Passiv for the Masses

Part I: Matthew O’Malia, GO LOGIC
Part II: Alan Gibson, GO LOGIC
Part III: Adam Cohen, PASSIV SCIENCE
GO Logic is a 28 person architecture and construction firm in Belfast, Maine, committed to designing and building passive house level buildings. Founded in 2008 by Contractor, Alan Gibson and Architect, Matthew O’Malia

GO Logic designs and builds a mix of projects including residential, multi-family and institutional, and has certified 6 passive houses and is currently in the process of certifying its 7th.
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WARREN WOODS
North America’s First Passive House Laboratory
Completed in Michigan, 2014

ECOVILLAGE
36 family complex of Near-Zero structures
WARREN WOODS
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the GO HOME
PassiveHaus Certified Home

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TERRA HAUS DORM
PassiveHaus Certified Dormitory, Unity College

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Passive house level residence

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LITTLE HOUSE THE FERRY
Three season summer home

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LITTLE HOUSE THE FERRY
Three season summer home

QUINCY HOUSE
Passive house level residence

HAYFIELD HOUSE
PassiveHaus Certified Home
COMSTOCK
Passive house level residence

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Three season summer home

QUNICY HOUSE
Passive house level residence

HAYFIELD HOUSE
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QUNICY HOUSE
Passive house level residence

GOOD WILL HINCKLEY
Historical Masonry Renovation
COMSTOCK
Passive house level residence

97 CUMBERLAND
Apartment Housing

QUNICY HOUSE
Passive house level residence

GOOD WILL HINCKLEY
Historical Masonry Renovation
COMSTOCK
Passive house level residence

97 CUMBERLAND
Apartment Housing

CORNERSPRING
MONTESSORI
Elementary School

SHELDON CALVARY CAMP
Dining Facility - Ohio
GATHERING CENTER
PassiveHaus certified Pending

97 CUMBERLAND
Apartment Housing

CORNERSPRING MONTESSORI
Elementary School

SHELDON CALVARY CAMP
Dining Facility - Ohio
CORNERSPRING MONTESSORI
Elementary School

GATHERING CENTER
PassiveHaus certified Pending

97 CUMBERLAND
Apartment Housing
GATHERING CENTER
PassiveHaus certified Pending
Why Passiv?
World population in 2016: 7 Billion
World population in 2016: 7 Billion

World population in 2050: 9 Billion
THE LOCK IN EFFECT

U.S. CODE built

Global Buildings Performance Network
THE LOCK IN EFFECT

40% MORE EFFICIENT THAN CODE

U.S. CODE built

Global Buildings Performance Network
THE LOCK IN EFFECT

- U.S. CODE built
- LEED
- PH

- 40% MORE EFFICIENT THAN CODE
- 80% MORE EFFICIENT THAN CODE

Global Buildings Performance Network
THE LOCK IN EFFECT

LIFESPAN OF BUILDING COMPONENTS

- BUILDING SHELL: 200+ yrs
- WINDOWS: 40 years
- MECHANICALS: 25 yrs
- SOLAR PANELS: 25 yrs
PASSIVE HOUSE 101

• HIGHLY INSULATED BUILDING SHELL: BUILDINGS THAT ARE 80% MORE EFFICIENT THAN STANDARD CONSTRUCTION

• NEARLY AIR TIGHT BUILDING ENCLOSURE

• VENTILATION WITH HEAT RECOVERY FOR IMPROVED INDOOR AIR QUALITY

• A COST-EFFECTIVE BUILDING SOLUTION FOR COLD CLIMATES
Standard house v. Passive house

INVEST IN THE BUILDING SHELL....
Standard house v. Passive house

INVEST IN THE BUILDING SHELL....
Standard house v. Passive house

INVEST IN THE BUILDING SHELL.... AND REDUCE THE HEATING SYSTEM TO A HAIR DRYER...
Standard house v. Passive house

INVEST IN THE BUILDING SHELL....
AND REDUCE THE HEATING SYSTEM TO A HAIR DRYER-
...THE SAVINGS IN MECHANICAL SYSTEMS PAYS FOR THE INSULATION
PASSIVE DESIGN CONCEPTS FOR A COLD CLIMATE: MODELING TAKE-AWAYS

