From Farm House to Eco-House: Retrofitting and Building New

PASA
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PART 1.
COMPETING CONCEPTS FOR GREEN HOUSING
Maine Co-Housing Prototype
# Comparison of Three Low-Energy Housing Concepts

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>1. Heat Gain:</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>heating source</td>
<td>From sun, but hard to get above 50% of total winter heat load, therefore requiring supplemental heat, e.g., oil, gas, wood, elect.</td>
<td>ditto, plus pv systems w/wo grid to achieve annual net zero</td>
<td>passive solar, and additional heat reduced to absolute min, equivalent to heating with hair dryer supplied through HRV</td>
</tr>
<tr>
<td>south-facing orientation</td>
<td>key feature, together with shallow east-west axis</td>
<td>ditto, esp for pv panels on roof</td>
<td>less important but still necessary</td>
</tr>
<tr>
<td>south facing windows</td>
<td>Large, requiring shutters to prevent winter heat loss, and shades/awnings/overhang to prevent summer overheating</td>
<td>less critical, as pv-grid make up shortfalls</td>
<td>less important, windows smaller but high performance (very low u values – German or Canadian)</td>
</tr>
<tr>
<td>thermal mass</td>
<td>large windows coupled with thermal mass (floors usually) to store day’s heat</td>
<td>ditto, but less critical</td>
<td>not necessary</td>
</tr>
</tbody>
</table>
## Comparison of Three Low-Energy Housing Concepts

<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>2. Prevent heat loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>insulation</td>
<td>modest: R-30 walls, R-40 ceilings</td>
<td>modest: R-30 walls, R-40 ceilings</td>
<td>heavy: R-60 walls and roofs; R-24 foundation perimeter; R-40 to 56 slabs</td>
</tr>
<tr>
<td>Air infiltration/fresh air in winter</td>
<td>air infiltration through bldg envelope as a source of outside air; ventilation through open windows</td>
<td>Ditto</td>
<td>reduce to minimum and rely on air exchangers: heat recovery ventilators in north (HRVs) and energy recovery ventilators in south (ERVs)</td>
</tr>
<tr>
<td>cooling</td>
<td>ventilation through open windows, solar chimneys, fans; roof overhang; smaller windows east and west, few and small windows on north</td>
<td>ditto, plus pv systems w/wo grid to achieve net zero; heat pumps</td>
<td>high efficiency air exchangers (HRVs), small heat pump</td>
</tr>
</tbody>
</table>
## Comparison of Three Low-Energy Housing Concepts

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>3. Energy-efficient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total energy use</td>
<td>energy-saving appliances using grid electricity (ac)</td>
<td>no real limit. Use as many pv panels as desire, w/wo grid</td>
<td>reduce total requirements to absolute minimum, under 120 kwh/m²/year</td>
</tr>
<tr>
<td>4. Examples:</td>
<td>Kachadorian, Saunders house, Annual Geothermal Storage (AGS), PAHS 1/</td>
<td>Solar Decathlon entries, McGreen mansions</td>
<td>15,000 in Europe, 15 in U.S. 1 in 4 new houses in Austria follow PH standards.</td>
</tr>
</tbody>
</table>

## Passive House Features and Standards

<table>
<thead>
<tr>
<th>Key Features</th>
<th>Realized through</th>
<th>Threshold standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Low space heating &amp; cooling requirements</td>
<td>* high insulation, • reduced thermal bridges, * air tightness (low infiltration), and * excellent windows * passive solar design</td>
<td>* R-50 walls, R-60 ceilings * annual heat &amp; cooling energy loads each ≤ 15 kWh/m2/year (4.75 kBtu/sf/yr) or 2,091 kWh/yr for a 1,500 sq.ft. house ($209/yr) 1/ Double for retrofits. * airtight building shell ≤ 0.6 ACH @ 50 pascal pressure, measured by blower-door test. 1.5 ACH50 for retrofits. * windows with a max u value of 0.14 (R-7+ or higher)</td>
</tr>
<tr>
<td>2. Mechanical Ventilation</td>
<td>* Heat Recovery Ventilators (HRVs) for cold north or * Energy Recovery Ventilators (ERVs) for humid south</td>
<td>* 0.3-0.6 ACH as far as I could determine * device efficiency ≥ 75%</td>
</tr>
<tr>
<td>3. Energy efficiency</td>
<td>* high efficiency appliances to reduce total electricity use</td>
<td>* (2/) total primary energy loads ≤ 120 kWh/m2/year (38.1 kBtu/sf/yr) or 16,729 kWh/yr for a 1,500 sq.ft. house * allowed plug load = 5,576 kWh/yr 3/</td>
</tr>
</tbody>
</table>
Schematic of a Passive House

