High-Performance Wood Structures: An Example of Increased Efficiency in Multi-Family Construction

Presented by: Michelle Apigian  AIA, LEED AP, AICP, CPHC

Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.
For this case study presentation, The Distillery's 28-unit Phase 1 building—a six-story, wood-frame over podium Passive House project under construction in South Boston—will be used to highlight design and construction principles that can radically reduce energy consumption. Applicable to nearly all building types, the discussion will highlight how this low-load building approach can be applied both to new construction as well as retrofit. Emphasis will be placed on the deepening knowledge and evolving strategies that helped produce a highly-efficient, cost-effective building that will be affordable to operate, comfortable and healthy to be in and highly resilient. Details, testing data and lessons learned will be shared, with a special focus on the thermal envelope, continuous air barrier implementation and efficient ventilation systems. Wood’s use as structural material will be discussed, as will its role in providing a cost-effective building approach that allowed this project to come to fruition and afforded further sustainability features to be implemented.
Learning Objectives


2. Highlight the construction details used to provide significant energy reduction.

3. Discuss the role that wood framing played in reducing construction costs on New England’s first multi-family Passive House project.

4. Explore lessons learned from the design and construction process of The Distillery project.

Learning Level: Level 300 - Application/Implementation
Agenda/Outline

• What is Passive House
  Goals
  History
  Examples

• How
  Super-Insulated
  Air Tight
  Continuously Ventilated

• Case Study: Distillery
  Evolution
  Details
PASSIVE HOUSE:
THE WORLD’S MOST ENERGY EFFICIENT PERFORMANCE STANDARD

Goal: lower consumption
   Radically reduce energy demand
Requirements: measurable criteria
   Meet a specifically low energy budget
WHAT IT IS NOT

HOLISTIC SUSTAINABLE DESIGN:
LEED, Living Building Challenge

- Site: 18%
- Materials: 13%
- Water: 12%
- Location: 8%
- Energy: 32%
- IEQ: 17%
WHAT IT IS  A SIGNIFICANT PIECE OF THE PUZZLE

49%

Energy
- Insulation
- Air Infiltration
- Windows
- Heating/Cooling
- Hot Water
- Lighting
- Appliances

IEQ
- Ventilation
- Moisture Control
- Heating/Cooling Distribution
- Air Filtering
WHAT IT IS NOT

NET ZERO: Balancing load with Renewable Energy

Energy Consumption
- Heating
- Cooling
- Ventilation
- Hot Water
- Lighting
- Appliances
- Plug Loads

Energy Generation
- Photovoltaic
- Wind
- Solar Thermal
- Geothermal
WHAT IT IS

FOUNDATION FOR NET ZERO:

#1 Minimize Load with Passive House

#2 Produce with Renewable Energy
WHAT IT IS

FOUNDATION FOR NET POSITIVE:

CONSUMPTION

GENERATION
WHAT IT IS  RADICALLY LOW ENERGY

[Graph showing energy levels for different home types, with Passive House at the lowest energy level.]
WHAT IT IS  THE HIGHEST ENERGY STANDARD
HISTORY

70’s Inception in North America
Saskatchewan Conservation House
85% reduction in energy use

Critical Concepts – New terminology:
• Superinsulation
• Air-tight construction
• Blower Door Test
• Thermal Bridging
• Low E glazing
• Triple Glazed Windows
• Heat Recovery Ventilators
Passive House Institute Founded in Germany in 1996

- Over 30,000 estimated worldwide
HISTORY

2000’S Back to the US

Passive House Institute US (PHIUS) Founded in 2006
EXAMPLES International School/University
EXAMPLES  International Retrofit
EXAMPLES US Multifamily
EXAMPLES