• FORM FACTOR - COMPACT BUILDING FORM HELPS

• PASSIVE SOLAR - GREAT WHEN YOU CAN GET IT - NOT ALL SITES ALLOW FOR IT. E

• INSULATION LEVELS DEPEND ON THE BUILDING - ONE SIZE DOES NOT FIT ALL

• IN A COLD CLIMATE, TRIPPLE GLAZED WINDOWS ARE REQUIRED

• OCCUPANCY HAS A MAJOR IMPACT ON INTERNAL GAINS

• LARGER BUILDINGS MAKE MEETING THE PH STANDARD EASIER THAN SMALLER BUILDINGS
FORM FACTOR: COMPACT BUILDING FORM IS A GOOD START

**Cube:**

\[
\text{Volume: } 2 \times 2 \times 2 = 8 \\
\text{Area: } 4 \times 6 = 24
\]

**Rectangle:**

\[
\text{Volume: } 1 \times 1 \times 8 = 8 \\
\text{Area: } 4 \times 8 + 2 \times 1 = 34
\]
FORM FACTOR: COMPACT BUILDING FORM IS A GOOD START

**Cube:**

- Volume: $2 \times 2 \times 2 = 8$
- Area: $4 \times 6 = 24$

30% greater heat loss!

**Rectangle:**

- Volume: $1 \times 1 \times 8 = 8$
- Area: $4 \times 8 + 2 \times 1 = 34$
ENERGY MODELING CASE STUDY

INFILL PROJECT IN PORTLAND, ME

TIGHT SITE WITH POOR SOLAR ACCESS

GOAL OF NEAR PASSIVE HOUSE LEVEL OF PERFORMANCE

ENERGY MODEL USED TO HELP IMPROVE CLIENT DECISIONS ON BUILDING SHELL DESIGN AND MECHANICAL SYSTEMS
RESIDENTIAL PROJECT, PORTLAND, ME
RESIDENTIAL PROJECT, PORTLAND, ME

1. Roof: R80
   U-Value – 0.061 W/m²K

2. HRV system
   83% efficient

3. Triple glazed windows:
   Passive solar
   g-Value – 0.5 / 0.6
   U_g Value – 0.7

4. Wall: R50
   U-Value – 0.111 W/m²K

5. Slab on grade:
   R30
   U-Value – 0.138 W/m²K
# GOL PH / LEED / CODE COMPARISON

## PH Building Envelope Data

| Option Title: 6" Mineral Wool / PH Windows | Comparison Data | %
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Above Grade</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windows &amp; Glazed Doors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area [SF]</td>
<td>978</td>
<td></td>
</tr>
<tr>
<td>R-Value</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>SHGC</td>
<td>SHGC</td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>363.31</td>
<td></td>
</tr>
<tr>
<td>SHGC</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>222.08</td>
<td></td>
</tr>
<tr>
<td>SHGC</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>87.625</td>
<td></td>
</tr>
<tr>
<td>SHGC</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>Doors (opaque)</td>
<td>93.1</td>
<td></td>
</tr>
<tr>
<td>Net Wall</td>
<td>4535.3</td>
<td></td>
</tr>
<tr>
<td>Skylights</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td>1523.5</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>80.00</td>
<td></td>
</tr>
<tr>
<td>Floor (ambient / cantilever)</td>
<td>685.56</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>65.00</td>
<td></td>
</tr>
<tr>
<td>Foundation Wall (above grade)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td><strong>Below Grade</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foundation Wall (below grade)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Slab (On Grade)</td>
<td>822.1</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>30.00</td>
<td></td>
</tr>
<tr>
<td>Foundation Edge</td>
<td>96.3</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>30.00</td>
<td></td>
</tr>
<tr>
<td>Slab (Below Grade)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>PH Typ. R Value</td>
<td>18.00</td>
<td></td>
</tr>
<tr>
<td><strong>Efficiency of HRV [%]</strong></td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>PH Typ. Efficiency</td>
<td>84%</td>
<td></td>
</tr>
<tr>
<td><strong>Infiltration Rate [ACH]</strong></td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>PH Typ. Rate</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td><strong>Heat Pump COP</strong></td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>PH Typ = 2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Proposed Occupancy</strong></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Often # of bedrooms</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Floor Area [SF]</strong></td>
<td>2,676.18</td>
<td></td>
</tr>
<tr>
<td><strong>Treated Floor Area [SF]</strong></td>
<td>2,554.83</td>
<td></td>
</tr>
<tr>
<td><strong>Building Volume [CF]</strong></td>
<td>33,557</td>
<td></td>
</tr>
<tr>
<td><strong>LEED</strong></td>
<td>60.00</td>
<td></td>
</tr>
<tr>
<td><strong>Code</strong></td>
<td>60.00</td>
<td></td>
</tr>
</tbody>
</table>
**Solar Data**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Heating Degree Days [deg. F]</td>
<td>6,689</td>
</tr>
<tr>
<td>Days of Heating</td>
<td>240</td>
</tr>
<tr>
<td>Percent Reduction for Shading</td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>60%</td>
</tr>
<tr>
<td>South</td>
<td>90%</td>
</tr>
<tr>
<td>West</td>
<td>50%</td>
</tr>
<tr>
<td>Available Roof Area for Solar Panels</td>
<td>300 sq ft</td>
</tr>
<tr>
<td>Sensible Gains [BTU/hr]</td>
<td>250 BTUs/hr</td>
</tr>
<tr>
<td>Glass of windows + doors [%]</td>
<td>70%</td>
</tr>
<tr>
<td>Hours of Sun per Year [hrs]</td>
<td>1234</td>
</tr>
</tbody>
</table>

