BUILDING INHERENT VALUE:
Implementing the Passive House Building Standard
Building Inherent Value: Implementing the Passive House Building Standard

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Michelle Apigian, AIA, LEED AP, AICP

September 21, 2018
OVERVIEW:

INSULATION
AIR TIGHTNESS
VENTILATION
METRICS
COST
INSULATION
Multifamily
THE DISTILLERY
South Boston, MA
• Mixed Use
• 28 Units
• 6” EPS ABOVE DECK

PROSOCO SEALANT SYSTEM AT ALL OPENINGS (TYP.)
TACK UP VB DURING CONSTRUCTION FOR LATER LAPPING OF VB ON SLAB
TAPE JOINT BETWEEN ZIP SHEATHING AND VAPOR BARRIER WITH ZIP TAPE OR ZIP SEALANT
SILL GASKET
1/2” ZIP SHEATHING, ALL JOINTS & INTERSECTIONS TAPED W/ ZIP TAPE OR ZIP SEALANT
10 MIL CONTINUOUS VAPOR BARRIER
WALLS R:34

- 3” MINERAL WOOL – CONTINUOUS
- 2X8 CAVITY FILLED WITH CELLULOSE
- CELLULOSE IN FIRST 3’ OF TRUSS
• TRUSS CAVITY FILLED WITH CELLULOSE
• 2” MIN CONT INSULATION ABOVE ROOF DECK
WINDOWS  U - 0.134

- KLEARWALL uPVC
SHADING

- PERMANENT 5’ DEEP OVERHANG FOR HIGH SUMMER SUN
- MOVEABLE SCREENS ON SOUTH SIDE
ENERGY
COMFORT
DIMINISHING RETURNS

SHADING: SOUTH ONLY (36”)
The WUFI results indicated below are based on a design with 36” shading devices installed on the Southern façade only.

Results:
18” SHADING:

SHADING: SOUTH, EAST & WEST (1'-6’)
The WUFI results indicated below are based on a design with 1'-6” shading devices installed on the South, East and West façades.

Results:
18” SHADING: South ONLY

Measured Changes: from 18” Shades
- HD – Up 0.07 k Btu/ft²/yr
- CD – Down 0.13 k Btu/ft²/yr
- HL – Up 0.02 Btu/hr/ft²
- CL – Down 0.05 Btu/hr/ft²
- Source – Down 8 kwh/p/yr
- Site: Down 0.03 k Btu/ft²/yr

Measured Changes: from 18” South Only
- HD – Up 0.12 k Btu/ft²/yr
- CD – Down 0.11 k Btu/ft²/yr
- HL – Up 0.02 Btu/hr/ft²
- CL – Down 0.06 Btu/hr/ft²
- Source – Down 3 kwh/p/yr
- Site: Down 0.02 k Btu/ft²/yr
Single family
7 PASSIVE HOUSE PROJECTS
3 HIGH PERFORMANCE HOMES
SLAB

10” EPS foam
15 mill vapor barrier
8” concrete
FOUNDATION
Walls

- Dense packed cellulose
- Wind and Weather Resistant Barrier with high perm rating
- Vapor control layer

Most structural connections inside vapor control layer

Load bearing 2x6 wall sits on concrete
Roofs
Shading

Calculate shade

Design windows for daylight and views.

September

Exterior shading
Windows
Windows

Figure 5: Sill temperature isotherm, (outer on left, centered on right)

Figure 6: Head temperature isotherms, (outer on left, centered on right)
# R-VALUE JUXTAPOSITION

<table>
<thead>
<tr>
<th></th>
<th>MULTI FAMILY</th>
<th>SINGLE FAMILY</th>
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<tbody>
<tr>
<td><strong>Ground</strong></td>
<td>R 23 (5” EPS foam)</td>
<td>R 45 (10” EPS foam)</td>
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<tr>
<td><strong>Walls</strong></td>
<td>R 27 (7.5” cellulose)</td>
<td>R 57 (15” cellulose)</td>
</tr>
<tr>
<td><strong>Roof</strong></td>
<td>R 60 (18-20”)</td>
<td>R 89-114 (24-36”)</td>
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AIR BARRIERS
Multifamily
SECTION EVOLUTION