US Commercial/Educational
<table>
<thead>
<tr>
<th><strong>THE STANDARD</strong></th>
<th>Measurable Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Passive House Institute" /></td>
<td><img src="image2.png" alt="Passive House Institute US" /></td>
</tr>
<tr>
<td>4.75 kBTU/ftsq/yr</td>
<td>Annual Space Heating Energy Demand</td>
</tr>
<tr>
<td>4.75 kBTU/ftsq/yr</td>
<td>Annual Space Cooling Energy Demand</td>
</tr>
<tr>
<td>4.4 BTU/ftsq/hr</td>
<td>Peak Heat Load</td>
</tr>
<tr>
<td>4.2 BTU/ftsq/hr</td>
<td>Peak Cooling Load</td>
</tr>
<tr>
<td>.6 ACH</td>
<td>Airtightness</td>
</tr>
<tr>
<td>38 kBTU/ftsq/yr</td>
<td>Primary Energy Demand Commercial</td>
</tr>
<tr>
<td>38 kBTU/ftsq/yr</td>
<td>Primary Energy Demand Residential</td>
</tr>
<tr>
<td>5.3 kBTU/ftsq/yr</td>
<td></td>
</tr>
<tr>
<td>2.9 kBTU/ftsq/yr</td>
<td></td>
</tr>
<tr>
<td>4.05 cfm/GSF @ 50 pa</td>
<td></td>
</tr>
<tr>
<td>38 kBTU/ftsq/yr</td>
<td></td>
</tr>
<tr>
<td>6200 kWh/person</td>
<td></td>
</tr>
</tbody>
</table>

*climate specific: Boston*
THE STANDARD  Measurable Criteria

Annual Space Heating/Cooling Demand = Miles Per Gallon for the Building
Airtightness = Durability
Primary Energy Demand = Carbon Footprint
Carbon Footprint  Source of Energy/Conversion Losses

**ELECTRICITY**
- 100 MMBTU source energy
- 88 Extraction, processing and transportation losses
- 29 Conversion losses
- 27 Distribution losses
- Delivered to customer

**NATURAL GAS**
- 100 MMBTU source energy
- 92 Extraction, processing and transportation losses
- 90 Distribution losses
- Delivered to customer

Thanks to lower conversion losses, three times more energy reaches the customer with natural gas than with electricity.
THE STANDARD  How does this Compare?

4.75 kBTU/ftsq/yr  Annual Space Heating Energy Demand  5.3 kBTU/ftsq/yr
4.75 kBTU/ftsq/yr  Annual Space Cooling Energy Demand  2.9 kBTU/ftsq/yr

*climate specific: Boston

Office: 33 kBTU/ftsq/yr
K-12: 29 kBTU/ftsq/yr
Res: 24 kBTU/ftsq/yr

**2-3 TIMES**
THE STANDARD  How does this Compare?

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Annual Space Heating Energy Demand</th>
<th>Annual Space Cooling Energy Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>33 kBTU/ft²/yr</td>
<td></td>
</tr>
<tr>
<td>K-12</td>
<td>29 kBTU/ft²/yr</td>
<td></td>
</tr>
<tr>
<td>Res</td>
<td>24 kBTU/ft²/yr</td>
<td></td>
</tr>
</tbody>
</table>

**Mass Maritime LEED Platinum**

- Annual Space Heating Energy Demand: 10.2 kBTU/ft²/yr

**2 TIMES**
THE STANDARD

How does this Compare?

Airtightness

.6 ACH

.05 cfm/GSF @ 50 pa
.08 cfm/GSF @ 75 pa

2009 IECC <7 ACH50
2012 IECC <.4 CFM/ftsq
Roughly equiv to <3 ACH50

**3 TIMES**
THE STANDARD
How does this Compare?

Highland Terrace
LEED Platinum
2.36 ACH50

**4 TIMES**
THE STANDARD  How does this Compare?

Highland Terrace 50-54
**THE STANDARD**  How does this Compare?