**Note:** The following values (Solar Factor and %Sun) can be found in the solar book on Gunther’s desk

<table>
<thead>
<tr>
<th>Month</th>
<th>South Solar Factor</th>
<th>East Solar Factor</th>
<th>West Solar Factor</th>
<th>% Sun</th>
<th>Heating Degree Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept</td>
<td>1144</td>
<td>1144</td>
<td>787</td>
<td>47%</td>
<td>168</td>
</tr>
<tr>
<td>Oct</td>
<td>1098</td>
<td>1098</td>
<td>582</td>
<td>47%</td>
<td>410</td>
</tr>
<tr>
<td>Nov</td>
<td>983</td>
<td>983</td>
<td>399</td>
<td>38%</td>
<td>750</td>
</tr>
<tr>
<td>Dec</td>
<td>895</td>
<td>895</td>
<td>307</td>
<td>37%</td>
<td>1053</td>
</tr>
<tr>
<td>Jan</td>
<td>1004</td>
<td>1004</td>
<td>405</td>
<td>41%</td>
<td>1248</td>
</tr>
<tr>
<td>Feb</td>
<td>1184</td>
<td>1184</td>
<td>603</td>
<td>44%</td>
<td>1054</td>
</tr>
<tr>
<td>Mar</td>
<td>1206</td>
<td>1206</td>
<td>829</td>
<td>43%</td>
<td>913</td>
</tr>
<tr>
<td>Apr</td>
<td>1128</td>
<td>1128</td>
<td>1000</td>
<td>44%</td>
<td>580</td>
</tr>
</tbody>
</table>

**Heating Data**

**Comparison Data**

<table>
<thead>
<tr>
<th>FUEL TYPE:</th>
<th>2&quot; Foam / Loewen Triple</th>
<th>2&quot; Foam / PH Windows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Electric</td>
<td>Grid Electric</td>
<td>Grid Electric</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel</th>
<th>% Inflation</th>
<th>Cost per unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>0%</td>
<td>$0.00 WATT</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>3%</td>
<td>$1.45 THERMS</td>
</tr>
<tr>
<td>#2 Oil</td>
<td>3%</td>
<td>$3.66 GAL</td>
</tr>
<tr>
<td>LP</td>
<td>3%</td>
<td>$3.22 GAL</td>
</tr>
<tr>
<td>Grid Electric</td>
<td>5%</td>
<td>$0.15 KWH</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>5%</td>
<td>$0.15 KWH</td>
</tr>
<tr>
<td>Firewood</td>
<td>3%</td>
<td>$200.00 CORDS</td>
</tr>
<tr>
<td>Pellets</td>
<td>3%</td>
<td>$300.00 TONS</td>
</tr>
</tbody>
</table>
(GOL) PASSIVE HOUSE PERFORMANCE

ENVELOPE (CONDUCTIVE LOSSES)

<table>
<thead>
<tr>
<th>Region</th>
<th>Area [SF]</th>
<th>R-Value [in-SF°F/Btu]</th>
<th>Heat Loss [Btu/hr]</th>
<th>% of Loss</th>
<th>% of Gross Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window</td>
<td>978</td>
<td>6.0</td>
<td>10106</td>
<td>45%</td>
<td>11%</td>
</tr>
<tr>
<td>Door</td>
<td>93.1</td>
<td>5.0</td>
<td>1154</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>Floor (Ambient)</td>
<td>685.58</td>
<td>65.0</td>
<td>654</td>
<td>3%</td>
<td>8%</td>
</tr>
<tr>
<td>Net Wall</td>
<td>4035.3</td>
<td>50.0</td>
<td>5624</td>
<td>25%</td>
<td>53%</td>
</tr>
<tr>
<td>Roof</td>
<td>1523.5</td>
<td>75.0</td>
<td>1259</td>
<td>6%</td>
<td>17%</td>
</tr>
<tr>
<td>Foundation</td>
<td>96.3</td>
<td>26.1</td>
<td>229</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Slab</td>
<td>822.1</td>
<td>26.1</td>
<td>1172</td>
<td>5%</td>
<td>9%</td>
</tr>
</tbody>
</table>