2011

TERRA COTTA VENEER PANEL SYSTEM, W/ MANUFACTURER ATTACHMENT SYSTEM
3/4" EXTERIOR RATED, WATER RESISTANT SHEATHING TONGUE & GROOVE, JOINTS TAPE
2X3 FURRING @16" O.C.
5/8" TYPE X GWB JOINTS TAPE AND VAPOR PERMEABLE ADHESIVE TAPE
2X3 WD STUDS @ 24" O.C.
71/2" DENSE PAK, DRY BLOWN CELLULOSE
5/8" GWB PTD

2014

TERRA COTTA VENEER PANEL SYSTEM, W/ MANUFACTURER ATTACHMENT SYSTEM
2" DOW THERMAX RIGID INSULATION
DOW WEATHERMATE FLASHING
DRAINAGE CAVITY
DOW KNIGHT CI SYSTEM FRAMING
1/2" ZIP SHEATHING, ALL JOINTS & INTERSECTIONS TAPE WITH ZIP TAPE OR ZIP SEALANT
71/2" DENSE PAK CELLULOSE
2X3 WD STUDS @ 24" O.C.
5/8" GWB PTD.
TESTING

<table>
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<tr>
<th>.6 ACH$_{50}$</th>
<th>2611 CFM$_{50}$</th>
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<tr>
<td>DUCLOS METHOD RECOMMENDATIONS</td>
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<tr>
<td>Stage #1 Test (envelope no windows &amp; Doors)</td>
<td>652.75 CFM$_{50}$</td>
</tr>
<tr>
<td>Stage #2 Test (windows &amp; doors)</td>
<td>1552.75 CFM$_{50}$</td>
</tr>
<tr>
<td>Stage #3 Test (MEP penetrations)</td>
<td>2219.35 CFM$_{50}$</td>
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</tbody>
</table>

5/16/17: 2563 CFM50 (189.9 in² leakage area) - .56 ach50
TRANSITIONS
Single family
TJI wall
Double stud wall
Section (d)evolution

- PRIMARY AIR BARRIER 1/2" ZIP
- WEATHER AND WIND RESISTANT BARRIER (CONTINUOUS VAPOR OPEN MEMBRANE)
- PRIMARY AIR BARRIER 1/2" CDX WITH VAPOR OPEN WRB
- SMART VAPOR RETARDER MOSTLY CONTINUOUS
Penetrations
VENTILATION
Multifamily
ENERGY RECOVERY VENTILATOR

• ZEHNDER: COMFOAIR 250
HEATING & COOLING

• INDIVIDUAL MITSUBISHI HEAT PUMPS
HOT WATER

CENTRAL SYSTEM: Lochinvar condensing water heater, gas fired

• Now about 30% of the total energy budget – next Frontier
Single family
-Flexible duct work
-ERV. No drain.
-commission systems
HEAT PUMPS & WOODSTOVES
HOT WATER

Heat Pump Water Heater

Electric water heater
(Vaughn 3” polyurethane foam)

Solar Thermal Systems
METRICS
### Electric Bills - 455 East First St., Unit 300

<table>
<thead>
<tr>
<th>Date</th>
<th>$</th>
<th>Kwh</th>
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<tbody>
<tr>
<td>7/15/2017</td>
<td>$56.07</td>
<td>254</td>
</tr>
<tr>
<td>8/16/2017</td>
<td>$90.53</td>
<td>418</td>
</tr>
<tr>
<td>9/12/2017</td>
<td>$65.69</td>
<td>298</td>
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<tr>
<td>10/15/2017</td>
<td>$67.68</td>
<td>308</td>
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<tr>
<td>11/14/2017</td>
<td>$56.36</td>
<td>257</td>
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<tr>
<td>12/15/2017</td>
<td>$63.23</td>
<td>297</td>
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<tr>
<td>1/13/2017</td>
<td>$88.87</td>
<td>431</td>
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<td>2/16/2018</td>
<td>$195.58</td>
<td>916</td>
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<tr>
<td>3/17/2018</td>
<td>$104.49</td>
<td>437</td>
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Annual Electric Bill = Appr. $1050

