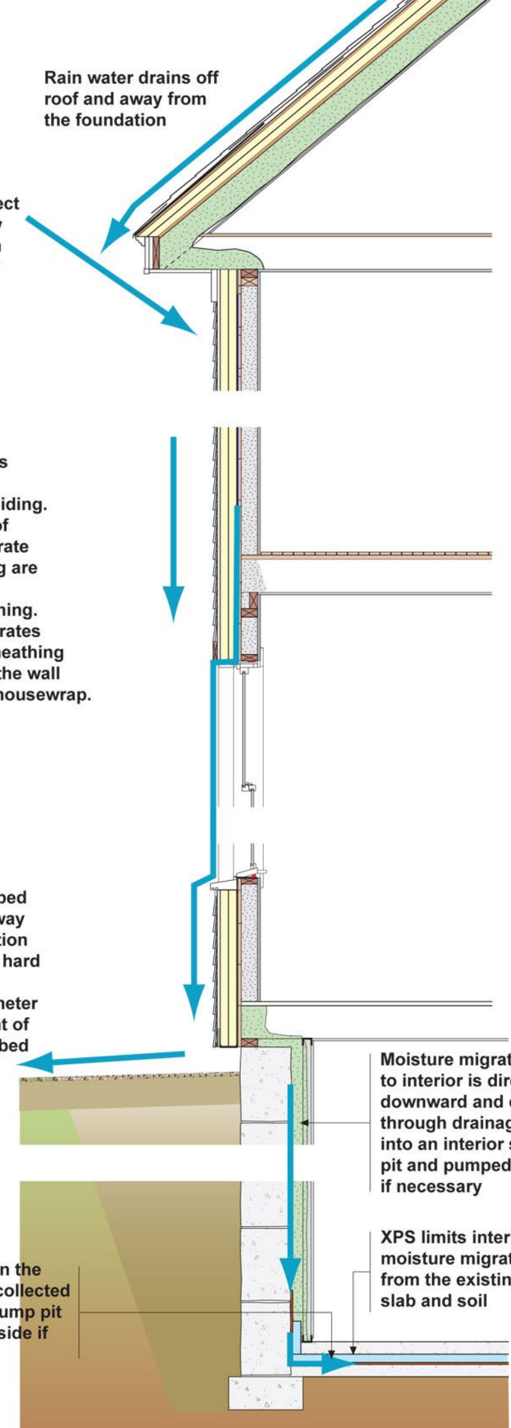
Mechanical System Upgrades



Air sealing	None	Retrofitted air barrier: spray polyurethane foam (basement, attic roofdeck, connections between components) and corrugated housewrap at above grade walls. Low expanding foam sealant around windows
Space heating	Original Oil Fired Boiler Circa 1916	92% AFUE sealed combustion low mass gas boiler in conditioned space
Cooling	Window air conditioner units	14 SEER split system in conditioned space
Thermostat	Standard – one zone	Setback – two zones
Water heating	Naturally-aspirated gas-fired tank water heater (~0.5 EF)	0.8 EF super-insulated sidearm storage tank
Mechanical ventilation	None	Supply-only system with outside air to return plenum of air handler; run at low speed with an ECM motor
Spot ventilation	None	Bath exhaust fans; kitchen range exhaust fan
Lighting	Standard Fixtures	100% Pin-based compact fluorescent lighting
Refrigerator	Circa 1980	Energy Star
Dishwasher	Circa 1980	Energy Star
Clothes washer	N/A	Energy Star
Infiltration rate	Not tested (estimated ~15 ACH 50)	2.5 sq. in. leakage area per 100 sq. ft. envelope (3 ACH 50)
Duct leakage (to outside)	N/A (radiator system)	None; ducts located in conditioned space
HERS Index	150+ (estimated)	49
Estimated total annual energy use	2680 therms/7300 kWh (estimated)	731 therms/5694 kWh (modeled) 670 therms/3865 kWh (utility bills)