At the Heart, A Heat Exchanger
The most important element in keeping a passive house warm is the heat exchanger, which uses heat from inside air to warm fresh air from outside. Stale air is constantly being replaced with fresh air; about one-third of the house’s air is replaced every hour.

HEAT EXCHANGER
Fresh air from outside
HEAT EXCHANGE WHEEL
Stale air from inside
Fresh air into rooms

INSIDE THE HEAT EXCHANGER
Intake flow
Exhaust flow

The heat exchanger contains a slowly rotating wheel made of a porous material. As outgoing air passes through it, heat and moisture are transferred to the incoming air, which also passes through it.

Keeping the Heat In
Exterior walls are two or three times thicker than those in a conventional house and are well insulated, with the amount of insulation varying by climate. A double-wall system is used, with a continuous air barrier between the two walls. Walls and studs are designed to minimize heat conductance.

AIR BARRIER
CELLULOSE INSULATION
INSULATED STUD

For comparison: a conventional house wall
6INCH INSULATION

TRIPLE GLAZING, COATED GLASS
INSULATION IN FRAME

Warning The Water, Too
Many passive houses have simple solar panels on the roof or side to heat water.

Winter sun
Summer sun

Minding the Sun
By orienting the house properly and incorporating overhangs into the design, the winter sun helps warm the house and the hot summer sun stays out, keeping it cooler.

Floor
A concrete slab rests on a six-inch layer of polystyrene insulation that also wraps around the slab’s edges, where the floor meets the walls.

Windows
Casement windows are usually used because they close tighter than other types. Coated glass helps reflect heat back inside the house in winter and keeps some heat out in summer.
PART 2.
PASSIVE HOUSE DESIGN IN NEW CONSTRUCTION
Idealized Building Envelope for a Passive House

- Insulating envelope (yellow)
- Airtight envelope (red)

Crucial joints too meet the rules of avoiding thermal bridging
Standard vs. Passive Heating Requirements

Building Stock

- Heating system: 10 kW
- 100 W/m²

Passive House

- Just a small postheater
- 10 W/m²
- Max. 1 kW
Schematic of High Performance Window

- triple pane glazing with 2 low-e coatings
- "warm-edge"
- super insulating passive house frame
Ventilating a Passive House
PART 3: PROPOSED DESIGN FOR A PASSIVE HOUSE ON OUR LOT IN LEMONT, PA

0.28 acres
Original inspiration for Eco-House: Three Sisters Bioshelter
Bioshelter: thermal mass is key

- Concrete water-filled tank w snorkel stove
- Gravel/soil beds to south
- Compost bins and barrels of water to north
- BTUs of body heat (chickens)
- Well-insulated north exterior wall

= 50°F+ in winter + moisture can obstruct view, overheats in summer
“The Passive House should be the baseline, before you start adding renewables.”

–Katrin Klingenberg, co-founder, Passive House Institute US

Eco-House Goals

- Test/Assess “green” technologies:
  - Living technologies: using plants to clean air and water (e.g., attached bioshelter with constructed wetlands)
  - Passive House + Passive solar greenhouse
  - Eco food preservation, storage: root cellar, solar food dehydrator, solar oven
  - Solar hot water heating
  - Use of DC electricity from photovoltaic (PV), including most appliances

- House interns/visitors

- Improve on or scrap as data dictates! Learn from it…

- graywater treatment with constructed wetlands
- “Living” shower
- vegetated “green” roof
- “breathing wall” to clean air
- dry composting toilets
“There’s nothing fundamentally green about a house, I’m sorry to say. We want it to be warm when it’s cool outside, cool when it’s warm outside.”