Total Envelope Loss: 89%

IN INFILTRATION AND VENTILATION LOSSES

<table>
<thead>
<tr>
<th>Ventilation Rate [CFM]</th>
<th>Efficiency of HRV (%)</th>
<th>Heat Loss [Btu/hr]</th>
<th>% of Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Volume [CF]</td>
<td>Infiltration Rate [ACH]</td>
<td>Heat Loss [Btu/hr]</td>
<td>% of Loss</td>
</tr>
<tr>
<td>Infiltration:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Air Leakage and Ventilation Loss 11%

Heat Loss: Ventilation vs. Conductive Loss

Component Heat Loss by Percent

Losses Relative to Area of Shell

- Window 45%
- Door 5%
- Net Wall 25%
- Roof 5%
- Infiltration 7%
- Ventilation 4%
- Foundation Edge 1%
- Slab (On Grade) 5%
- Slab (Ambient) 3%
- Roof 6%
- Floor (Ambient) 3%

% of Bldg. Shell % of Loss
(GOL) PASSIVE HOUSE PERFORMANCE

Heat Loss: Ventilation vs. Conductive Loss

- Total Air Leakage and Ventilation Loss: 11%
- Other: 89%

Component Heat Loss by Percent

- Window: 45%
- Net Wall: 25%
- Door: 5%
- Foundation Edge: 1%
- Slab (On Grade): 5%
- Floor (ambient): 3%
- Roof: 6%

Losses Relative to Area of Shell

- Net Wall
  - % of Bldg. Shell: 40%
  - % of Loss: 25%
- Window
  - % of Bldg. Shell: 5%
  - % of Loss: 45%
- Roof
  - % of Bldg. Shell: 5%
  - % of Loss: 1%
(GOL) PASSIVE HOUSE PERFORMANCE

Heat Loss: Ventilation vs. Conductive Loss

- Total Air Leakage and Ventilation Loss: 11%
- Other: 89%
- Window: 45%
- Door: 5%
- Net Wall: 25%
- Roof: 6%
- Floor (ambient): 3%
- Slab (On Grade): 5%
- Foundation Edge: 1%

Component Heat Loss by Percent

- Window: 45%
- Door: 5%
- Net Wall: 25%
- Infiltration: 7%
- Ventilation: 4%
- Foundation Edge: 1%
- Slab (On Grade): 5%
- Floor (ambient): 3%
- Roof: 5%

Losses Relative to Area of Shell

- Roof
- Net Wall
- Window

% of Bldg. Shell vs. % of Loss
(GOL) PH / LEED / CODE COMPARISON

Heating Load per Square Foot by Option

- Passive House Standard: 4750 BTUs
- GOL Passive House: 8054 BTUs
- LEED: 32785 BTUs
- Code: 43768 BTUs
- Conventional Construction: 50000 BTUs

Component Losses by Option

- Slab (Below Grade)
- Foundation Edge
- Slab (On Grade)
- Foundation Wall (below grade)
- Foundation Wall (above grade)
- Floor (ambient)
- Roof
- Skylights
- Net Wall
- Door
- Window

Heat Loss (BTU/hr)
### Energy Model: Active & Passive Gains Comparison by Option P.4

<table>
<thead>
<tr>
<th></th>
<th>Code</th>
<th>LEED</th>
<th>GOL Passive House</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Solar Gains</td>
<td>5917 kWh</td>
<td>5917 kWh</td>
<td>7490 kWh</td>
</tr>
<tr>
<td>Internal Gains</td>
<td>6201 kWh</td>
<td>4675 kWh</td>
<td>3658 kWh</td>
</tr>
<tr>
<td>Active Heat Load</td>
<td>32772 kWh</td>
<td>24549 kWh</td>
<td>6031 kWh</td>
</tr>
</tbody>
</table>

#### Annual Heating Loads

- **Passive Solar Gains**
- **Internal Gains**
- **Active Heat Load**

- **Code**:
  - Passive Solar Gains: 5917 kWh
  - Internal Gains: 6201 kWh
  - Active Heat Load: 32772 kWh

- **LEED**: Passive Solar Gains: 5917 kWh, Internal Gains: 4675 kWh, Active Heat Load: 24549 kWh