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### Electricity Demand (without Heat Pump)

<table>
<thead>
<tr>
<th>Electricity Demand</th>
<th>PE Value</th>
<th>CO₂-Emissions Factor (CO₂-Equivalent)</th>
</tr>
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<tbody>
<tr>
<td>Covered Fraction of Space Heat Demand</td>
<td>0k</td>
<td>kBTU/lbCTU</td>
</tr>
<tr>
<td>Covered Fraction of DHW Demand</td>
<td>0k</td>
<td>kBTU/lbCTU</td>
</tr>
<tr>
<td>Direct Electric Heating</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>DHW Production, Direct Electric (without Wash&amp;Dish)</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Electric Postheating DHW Wash&amp;Dish</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Electricity Demand Household Appliances</td>
<td>3.6</td>
<td>9.6</td>
</tr>
<tr>
<td>Electricity Demand - Auxiliary Electricity</td>
<td>1.2</td>
<td>3.3</td>
</tr>
<tr>
<td>Total Electricity Demand (without Heat Pump)</td>
<td>4.8</td>
<td>12.9</td>
</tr>
</tbody>
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### Heat Pump

<table>
<thead>
<tr>
<th>Electricity Demand</th>
<th>PE Value</th>
<th>CO₂-Emissions Factor (CO₂-Equivalent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covered Fraction of Space Heat Demand</td>
<td>100%</td>
<td>kBTU/lbCTU</td>
</tr>
<tr>
<td>Covered Fraction of DHW Demand</td>
<td>0%</td>
<td>kBTU/lbCTU</td>
</tr>
<tr>
<td>Energy Carrier - Supplementary Heating</td>
<td></td>
<td></td>
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<tr>
<td>Annual Coefficient of Performance - Heat Pump</td>
<td>Separate Calculation</td>
<td>2.17</td>
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<tr>
<td>Total System Performance Ratio of Heat Generator</td>
<td>Separate Calculation</td>
<td>0.46</td>
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<tr>
<td>Electricity Demand Heat Pump (without DHW Wash&amp;Dish)</td>
<td>Q_Hp</td>
<td>1.1</td>
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<tr>
<td>Non-Electric Demand, DHW Wash&amp;Dish</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total Electricity Demand Heat Pump</td>
<td>1.1</td>
<td>2.8</td>
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CONCORD HIGHLANDS

Green "checks" show building meets PHIUS+ requirements.

- Heating demand: 4.09 kBtu/ft²yr
- Cooling demand: 2.76 kBtu/ft²yr
- Heating load: 2.89 Btu/hr ft²
- Cooling load: 3.05 Btu/hr ft²
- Source energy: 4,566 kWh/Person yr
- Site energy: 18.53 kBtu/ft²yr

Darkened vertical lines indicate thresholds for PHIUS compliance.
Hidden Lake passive house

Calculated energy usage:
3,822 kWh/yr
(12% off PHPP)
Newry passive house

Energy Usage 2017:
6658kWh
1/8 cord hardwood (880kWh)
Total 7538 kWh (16% off PHPP)
More $ - Envelope
Less $ - Mechanical Systems/ductwork
Always Saving - Low Operational Costs for life

COST
SheepskinBog Addition

Original proposal:
2x6 wall w/ 2x2 (7” wall)
Andersen 400 windows
No heat
$108,000 - $193/SF (INCL SITEWORK)

Updated proposal:
12” double stud wall
Triple pane windows
electric heaters
Airtight details
$115,000 ($206 SF)
(6.5% increase)