–Paul Eldrenkamp, owner, Byggmesiter, a residential remodeling company

Permaculture Planning and Annual Solar Map for 40° North Latitude, Eastern Standard Time

- Winter Solstice Sunrise ~7:15 AM
- Equinox Sunrise 6 AM
- Summer Solstice Sunrise ~4:30 AM
- Winter Solstice Sunset ~4:45 PM
- Equinox Sunset 6 PM
- Summer Solstice Sunset ~7:30 PM

- Conifers buffer cold north winds
- Large deciduous trees block hot summer sun
- Conifers block hot summer sun
- Large deciduous trees shade house in AM
- Smaller trees farther away

- Keep southern corridor clear for optimal solar gain in winter months

- Concept layout (idealized)
Panorama with Wiley Solar Asset

8PM, 13 May: Solar Access

How much **sky** does your site see?

How much sun can reach your house, garden?
## RESULTS from Wiley Solar Asset

<table>
<thead>
<tr>
<th>Month</th>
<th>light shaded (%)</th>
<th>sunlight/day (hours)</th>
<th>available sunlight (hours)</th>
<th>potential energy (kW·hr/kW)</th>
<th>available energy (kW·hr/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>34.9</td>
<td>3.12</td>
<td>2.03</td>
<td>78</td>
<td>51</td>
</tr>
<tr>
<td>February</td>
<td>33</td>
<td>3.64</td>
<td>2.44</td>
<td>81</td>
<td>55</td>
</tr>
<tr>
<td>March</td>
<td>33.3</td>
<td>4.49</td>
<td>3</td>
<td>106</td>
<td>72</td>
</tr>
<tr>
<td>April</td>
<td>27.9</td>
<td>4.53</td>
<td>3.27</td>
<td>99</td>
<td>73</td>
</tr>
<tr>
<td>May</td>
<td>30</td>
<td>5.02</td>
<td>3.52</td>
<td>109</td>
<td>79</td>
</tr>
<tr>
<td>June</td>
<td>27</td>
<td>5.14</td>
<td>3.75</td>
<td>106</td>
<td>80</td>
</tr>
<tr>
<td>July</td>
<td>29.1</td>
<td>5.24</td>
<td>3.71</td>
<td>110</td>
<td>81</td>
</tr>
<tr>
<td>August</td>
<td>30.2</td>
<td>5.1</td>
<td>3.56</td>
<td>108</td>
<td>77</td>
</tr>
<tr>
<td>September</td>
<td>28.3</td>
<td>4.57</td>
<td>3.28</td>
<td>98</td>
<td>71</td>
</tr>
<tr>
<td>October</td>
<td>33.4</td>
<td>3.79</td>
<td>2.53</td>
<td>85</td>
<td>57</td>
</tr>
<tr>
<td>November</td>
<td>31.6</td>
<td>2.61</td>
<td>1.78</td>
<td>58</td>
<td>40</td>
</tr>
<tr>
<td>December</td>
<td>35.8</td>
<td>2.39</td>
<td>1.53</td>
<td>57</td>
<td>36</td>
</tr>
<tr>
<td>average</td>
<td>31.2</td>
<td>4.14</td>
<td>2.87</td>
<td>total 1095</td>
<td>773</td>
</tr>
</tbody>
</table>

Shading factor reference: 1.00 = total sun

Shading factor = 0.69

Site shading factor > 0.90 for most solar tax credits
OR How much SHADE do you see on the ground?
View to South: 5pm shade on Sept 25th
Morning shade from Maples

10:18 am

We recorded shade patterns on a base map →

“House” sees ~3 hrs of full sun

Afternoon shade from Hedgerow

12:40 pm

4:00 pm

25 September

We recorded shade patterns on a base map →

“House” sees ~3 hrs of full sun

10:18 am

12:40 pm

4:00 pm
Shade Factors: Even in Winter
Working with the slope

View to North
SITE: 80 ft x 150 ft

EXISTING FEATURES & Analysis

Winter Solstice Sunrise ~7:15 AM
Equinox Sunrise 6 AM
Summer Solstice Sunrise ~4:30 AM

Winter Solstice Sunset ~4:45 PM
Equinox Sunset 6 PM
Summer Solstice Sunset ~7:30 PM

Slope, water flow

0°

1 square = 5 feet
(Sugar) Maples

House: Long side faces south 40 ft

h = ~14 ft

Hedgerow

Cross Sectional View Looking South

Scale: 10 ft
(1 square = 2 ft)
Cross Sectional View Looking South

[Sugar] Maples

Earth-bermed workshop

Root cellar

Proper drainage!