- **GOL Passive House**: Passive Solar Gains: 7490 kWh, Internal Gains: 3658 kWh, Active Heat Load: 6031 kWh

---

"This is what it means to be passive"
(GOL) PH / LEED / CODE COMPARISON

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Code</th>
<th>LEED</th>
<th>GOL Passive House</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>$1,966.34</td>
<td>$1,472.93</td>
<td>$361.86</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$93,847.78</td>
<td>$70,298.68</td>
<td>$17,270.56</td>
</tr>
<tr>
<td>Difference from PH</td>
<td>$76,577.22</td>
<td>$53,028.12</td>
<td></td>
</tr>
</tbody>
</table>

Quebec St

<table>
<thead>
<tr>
<th>Years</th>
<th>Heating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

- Code: $93,847.78
- LEED: $70,298.68
- GOL Passive House: $17,270.56
(GOL) PH / LEED / CODE COMPARISON

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Code</th>
<th>LEED</th>
<th>GOL Passive House</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Operating Costs:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Pump</td>
<td>$1,966.34</td>
<td>$1,472.93</td>
<td>$361.86</td>
</tr>
<tr>
<td>Operating Costs after 25 Years:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Pump</td>
<td>$93,847.78</td>
<td>$70,298.68</td>
<td>$17,270.56</td>
</tr>
<tr>
<td>Difference from PH</td>
<td></td>
<td>$76,577.22</td>
<td>$53,028.12</td>
</tr>
</tbody>
</table>

Heating Costs

Graph showing the comparison of heating costs over 25 years for different fuel types and building codes.
(GOL) PH / LEED / CODE COMPARISON

<table>
<thead>
<tr>
<th></th>
<th>Code</th>
<th>LEED</th>
<th>GOL Passive House</th>
</tr>
</thead>
<tbody>
<tr>
<td>kW required</td>
<td>10.62</td>
<td>7.96</td>
<td>1.95</td>
</tr>
<tr>
<td>SF array required (sf)</td>
<td>744 sf</td>
<td>557 sf</td>
<td>137 sf</td>
</tr>
<tr>
<td>Approx. Available Roof Area (sf)</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Cost of Installed Array</td>
<td>$42,492.52</td>
<td>$31,829.93</td>
<td>$7,819.79</td>
</tr>
</tbody>
</table>

Each Panel:
- sf: 70
- kw: 1
- panel: 250w
- cost/kw: $4,000

PV Requirements for the annual heating demand, shown against the roof area available.
## PH Building Envelope Data

<table>
<thead>
<tr>
<th>Option Title</th>
<th>Area [SF]</th>
<th>R-Value</th>
<th>PH Typ. R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Above Grade</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windows &amp; Glazed Doors</td>
<td>978</td>
<td>6.00</td>
<td>6</td>
</tr>
<tr>
<td>North</td>
<td>304.985</td>
<td>SHGC</td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>363.31</td>
<td>0.50</td>
<td>0.6</td>
</tr>
<tr>
<td>South</td>
<td>222.08</td>
<td>0.50</td>
<td>0.6</td>
</tr>
<tr>
<td>West</td>
<td>87.625</td>
<td>0.50</td>
<td>0.6</td>
</tr>
<tr>
<td>Doors (opaque)</td>
<td>93.1</td>
<td>5.00</td>
<td>5</td>
</tr>
<tr>
<td>Net Wall</td>
<td>4535.3</td>
<td>50.00</td>
<td>50</td>
</tr>
<tr>
<td>Skylights</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>Roof</td>
<td>1523.5</td>
<td>75.00</td>
<td>80</td>
</tr>
<tr>
<td>Floor (ambient / cantilever)</td>
<td>685.56</td>
<td>65.00</td>
<td>60</td>
</tr>
<tr>
<td>Foundation Wall (above grade)</td>
<td>0</td>
<td>0.00</td>
<td>30</td>
</tr>
<tr>
<td><strong>Below Grade</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foundation Wall (below grade)</td>
<td>0</td>
<td>0.00</td>
<td>20</td>
</tr>
<tr>
<td>Slab (On Grade)</td>
<td>822.1</td>
<td>26.10</td>
<td>30</td>
</tr>
<tr>
<td>Foundation Edge</td>
<td>96.3</td>
<td>26.10</td>
<td>30</td>
</tr>
<tr>
<td>Slab (Below Grade)</td>
<td>0</td>
<td>0.00</td>
<td>18</td>
</tr>
</tbody>
</table>