<table>
<thead>
<tr>
<th></th>
<th>Primary Energy Demand Commercial</th>
<th>Primary Energy Demand Residential</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>148 kBTU/ftsq/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-12</td>
<td>141 kBTU/ftsq/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Res.</td>
<td>68 kBTU/ftsq/yr</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**2-3 TIMES**
THE STANDARD  How does this Compare?

Figure 2: Source Energy Use Intensity (EUI) Comparison

- NYC Office (median): 207 KBTU/SF/year
- NYC Residential (median): 132 KBTU/SF/year
- NYS-Owned Buildings (median): 183 KBTU/SF/year
- 2009 IECC: 84 KBTU/SF/year
- 2012 IECC: 57 KBTU/SF/year
- Passive House (PHI): 38 KBTU/SF/year

NYC’s ‘60x50’ target is 207 KBTU/SF/year, which is 60% of the median value for NYC Office buildings.
THE STANDARD  How does this Compare?

Energy Footprint

Code

Passive House

- 90% less heating energy
- 66% less total energy
HOW DO YOU GET THERE?
HOW DO YOU GET THERE?  What drives Energy Demand?

Heating and Cooling makes up nearly 50% energy Demand
HOW DO YOU GET THERE? Drive Down Loads

- Thermal Control
- Air Tightness
- Mechanical Systems
- Lighting/Appliances/Plug Loads
HOW DO YOU GET THERE? Drive Down Loads

Thermal Control

- Geometry (Lower surface to Volume Ratio)
- Orientation (Optimize Solar Heat Gain/Shading)
- R-Value (Slab, Roof, Walls & Windows)
- Minimize Thermal Bridging

= HUMAN COMFORT
HOW DO YOU GET THERE? Drive Down Loads

Thermal Control

- Geometry (Lower surface to Volume Ratio)
- Orientation (Optimize Solar Heat Gain/Shading)
- R-Value (Slab, Roof, Walls & Windows)
- Minimize Thermal Bridging

= HUMAN COMFORT
HOW DO YOU GET THERE? Drive Down Loads

Thermal Control

Brooklyn Hts Passive House
Taken on a Freezing night, Winter 2012
Air Tightness

- Continuous Air Tight Layer
- Minimize and Seal all Penetrations
- Detail Transitions
- Consider Construction sequence

= DURABILITY
Infiltration Leads to
• Heat Loss
• Moisture Migration
HOW DO YOU GET THERE? Drive Down Loads

Air Tightness

Determine the boundary of the PH envelope
HOW DO YOU GET THERE? Drive Down Loads

Air Tightness

The Devil is in the Details
HOW DO YOU GET THERE?  Drive Down Loads

Air Tightness  Test For Continuity
HOW DO YOU GET THERE?  Drive Down Loads

Thermal Control

Air Tightness

SUPERINSULATED

+  

AIR TIGHT =
HOW DO YOU GET THERE? Drive Down Loads

Mechanical Systems

- Balanced Ventilation (ERV/HRV)
- Heating/Cooling (Point source vs Distributed)
- Hot Water
How do you get there? Drive down loads

Mechanical Systems

Benefits of the HRV/ERV

• Controlled Ventilation
• Transfers Heat
  • Reduces Heating need in winter
  • Reduces Cooling need in summer
• Reduces Condensation/Mold
HOW DO YOU GET THERE?  Drive Down Loads

Mechanical Systems

Infiltration vs. Ventilation
HOW DO YOU GET THERE? Drive Down Loads

Lighting/Appliances/Plug Loads

- Efficiency
- Life Cycle
- Smart Controls
- Renewables – Plan for them, but don’t count on them
BENEFITS

• Reduced Carbon Footprint: Radically low energy
• Comfortable: No drafts or temperature swings
• Healthy: High Quality, Continuously filtered Air
• Resilient: Extreme Thermal Stability
• Affordable to Operate: Low Utility Bills for life
Passive House in Practice