Preserving wall

Glazed, covered Walkway

Retaining wall

Structure insulated to Passive House standards; no north entrance!

Basement: fully underground

Graywater aeration tank

[North face of house: small, minimal amount of windows, glazing]
Structure insulated to Passive House standards: Large Windows on South Side

Scale: 10 ft  
(1 square = 2 ft)

Hedgerow

(Sugar) Maples

L-shaped Earth-bermed garden workshop

Retaining wall

h = ~14 ft

Proper drainage!

Garden shed + workshop

Root cellar

Basement: fully underground

Removable glazing

Graywater aeration tank

Discharge to landscape

Cross Sectional View Looking North
Attached Winter Greenhouse:

definition

Solar analysis

Cross Sectional View Looking EAST

Summer Solstice:
$73^\circ$

Winter Solstice:
$27^\circ$

Gravel for thermal mass

Heat flow

Plenum to distribute heat

Biointensive beds with cover crops in winter months

Living roof

Liner for constructed wetland

Land slopes $\sim 3^\circ$

Removable glazing

Overhang to block summer rays

Heat @ top circulated to gravel below

PV & SHWH
Eco-House Plan View

- Solar oven & dehydrator
- Garden shed & workshop (15’ x 25’)
- 12’ x 15’ Shop + stairs down to root cellar
- Covered entryway
- Kitchen Island on wheels, Laundry area, 1/2 bath, Chest freezer, Chest fridge, Duct to plenum, Return plenum
- Dining-meeting area
- Neo-Terra’s office
- Covered entryway
- Root cellar via stairs
- Return plenum
- Tropicals
- 240 sq ft grow beds
- Constructed wetland 4’x19’x3’ deep
- Construction cabinets, Earth-bermed
- Solar shower

Scale: 1 square = 1.5 ft
Eco-House Plan View

- 15’ x 25’ Garden shed & workshop
- 12’ x 15’ Shop + stairs down to root cellar
- 240 sq ft grow beds
- Tropicals
- Solar shower
- Removable glazing
- VIEW OVER WINTER GREENHOUSE

Earth-bermed

2nd Floor
- BR1
- BR2
- BR3
- BR4
- CL
- CL
- CL
- CL

1/2 bath
1/2 bath

Covered entryway

SCALE: 1 square = 1.5 ft
Eco-House Plan View

- Earth-bermed
- Experimental: ice closet
  - Ice CL
  - Dry root cellar
  - Wet root cellar

- Up

- 4'x19'x3'deep wetland foundation

- Insulated foundation and gravel bed for active solar thermal mass

- Hot air flow through gravel

- Hot air channel plenum

- Graywater Aeration tank
  - Solar Hot Water Tanks
  - Heat Sink tank
  - Domestic HW Tank

- Multipurpose Furniture

- Track

- Library

- Extra non-perishable food storage

- Utility area
  - Supplies

- PV utility

- Electronics & winter workshop area

- Multifunction area on tracks

- Light tube

- Light & Sound Therapy

- 4x19x3 deep wetland foundation

SCALE: 1 square = 1.5 ft
“If you have a heating or cooling system in your house you have made a mistake in construction.”

— Gunter Lang, chief executive director of IG Passivhaus Austria
“I invite friends.”

— Katrin Klingenberg, on how she heats her house

Warm, bright and green in Winter…
Merged with garden in summer...
PART 4. APPLYING PASSIVE HOUSE TO RETROFITS
Current Thinking on Passive House Retrofits

- Double the heating and cooling limits to 30 kWh/m²/yr (9,500 Btu/ft²/yr)
- Adjust the air tightness limit to 1.5 ACH50 (instead of 0.6 ACH)
- Ensure insulation levels with high R values (50-60)
- Install triple glazed windows with insulated frames
- Reduce thermal bridges to a minimum
- Install a ventilation system with highly efficient heat recovery (85% efficiency or above)
- Install thermal solar collectors providing up to 60% of the annual energy demand for domestic hot water
- Provide heat using highly efficient condensing gas or biomass boilers, using well-insulated ducts.
<table>
<thead>
<tr>
<th>Neo-Terra Farmhouse Retrofits</th>
<th>$/gal</th>
<th>$ Cost</th>
<th>Saving gal/yr</th>
<th>Year done</th>
<th>Payback yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy House Retrofits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Reduce use:**
- Lower thermostat, wear warmer clothes
  - $/gal: 0
  - $ Cost: 0
  - Saving gal/yr: 200
  - Year done: 89
  - Payback yrs: 0