### Comparison Data

<table>
<thead>
<tr>
<th>Option 1: 2&quot; Foam / Loewen Triple</th>
<th>Option 2: 2&quot; Foam / PH Windows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency of HRV [%]</td>
<td>84</td>
</tr>
<tr>
<td>Infiltration Rate [ACH]</td>
<td>0.04</td>
</tr>
<tr>
<td>Heat Pump COP</td>
<td>2.5</td>
</tr>
<tr>
<td>Proposed Occupancy</td>
<td>4</td>
</tr>
<tr>
<td>Total Floor Area [SF]</td>
<td>2,676.18</td>
</tr>
<tr>
<td>Treated Floor Area [SF]</td>
<td>2,554.83</td>
</tr>
<tr>
<td>Building Volume [CF]</td>
<td>33,557</td>
</tr>
</tbody>
</table>

**PH Typ. Efficiency = 84%**
**PH Typ. Rate = 0.04**
**PH Typ = 2.5**
Heating Load Requirements per Square Foot by Option

- **Passive House Standard**: 4750 BTUs
- **6" Mineral Wool / PH Windows**: 11264 BTUs
- **2" Foam / Loewen Triple**: 23096 BTUs
- **2" Foam / PH Windows**: 19146 BTUs
- **Conventional Construction**: 50000 BTUs

Percentage Division of Energy Loads

- **Annual Passive Solar Gains**: 30%
- **Net Annual Heat Load**: 49%
- **Annual Internal Gains**: 21%

Component Losses by Option

- Slab (Below Grade)
- Foundation Edge
- Slab (On Grade)
- Foundation Wall (below grade)
- Foundation Wall (above grade)
- Floor (ambient)
- Roof
- Skylights
- Net Wall
- Door
- Window

Heat Loss (BTU/hr)
Annual Heating Loads

2" Foam / Loewen Double
2" Foam / Loewen Triple
6" Mineral Wool / PH Windows
**PH / REDUCED SHELL / REDUCED SHELL AND WINDOW COMPARISON**

<table>
<thead>
<tr>
<th></th>
<th>2&quot; Foam / PH Windows</th>
<th>2&quot; Foam / Loewen Triple</th>
<th>6&quot; Mineral Wool / PH Windows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Type</td>
<td>Grid Electric</td>
<td>Grid Electric</td>
<td>Grid Electric</td>
</tr>
<tr>
<td>Annual Operating Costs:</td>
<td>$2,150.36</td>
<td>$2,594.04</td>
<td>$1,265.13</td>
</tr>
<tr>
<td>Operating Costs after 25 Years:</td>
<td>$102,630.47</td>
<td>$123,806.07</td>
<td>$60,380.78</td>
</tr>
<tr>
<td>Difference from PH</td>
<td>$42,249.69</td>
<td>$63,425.29</td>
<td></td>
</tr>
</tbody>
</table>

- **Cost of Space Heating**
  - **2" Foam / PH Windows**: $102,630.47
  - **2" Foam / Loewen Triple**: $123,806.07
  - **6" Mineral Wool / PH Windows**: $60,380.78

- **Years**: 0, 5, 10, 15, 20, 25

- **Difference from PH**: $42,249.69, $63,425.29, $60,380.78
Massive Passiv Walls for the Masses
Why Walls?

- In the land of passivhaus, walls are thick and complicated.
- They hold up the floor and the roof.
- They want to be as thin as possible to reduce cost and be acceptable to the architect.
- Architects are at the mercy of builders, and builders have their methods.
- They need to be evaluated on a number of criteria, including but not limited to:
Evaluation Criteria

- Load Path and Shear
- Bulk Moisture Control (given)
- Insulation value
- Airtightness (given)
- Thermal bridge-free (mostly given)
- Vapor Control
- Buildability and Cost
Assumptions

- There are many ways to build walls.
- Some are better than others.
- The walls I am presenting are generally for cold climates.
- The walls I am presenting are wood frame.
Passivhaus Wall Survey Results

1. Double Stud
   a. Not Good Way
   b. Better Way

2. Stud Wall with Exterior Insulation
   a. Foam/SIP
   b. Larsen Truss
   c. Mineral Wool
   d. Sorry, no spray foam here
In the beginning: simple stick framing. Life was good.
1977
Saskatchewan Conservation House

Made in Canada
1980s: 2x6 wall with poor insulation
Fast Forward: Passivhaus:

Hello, R50

Standard insulation values: R 3.5-4/inch
Wall 14”-16” thick
Double Stud: not good way

5/8" GWB Finish

MONOLITHIC CONCRETE SLAB

1 1/2" LAYER FLOWABLE FILL OR COMPACTED STONE DUST (SEE SPEC)