Water Control Layer

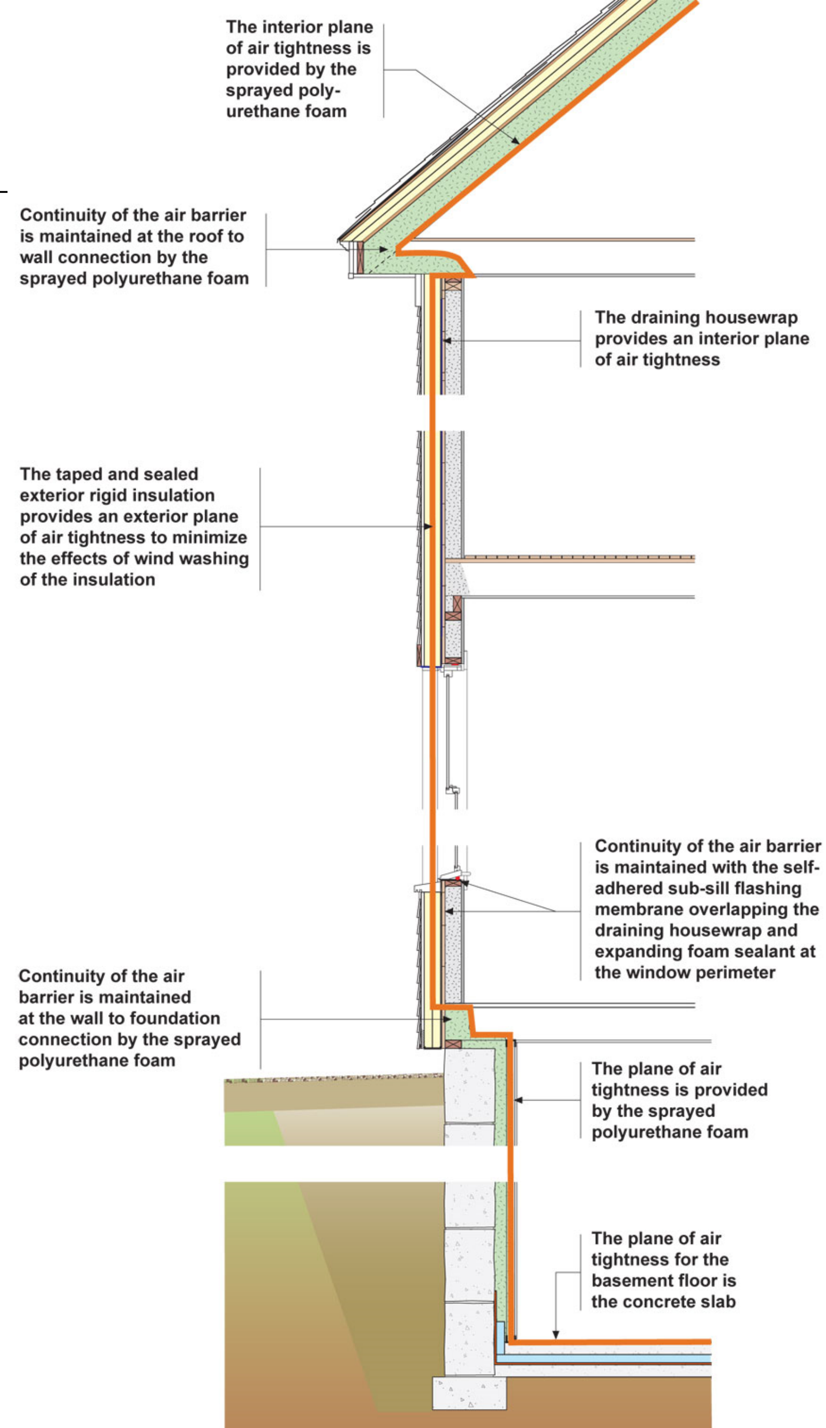
Continuity



Water Control Layer Continuity

Air Control Layer

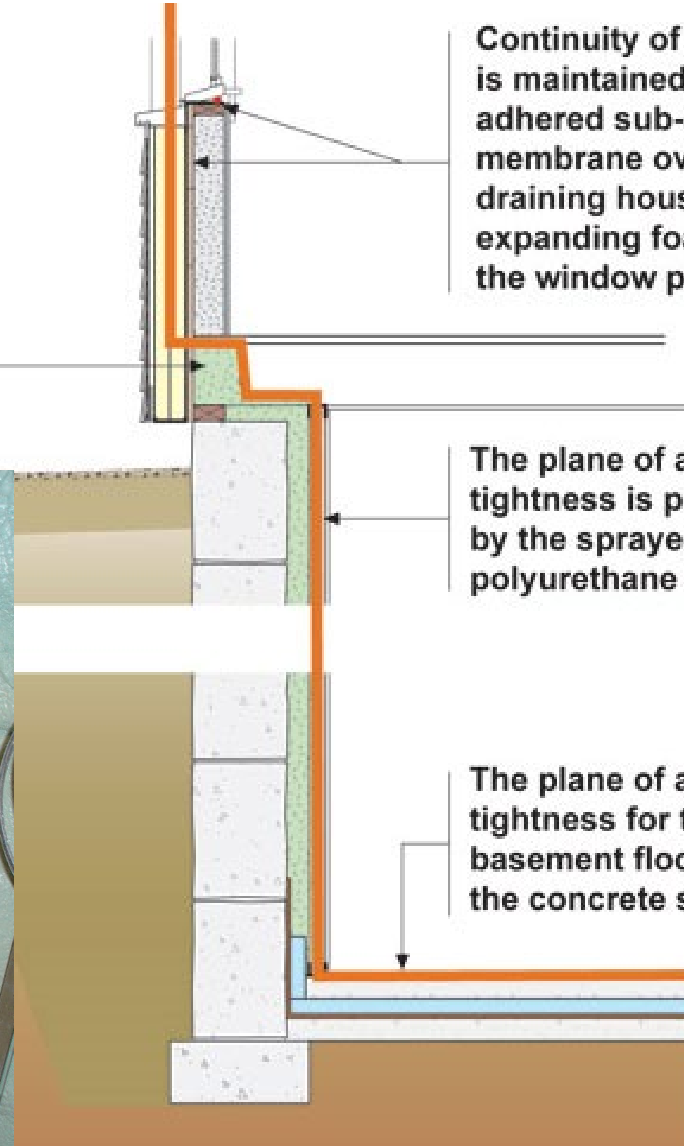
Continuity



Air Control Layer Continuity

Continuity of the air barrier is maintained with the self-adhered