**Prevent Heat Loss:**
- Make foam board shutters
  - $/gal: 1.39
  - $ Cost: 100
  - Saving gal/yr: 10
  - Year done: 0
  - Payback yrs: 7.2
- Improve insulation in 2 attic areas
  - $/gal: 1.39
  - $ Cost: 400
  - Saving gal/yr: 15
  - Year done: 0
  - Payback yrs: 19
- Improve insulation in 3rd attic
  - $/gal: 1.39
  - $ Cost: 1,600
  - Saving gal/yr: 15
  - Year done: 1
  - Payback yrs: 77
- Replace insulation in living room with foam
  - $/gal: 1.39
  - $ Cost: 7,600
  - Saving gal/yr: 20
  - Year done: 1
  - Payback yrs: 273
- Improve insulation in east, south walls
  - $/gal: 2.90
  - $ Cost: 5,780
  - Saving gal/yr: 20
  - Year done: 8
  - Payback yrs: 100
- Replace 13 old windows
  - $/gal: 2.90
  - $ Cost: 21,388
  - Saving gal/yr: ?
  - Year done: 10
  - Payback yrs: ?

(includes $1,500 Fed tax credit)

**Increase Solar Insolation:**
- Duggin hot air collector ('03)
  - $/gal: 1.50
  - $ Cost: 2,000–
  - Saving gal/yr: 50–100
  - Year done: No
  - Payback yrs: 18–27
- Install hot water collectors for winter heat, summer hot water
  - $/gal: 2.10
  - $ Cost: 2,854
  - Saving gal/yr: 10+$60 e
  - Year done: 0
  - Payback yrs: 35
- Kreamer hot air collectors
  - $/gal: 2.90
  - $ Cost: 738
  - Saving gal/yr: 10
  - Year done: 0
  - Payback yrs: 25

**Reduce Use, 2nd Round, Geothermal**
- GTh heating (w. 30% Fed. tax credit)
  - $/gal: 2.35
  - $ Cost: 18,000
  - Saving gal/yr: e↑ $208
  - Year done: 0
  - Payback yrs: 21
## COMPARING INSULATION RETROFITS

<table>
<thead>
<tr>
<th>Insulation Project</th>
<th>R-value before</th>
<th>R-value after</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ATTICS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back attic: more fiberglass</td>
<td>13</td>
<td>43</td>
<td>60</td>
</tr>
<tr>
<td>New attic: more fiberglass</td>
<td>19</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Old attic: replace rock wool with polyicynene</td>
<td>19</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td><strong>WALLS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living room walls: replace old fiberglass with Polyicynene and 1” foam board</td>
<td>9</td>
<td>22</td>
<td>50</td>
</tr>
<tr>
<td>East wall: add two 1” layers of foam board</td>
<td>18</td>
<td>28</td>
<td>50</td>
</tr>
<tr>
<td>South wall: replace old fiberglass with urethane foam plus 1” foam board</td>
<td>11</td>
<td>26</td>
<td>50</td>
</tr>
<tr>
<td>Interior apt north wall: replace old fiberglass with 3” foam board over concrete block</td>
<td>8.9</td>
<td>16.5</td>
<td>50</td>
</tr>
<tr>
<td>Kitchen wall: has rock wool, sheathing and two layers of wood siding</td>
<td>12</td>
<td>Not done</td>
<td>50</td>
</tr>
<tr>
<td>North porch wall plus dormer</td>
<td>12</td>
<td>Not done</td>
<td>50</td>
</tr>
<tr>
<td><strong>FOUNDATION</strong></td>
<td>1</td>
<td>Not done</td>
<td>14</td>
</tr>
<tr>
<td><strong>SLAB</strong></td>
<td>1</td>
<td>Not done</td>
<td>20</td>
</tr>
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</table>
### Assessing Two Alternatives for East Wall Retrofit