2X4 STAGGERED WALL WITH DENSE PACK CELLULOSE

1/2" OSB SHEATHING

AIR TIGHT LAYER

BUILDING PAPER

VERTICAL STRAPPING

SIDING

SIDING VENT

AIR BARRIER

ALUMINUM FLASHING

RIGID EPS INSULATION

4" DIA PERFORATED DRAIN TO DAYLIGHT
Double Stud: not good way

- Load Path, Shear
- Insulation value (R42)
- Airtightness
- Vapor Control
- Buildability and Cost—need to separate bays for cellulose; not as cheap as you think
Vapor Control Basics

- Vapor drive is real. Moisture goes from more humid to less humid, just like heat moves from warm to cool.
- Walls must be able to dry to one side or the other. Winter condition in cold climate: keep moisture out of wall and away from condensing surface (typically the sheathing).
- This means exterior skin must be more vapor permeable than interior skin, by at least 5 times
Double Stud: not good way

Gwb (interior) perm rating: 50
o.s.b. (exterior) perm rating: 1
Must use vapor retarder on
Interior, and make sure it’s smart.
Double Stud Wall: Better Way 1

- 5/8" GWB Finish
- Monolithic Concrete Slab
- 1 1/2" Layer Flowable Fill or Compacted Stone Dust (See Spec)
- Horizontal Strapping
- WRB
- Vertical Strapping
- Siding
- Siding Vent
- Air Barrier
- Aluminum Flashing
- Rigid EPS Insulation
- 4" Dia Perforated Drain to Daylight
Double Stud Wall: Better Way 1
Double Stud Wall: Better Way 2

5/8" GWB FINISH

MONOLITHIC CONCRETE SLAB

1 1/2" LAYER FLOWABLE FILL OR COMPACTED STONE DUST (SEE SPEC)

AIR TIGHT LAYER
HORIZONTAL STRAPPING
WRB
VERTICAL STRAPPING
SIDING
SIDING VENT

AIR BARRIER
ALUMINUM FLASHING
RIGID EPS INSULATION

4" DIA PERFORATED DRAIN TO DAYLIGHT
Double Stud Wall: Better Way 3

MONOLITHIC CONCRETE SLAB

5/8" GWB FINISH

RIGID EPS INSULATION

1 1/2" LAYER FLOWABLE FILL OR COMPACTED STONE DUST (SEE SPEC)

2X4 STAGGERED WALL WITH DENSE PACK CELLULOSE

1/2" OSB SHEATHING

AIR TIGHT LAYER

BUILDING PAPER

VERTICAL STRAPNING

SIDING

SIDING VENT

AIR BARRIER

FROST WALL
Stud Wall with Exterior Insulation

5/8" GWB FINISH

2X6 STUD WALL WITH DENSE PACK CELLULOSE

VERTICAL STRAPPING

8.25" SIP (EPS FOAM)

SIDING

SIDING VENT

MONOLITHIC CONCRETE SLAB

ALUMINUM FLASHING

ICE & WATER SHIELD

RIGID EPS INSULATION

4" DIA PERFORATED DRAIN TO DAYLIGHT
Sheathing, foam, sheathing: SIP
Sheathing, foam, sheathing: SIP
Stud Wall with Exterior Insulation

5/8" GWB FINISH

2X6 STUD WALL WITH DENSE PACK CELLULOSE

VERTICAL STRAPPING

SIDING

SIDING VENT

MONOLITHIC CONCRETE SLAB
ALUMINUM FLASHING
ICE & WATER SHIELD
RIGID EPS INSULATION

4" DIA PERFORATED DRAIN TO DAYLIGHT

Temp here
Calculate temp inside the wall, and dew point

\[ T_{si} = T_i - \left( \frac{R_{\text{interior}}}{R_{\text{total}}} \right) \Delta T \]
\[ T_{si} = T_i - \left( \frac{R_{\text{interior}}}{R_{\text{total}}} \right) \times \Delta T \]

\[ T_{si} = 68^\circ - (\frac{19}{52}) \times 48^\circ \]

\[ T_{si} = 50^\circ \]
Stud Wall with Exterior Insulation

- 5/8" GWB Finish
- VERTICAL STRAPPING
- SIDING
- SIDING VENT
- MONOLITHIC CONCRETE SLAB
- ALUMINUM FLASHING
- ICE & WATER SHIELD
- RIGID EPS INSULATION
- 4" DIA PERFORATED DRAIN TO DAYLIGHT

50°
Online Dew Point Calculator: http://www.dpcalc.org/
2/5 Rule: put sheathing no more than 2/5 of the total R value into the wall (from the interior).
R702.7.1 Class III vapor retarders.
Class III vapor retarders shall be permitted where any one of the conditions in Table R702.7.1 is met.