- New Construction
- Retrofit

1. Thermal Control
2. Air Tightness
3. Mechanical Systems
4. Lighting/Appliances/Plug Loads
Passive House in Practice  New Construction
Passive House in Practice  New Construction

The Distillery
South Boston, MA
• Mixed Use
• 28 Units
Passive House in Practice  New Construction

The Distillery
South Boston, MA
• Mixed Use
• 28 Units
Passive House in Practice

New Construction

4 Stories Wood over Podium
- Cost Effective
- Efficient – Panelized
- Flexible
Passive House in Practice  New Construction

TRIPLE GLAZED WINDOWS
Offer superior energy efficiency, comfort, and noise reduction. Thermal performance is maximized through higher R-values, reduced thermal bridging and air tightness.

ENERGY STAR APPLIANCES
Reduce long-term operating costs and overall load through high-efficiency refrigerators and dishwashers.

HIGH EFFICIENCY LIGHTING
Combines LED + Energy Star. Fuses with occupancy sensors to reduce lighting load.

WATER CONSERVING FIXTURES
Including low-flow faucets, showerheads, and toilets to conserve water, which in turn consumes energy by reducing the water delivery, treatment and heating demand.

CONDENSING DRYERS
Help maintain the air tight building envelope by providing energy efficiency without exhausting substantial quantities of indoor air.

HIGH SUMMER SUN
Blocked from entering.

LOW SUMMER SUN
Enters to warm space.

COOL ROOF
Reduces the heat island effect. A high reflectivity coating provides reflectivity to reduce the heat island effect. Planted containers absorb heat and capture rainwater, reducing storm water runoff.

SLIDING SUNSCREEN LOUVERS
Provide flexible sun control to limit heat gain during the summer while allowing passive solar gain in the winter.

PASSIVE HOUSE ENVELOPE
Enhances comfort and reduces energy use by 80-90% integrating a high performance shell with air tightness and robust insulation to maintain a consistent temperature.

Passive House in Practice  New Construction
Passive House in Practice New Construction

Thermal Control

SLAB: (R-23)
6” EPS above deck
Passive House in Practice  New Construction

**Thermal Control**

WALL: (R-54)
3” cont. mineral wool
2X8 wood studs filled w/ cellulose
Passive House in Practice  New Construction

Thermal Control

ROOF: (R-64)
Truss cavity filled with batt insulation
Passive House in Practice  New Construction

Thermal Control

WINDOWS: U-0.134
Passive House in Practice  New Construction

Thermal Control

Solar Gain Optimization

Diagram showing thermal control measures, including cool roof and sliding sunscreen louvers.
Passive House in Practice

New Construction

Air Tightness

SLAB
Passive House in Practice  New Construction

Air Tightness
Passive House in Practice  New Construction

Air Tightness
Passive House in Practice  New Construction

Air Tightness

TRANSITIONS
Passive House in Practice  New Construction

Air Tightness

TRANSITIONS
Passive House in Practice  New Construction

Air Tightness  TRANSITIONS
Passive House in Practice  New Construction

Air Tightness
Passive House in Practice  New Construction

Air Tightness
Passive House in Practice  
New Construction

**SYSTEMS**

Ventilation
Energy Recovery Ventilator - Zehnder
Passive House in Practice  New Construction

SYSTEMS

Heating/Cooling
Heat Pumps - Mitsubishi
BENEFITS

- Reduced Carbon Footprint: Radically low energy
- Comfortable: No drafts or temperature swings
- Healthy: High Quality, Continuously filtered Air
- Resilient: Extreme Thermal Stability
- Affordable to Operate: Low Utility Bills for life
BUILDING INHERENT VALUE

Re-Prioritize Costs

More $ - Envelope
Less $ - Mechanical Systems/ductwork
Always Saving - Low Operational Costs for the life of the Building
This concludes The American Institute of Architects Continuing Education Systems Course.

Michelle Apigian
ICON Architecture, inc.
mapigian@iconarch.com