sub-sill flashing membrane overlapping the draining housewrap and expanding foam sealant at the window perimeter

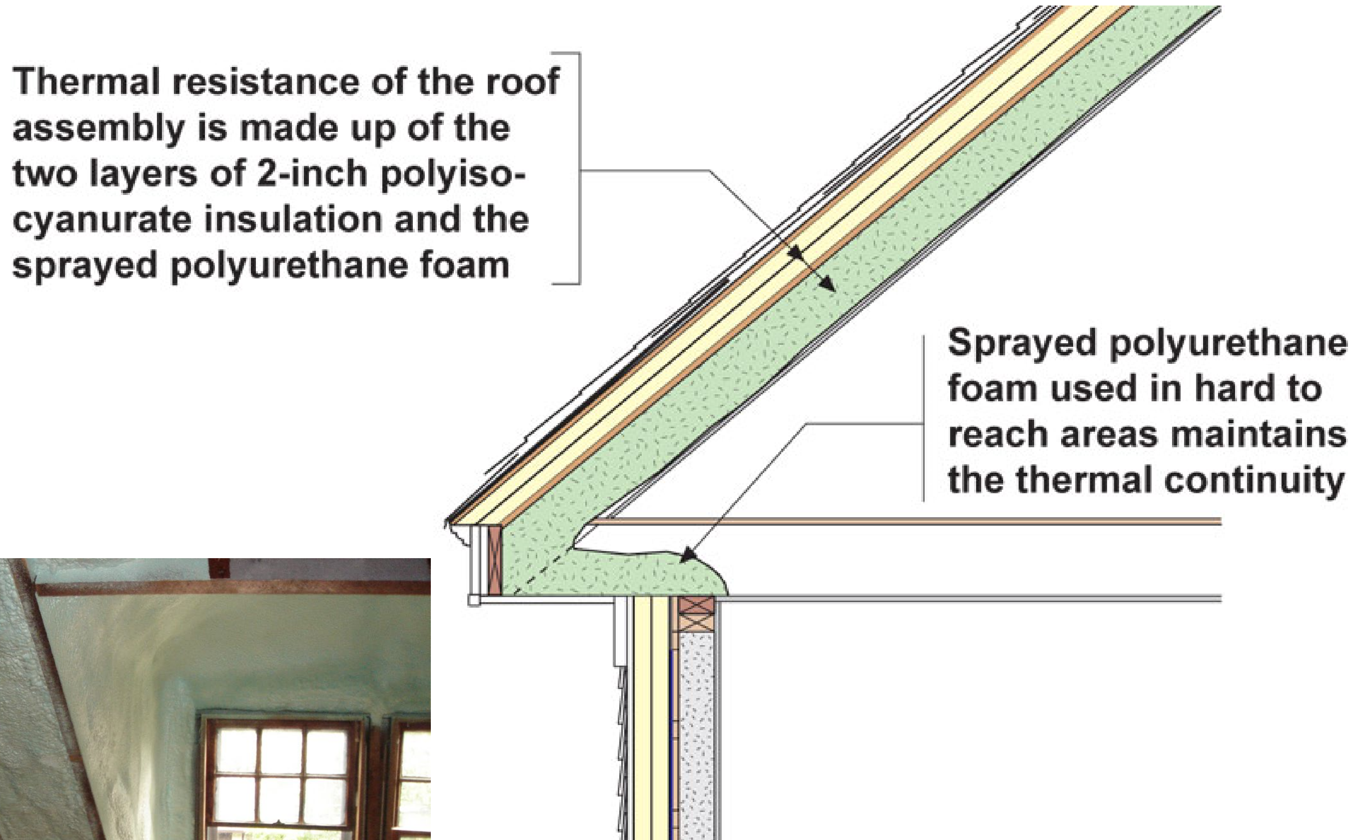
Continuity of the air barrier is maintained at the wall to foundation connection by the sprayed polyurethane foam