**TABLE R702.7.1 CLASS III VAPOR RETARDERS**

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>CLASS III VAPOR RETARDERS PERMITTED FOR:</th>
</tr>
</thead>
</table>
| Marine 4     | Vented cladding over wood structural panels.  
                Vented cladding over fiberboard.  
                Vented cladding over gypsum.  
                Insulated sheathing with $R$-value $\geq 2.5$  
                over $2 \times 4$ wall.  
                Insulated sheathing with $R$-value $\geq 3.75$  
                over $2 \times 6$ wall. |
| 5            | Vented cladding over wood structural panels.  
                Vented cladding over fiberboard.  
                Vented cladding over gypsum.  
                Insulated sheathing with $R$-value $\geq 5$  
                over $2 \times 4$ wall.  
                Insulated sheathing with $R$-value $\geq 7.5$  
                over $2 \times 6$ wall. |
| 6            | Vented cladding over fiberboard.  
                Vented cladding over gypsum.  
                Insulated sheathing with $R$-value $\geq 7.5$  
                over $2 \times 4$ wall.  
                Insulated sheathing with $R$-value $\geq 11.25$  
                over $2 \times 6$ wall. |
| 7 and 8      | Insulated sheathing with $R$-value $\geq 10$  
                over $2 \times 4$ wall.  
                Insulated sheathing with $R$-value $\geq 15$  
                over $2 \times 6$ wall. |
2x6 stud wall with TJI Larsen Truss
2x6 stud wall with TJI Larsen Truss

- Vertical Strapping
- Horizontal Strapping
- OSB Sheathing
- Air Tight Layer
- 2x6 Stud Wall w/ Dense-Pack Cellulose
- 12" TJI Wall w/ Dense-Pack Cellulose
- Siding
- Gravel
- Monolithic Concrete Slab
- Rigid EPS Insulation
- 3" x 4' Rigid EPS Insulation
2x6 stud wall with 12” TJI Larsen Truss

Pros
- Load and shear resolved in sheathed stud wall
- TJI’s provide structure for bolt-ons
- R 63
- No dewpoint concerns—sheathing is warm, exterior vapor open
Cons
- Too fat?
- 2x4 wall limited structurally
- Fluffy stuff held in by fabric
- Getting expensive
2x8 wall with exterior mineral wool

- 5/8" GWB finish
- 2x8 stud wall with dense pack cellulose
- 6" mineral wool insulation
- Vertical strapping
- Siding
- Siding vent
- Monolithic concrete slab
- Aluminum flashing
- Ice & water shield
- Rigid EPS insulation
- 4" dia perforated drain to daylight
2x8 wall with exterior mineral wool

- 2x8 Stud Wall w/ Dense-Pack Cellulose
- OSB Sheathing
- Air Tight Layer
- Building Wrap
- 6" MineralWool Insulation
- Wood Strapping
- Siding
- Flashing
- Gravel
- Monolithic Concrete Slab
- Rigid EPS Insulation
- 2" x 4" Rigid EPS Insulation
2x8 wall with exterior mineral wool

Pros
- Load and shear resolved
- R 52
- Mineral wool:
  - Vapor open
  - Hydrophobic
  - Fire resistant
  - Rigid board
2x8 wall with exterior mineral wool

Cons

- Doesn’t conform to 2/5 rule
  (but mineral wool is highly permeable so it’s fine)
- Need to engineer connection between strapping and studs depending on weight of siding
Temperature, RH (Monitor Position 3, 4)
Prefabrication
Prefabration
Prefabrication
Prefabrication
The Cost Question
As R value increases, insulation’s effectiveness decreases.
As R value increases, heat loss slows down
Cost
As R value increases, cost increases less
Cost per square foot per per R value

2x6 wall with cellulose: $0.27
2x6 wall with 7.25” I-joist, fabric, cellulose: $0.33
2x6 wall with 9.25” I-joist, fabric, cellulose: $0.28
2x6 wall with 12” I-joist, fabric, cellulose: $0.26
12: double stud wall: $0.26
2x8 wall with 6” mineral wool: $0.26
2x6 wall with 8.25” SIP: $0.35
Thank you.

Thanks to:
Martin Holladay, Green Building Advisor
Passive House Academy
Northeast Insulation
Albert Putnam, PE
Floris Keverling Buisman, 475 Building Supply