<table>
<thead>
<tr>
<th>East Wall Components</th>
<th>As Is R-values</th>
<th>Alternative 1: replace insulation w foam</th>
<th>Alternative 2: adding 2” of foamboard</th>
</tr>
</thead>
<tbody>
<tr>
<td>change in wall thickness</td>
<td></td>
<td>-0.50”</td>
<td>Adds 2”</td>
</tr>
<tr>
<td>15 mph wind</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Vinyl siding</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>¼” Styrofoam</td>
<td>1.25</td>
<td></td>
<td>1.25</td>
</tr>
<tr>
<td>1” foam board</td>
<td>-</td>
<td>5.00</td>
<td>-</td>
</tr>
<tr>
<td>2” foam board (1” over 1”)</td>
<td>-</td>
<td>-</td>
<td>10.00</td>
</tr>
<tr>
<td>¾” wood siding</td>
<td>0.75</td>
<td>-</td>
<td>0.75</td>
</tr>
<tr>
<td>1” brown board sheathing</td>
<td>1.00</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>½” CDX</td>
<td>-</td>
<td>0.50</td>
<td>-</td>
</tr>
<tr>
<td>3 5/8” urethane foam</td>
<td>-</td>
<td>18.13</td>
<td>-</td>
</tr>
<tr>
<td>3 5/8” rock wool (but some has settled!)</td>
<td>13.84</td>
<td>-</td>
<td>13.84</td>
</tr>
<tr>
<td>½” gypsum</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>still airspace inside</td>
<td>0.68</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Total R</strong></td>
<td><strong>18.14</strong></td>
<td><strong>24.9</strong></td>
<td><strong>28.1</strong></td>
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</tbody>
</table>
Thermal Shutters
Attics
Living Room Walls
South Wall
Urethane Foam on South Wall
South Wall:
Spray Foam -> Sheath -> Foam board

... plus prepare for solar hot air collectors
Thermal Bridging in Our House: Foundation, Window Frames, Chimney, Dormer Seam

Sept. 8, 2008, 11 pm
Installing Coil; Filling Weight Cavities

Cellulose insulation, blown in
Before and After New Windows and Coil
Kitchen Window:
Old double-hungs -> New Casement
Solar Hot Water Heating
SHWH: Raising the Collectors
SHWH: Team help
SHWH: Tanks, plumbing
SHWH: Tailoring your system

Heat exchanger box on Jotul woodstove

Pipes feed through duct to baseboard heaters
Solar Hot Air Collectors
Solar Hot Air Collector

Testing the fan

Inside view, finished
Solar Hot Air Collectors
Supplemental Heat: Ground Source Heat Pump

Old

New
Drilling the Wells
Ground-Source Heat Pump: “Geothermal”
## Comparing Electricity Consumption, Fuel Oil vs Heat Pump

<table>
<thead>
<tr>
<th>Electricity Use</th>
<th>Winter, fuel oil kwh, 62 deg, 08-09</th>
<th>Winter, heat pump kwh, 64 deg, 09-10</th>
<th>Winter, heat pump kwh 70 degrees</th>
<th>Total electrical kwh, 09-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Electric</td>
<td>9,250</td>
<td>2,081</td>
<td>5,090</td>
<td>10,791</td>
</tr>
<tr>
<td>Furnace/Heat Pump</td>
<td>13,652</td>
<td>2,081</td>
<td>5,090</td>
<td>5,090</td>
</tr>
<tr>
<td>Electric Heater</td>
<td>668</td>
<td>668</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wood</td>
<td>2,997</td>
<td>2,997</td>
<td>0</td>
<td>2,997</td>
</tr>
<tr>
<td>Total Heat Energy:</td>
<td>17,317</td>
<td>5,746</td>
<td>5,090</td>
<td>5,090</td>
</tr>
<tr>
<td>Total All Energy:</td>
<td>26,567</td>
<td>5,746</td>
<td>5,090</td>
<td>13,788</td>
</tr>
<tr>
<td>Our kwh/m²</td>
<td>105</td>
<td>35</td>
<td>31</td>
<td>83</td>
</tr>
<tr>
<td>PH retrofit kwh/m²</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>120</td>
</tr>
</tbody>
</table>
Blower Door Test
## Air-Tightness