The plane of air tightness is provided by the sprayed polyurethane foam

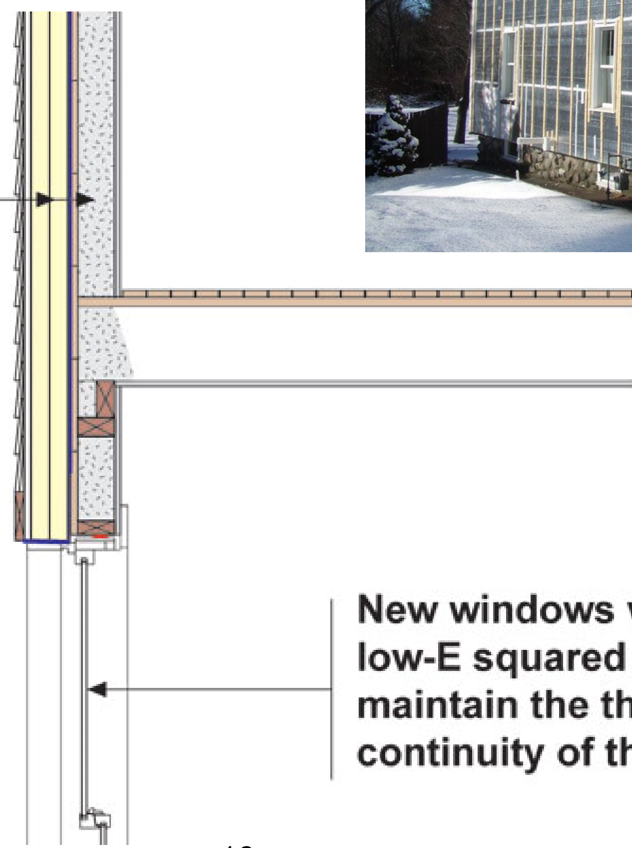
The plane of air tightness for the basement floor is the concrete slab

Thermal Control Layer Continuity



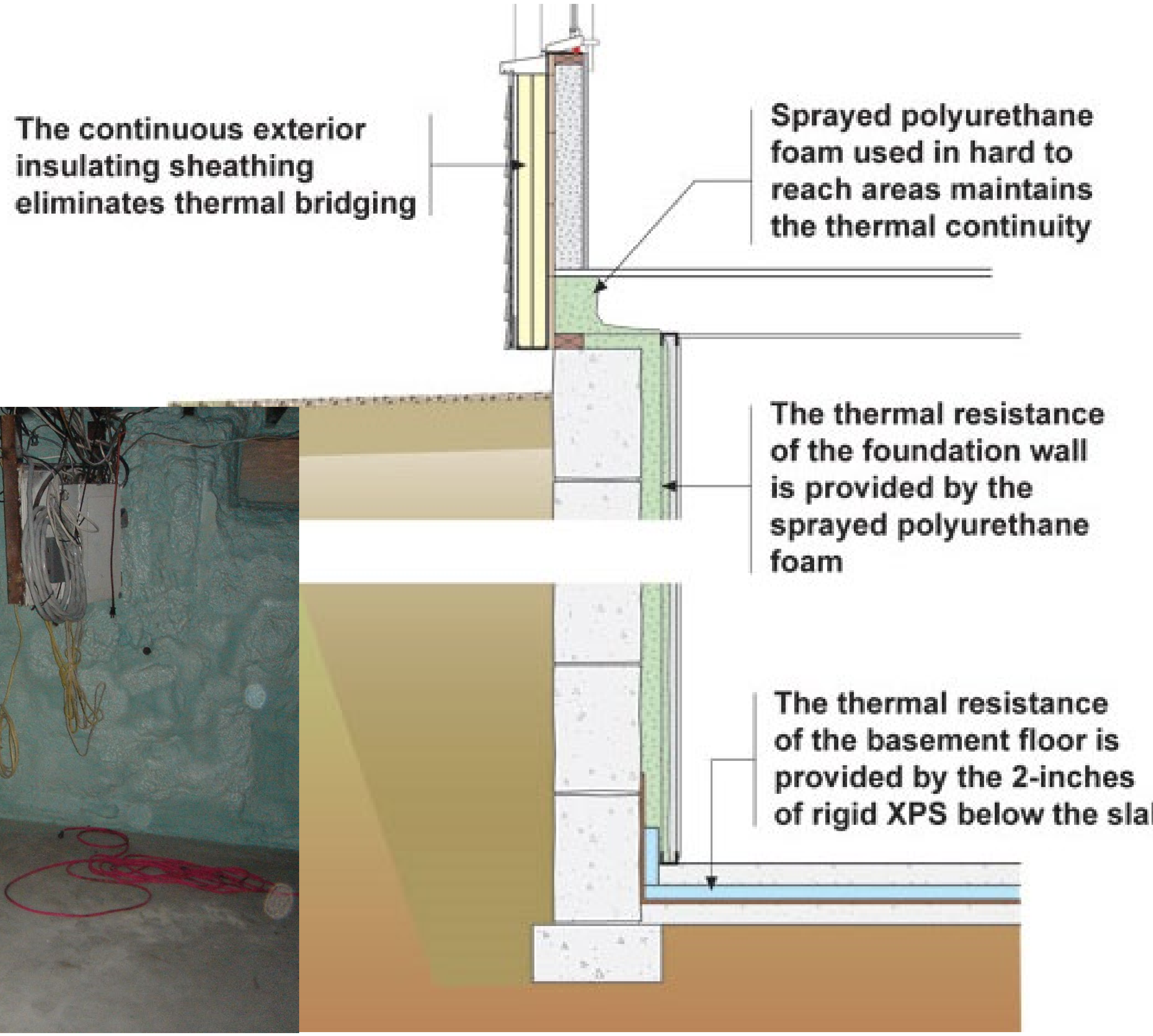
Thermal Control Layer Continuity

The thermal resistance of the wall assembly is made up of the blown cellulose cavity insulation and the two layers of 2-inch rigid polyisocyanurate insulating sheathing



New windows with low-E squared glazing maintain the thermal continuity of the wall