<table>
<thead>
<tr>
<th>House Types</th>
<th>CFM50</th>
<th>ACH50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive House Standard for new housing 1/</td>
<td>113</td>
<td>0.6</td>
</tr>
<tr>
<td>Passive House Standard for retrofits 1/</td>
<td>283</td>
<td>1.5</td>
</tr>
<tr>
<td>Canadian R-200 program</td>
<td>283</td>
<td>1.5</td>
</tr>
<tr>
<td>New homes in Minnesota</td>
<td>471</td>
<td>2.5</td>
</tr>
<tr>
<td>New homes in Wisconsin (study of 24 homes)</td>
<td>735</td>
<td>3.9</td>
</tr>
<tr>
<td>A typically tight house</td>
<td>500-1,500</td>
<td>2.7-8.0</td>
</tr>
<tr>
<td><em>Threshold rule-of-thumb below which one should install whole-house mechanical ventilation</em> 2/</td>
<td>1,000</td>
<td>5.3</td>
</tr>
<tr>
<td>Older houses</td>
<td>6,500-8,500</td>
<td>4/</td>
</tr>
<tr>
<td>Passive House standard for our house 3/</td>
<td>420</td>
<td>1.5</td>
</tr>
<tr>
<td>Actual blower door test results for our house</td>
<td>1,910</td>
<td>6.9</td>
</tr>
<tr>
<td>ASHRAE 5/ with 4 occupants</td>
<td>45</td>
<td>0.24</td>
</tr>
</tbody>
</table>
Air Tightness References/Notes

1/ Standard house of 1,500 sq.ft. w 7.5’ ceilings
2/ Holladay article
3/ Our house is 1,780 sq.ft. to which we must add the cellar (another 451 sq.ft.) giving a total of 2,231 sq.ft., or 420 cfm using the PH standard for retrofits.
4/ Without knowing the volume of an older house, we cannot determine ACH.
5/ American Society of Heating, Refrigeration and Air Conditioning Engineers. This is a ventilation standard, not an air-tightness standard.
Actions to Improve Air Tightness

- Caulk the remaining 9 old windows and 3 door frames.
- Seal two storage rooms on the perimeter in the cellar and a cubby off an upstairs room.
- Investigate the area around the attic door for leaks there and through attic floor to living room.
- Retrofit the two remaining walls of the house, including dormer (big bucks – $10,000 to $16,000).
- Replace remaining 9 windows (big bucks – $12,000).
- Replace three doors with high performance, well insulated doors (more big bucks).

First 3 might reduce leakage by 200 cfm, not a lot.
Key Idea: Microorganisms on plant roots render toxins harmless (Dr. John Todd)

Living Machines & Lake Restorers
Concept Diagram For Breathing Wall
Environmental Room with Breathing Wall
Plants: Natural Scrubbers

HOW TO GROW FRESH AIR
50 Houseplants that Purify Your Home or Office
Dr. B.C. Wolverton
Tax Credits and Other Assistance

- Federal Tax Credits (Form 5695) $1,500 for energy efficiency improvements (better windows, furnaces), and a 30% tax credit for PV, wind, geothermal devices.
- USDA has programs focused on your farm as a business. Each state also has an Energy Coordinator.
- PA DEP has an Energy Program, PA Sunshine Solar Program but these seem geared to projects that produce energy as part of a business.
- Check out our website for web links.
Lessons Learned

• Until everything is done, you will not realize the savings you had hoped for.
• Technology and building practices are changing rapidly in response to rising energy prices and more widely shared assumptions on global warming and the destructive impacts of petroleum and natural gas development.
• Passive House is the new standard for energy-efficient design & retrofits.
• Focus on the building envelope: “build tight and ventilate right.”
• We should have used more insulation – more layers of foam board!
• We should have reduced window area in the LR retrofit in 2001.
• Choose drainback over pressurized glycol and drainback for flat plate solar hot water units.
• Be skeptical of performance claims and advertised payback periods. Do your own math.
• During retrofits, correct mistakes as you (or your contractors) make them.
• One way to build a proper structure inexpensively is to buy a fabricated structure (e.g., a Morton building) and super-insulate it.