Thermal Control Layer Continuity



New Windows

Photos courtesy of Dan Morrison, *Fine Homebuilding Magazine*

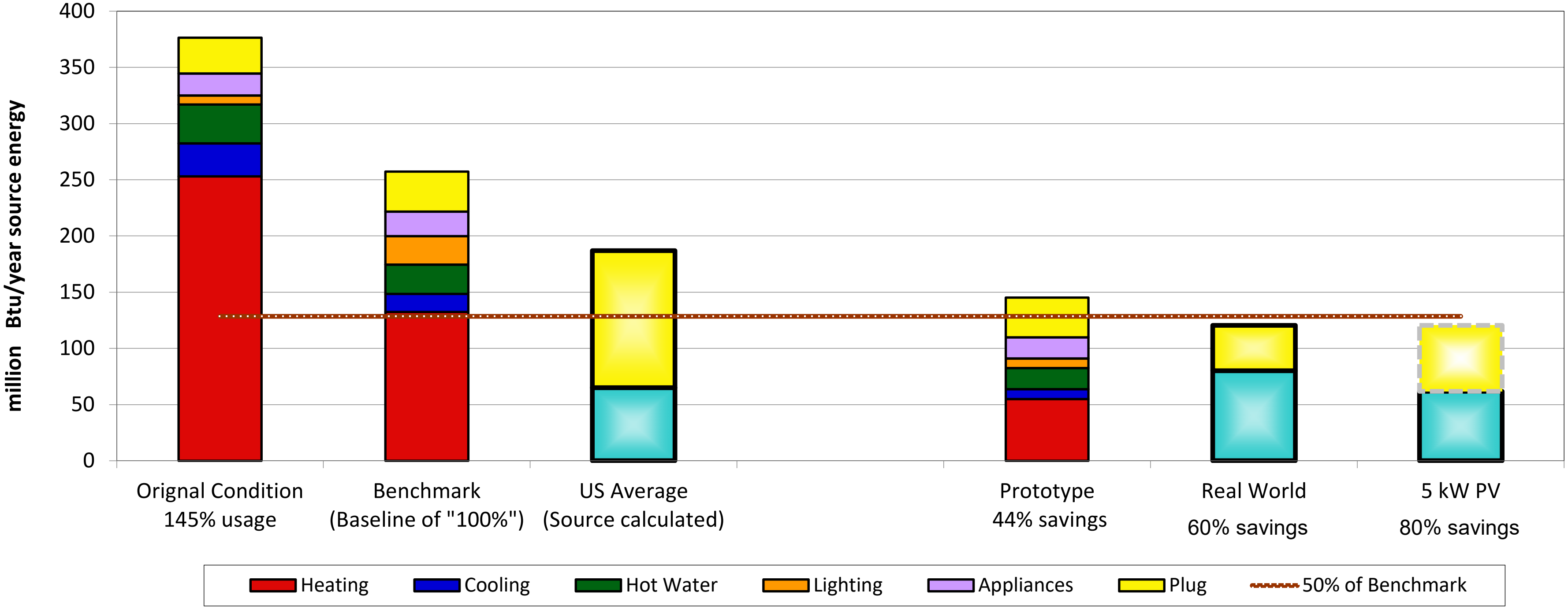
New Windows


Tyvek

2010 - 4.9 kW PV System – 28 @ 175w panels with microinverters

Actual Performance

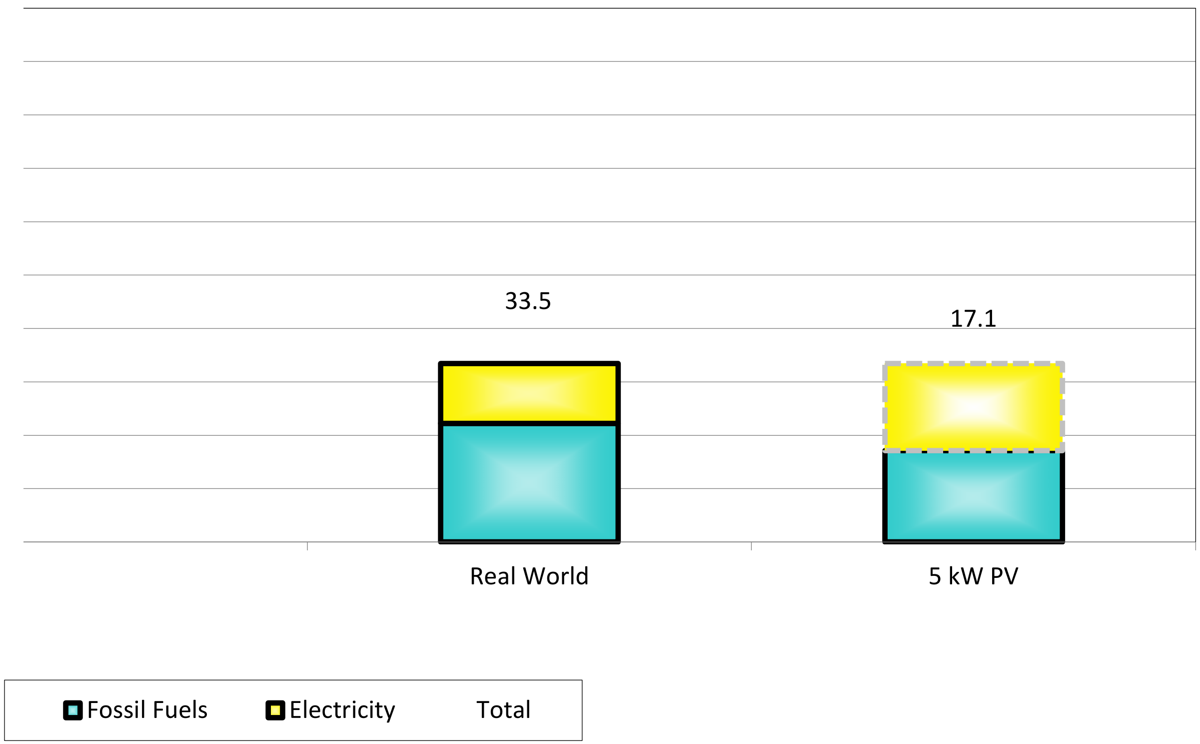
- Without the PV’s, the house had a 75% reduction with respect to its original energy use.
- Without the PV’s, the house had a 60% reduction with respect to the national average.
- With the PV’s, the house had an 80% reduction with respect to the national average.



Metrics

- Total Energy Use is 62 MMBtu’s source. National average is 190 MMBtu’s source.

- Total conditioned square ft = 3600. kBtu’s per sq. ft. before PV’s = 33.5
- With the PV’s (average collected = 5600 kWh per year) kBtu’s per sq. ft. = 17.1



Original Goals Were Met

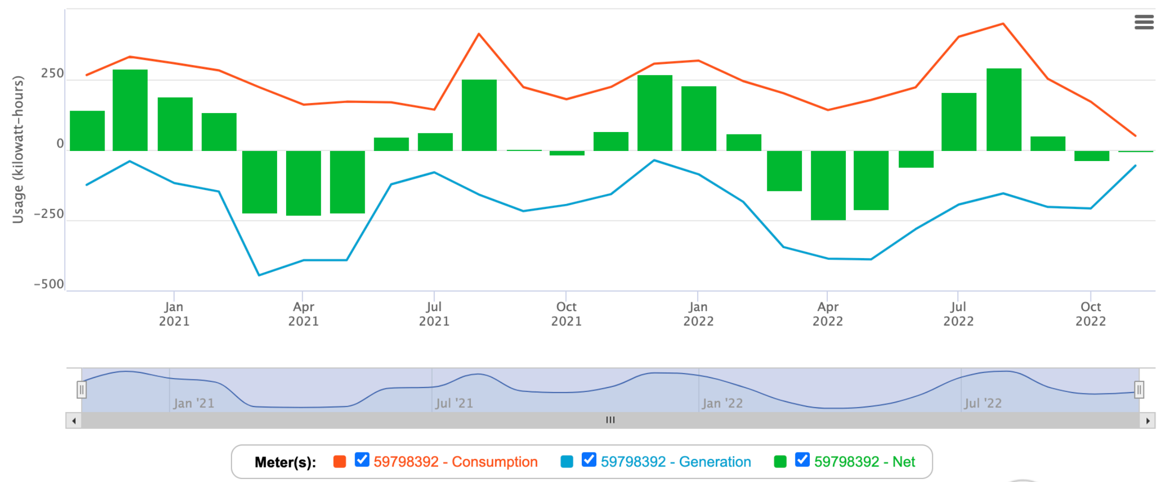
- Airtighness Matters
  - Airtighness improved to 1 (one) ACH@50 Pascals by
    - Replacing leaky bulkhead door, leaky front door, leaky back kitchen door
    - fixing connection of porch roof to walls and removing chimney
  - An HRV was installed eliminating the need for the central air handler fan to run to bring in outside air

- Super insulated assemblies worked
    - Roof –Chimney was removed and there was opportunity to see into the roof assembly – no damage over time in the assembly
    - Windows - Three R-5 windows have replaced original replacements in key locations – no damage was observed in walls
    - Basement – a 100 year flood caused the adjacent pond to overflow, flooding the basement – repairs were easy due to steel studs holding gypsum – and closed cell spray foam in walls

Why is the Net Electric Use 450 kWh's?*

*** 2020 – 2022 = 910.77/2 =**

Zoom 3m 6m YTD 1y | Monthly Daily Hourly | From Nov 2020 | To Nov 2022



Green Button Download My Data

Usage	
Meter:	59798392 - Consumption
High Usage:	449.09
Low Usage:	50.13
Average Usage:	241.35
Total Usage:	6,033.73

Weather	
Average Temperature:	52° F
Average High Temperature:	76° F
Average Low Temperature:	25° F

Usage	
Meter:	59798392 - Generation
High Usage:	-36.73
Low Usage:	-446.13
Average Usage:	-204.92
Total Usage:	-5,122.99

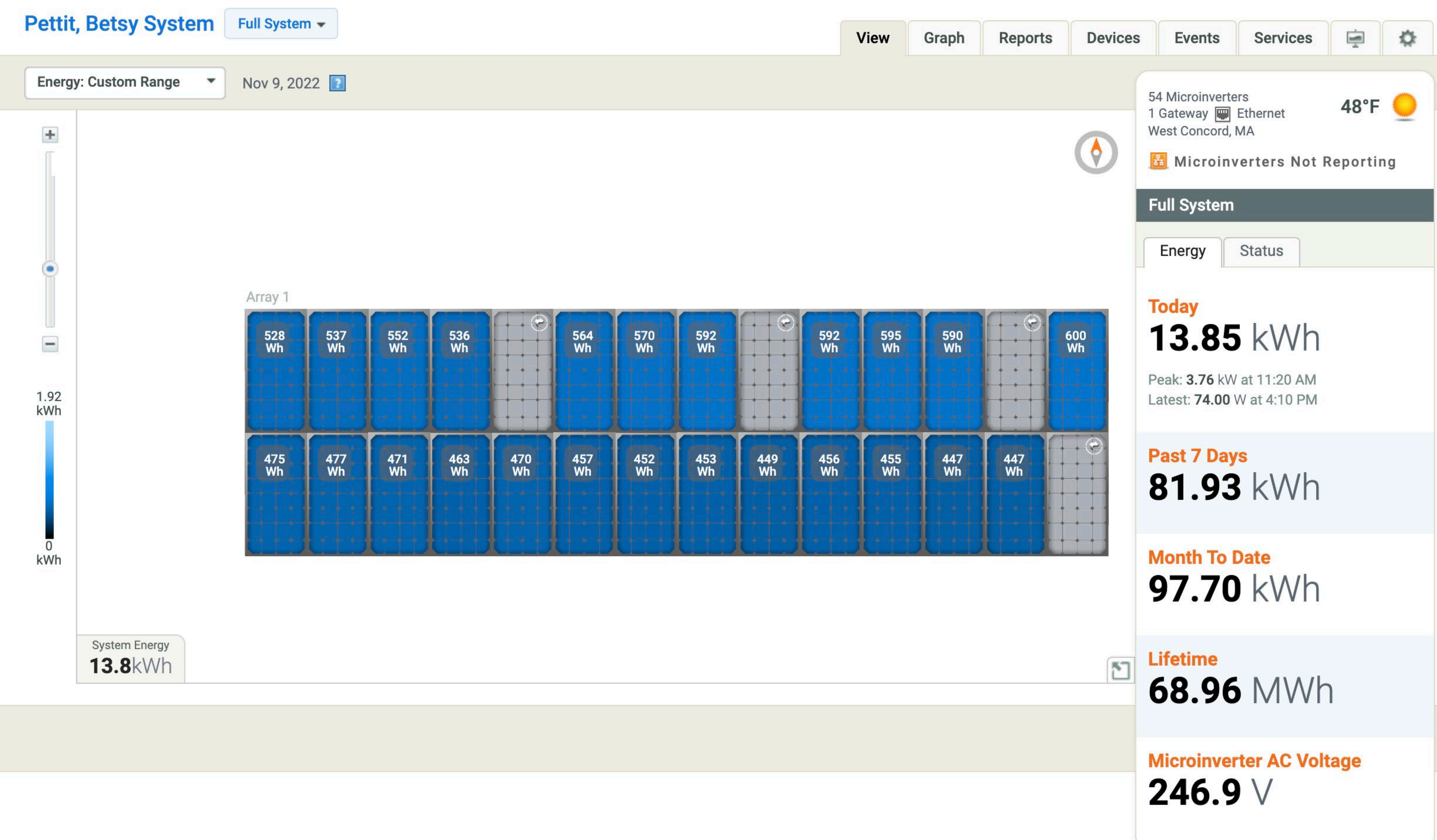
Weather	
Average Temperature:	52° F
Average High Temperature:	76° F
Average Low Temperature:	25° F

Usage	
Meter:	59798392 - Net
High Usage:	294.39
Low Usage:	-245.07
Average Usage:	36.43
Total Usage:	910.77

Weather	
Average Temperature:	52° F
Average High Temperature:	76° F
Average Low Temperature:	25° F

Micro - Inverter Failure

Over 12 years should have been 73,000 MWh



No Storage for Excess Production

- First three years average production – 5,600 kWh's
- Average electrical use – 4,000 kWh's
- Hot Water Use = 170 therms
- Heat = 400 therms
- There could have been enough left over to provide hot water
  - 1,600 excess Btu's per year would cover 1/3 of the hot water use

Impacts Made

Deep Energy Retrofit pilot programs all over U.S.

- National Grid in Massachusetts
- NYSERDA in New York State
- Training for the trades – skilled labor required
- Continued Building America research – And this conference has at least 20 presentations tied to retrofits
- ABC Collaborative looking at robotics and industrialized production to scale
- Phius REVIVE certification for Energy Retrofits

Goals have changed

- For this house - All electric and positive energy
  - Gas range changed to Induction Range
- Next - Heat Pump hot water heater – with PV inverters fixed and excess capacity over use of 1,600 kWh – use as hot water source as well as storage
- Add PV's - will be used to cover heating with storage. Perhaps an additional electric hot water heater with time of use tied to Production.

- And may change again after listening to the great presenters at this conference this week

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Key word: Retrofit