Achieving Passive House for Multi-Family Residential Projects

**Orchards at Orenco Case Study**

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PRESENTED TO: BESF

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*inspire interpret integrate*
Presentation Outline

- Introduction to Passive House
- Case Study: Orchards at Orenco Housing
- Differences between PHPP and eQUEST
- Lessons Learned
Introduction to Passive House
Introduction to Passive House

Beginnings of Passivhaus

The Passivhaus standard

- Developed in Germany
- Founded in the early 1990s
- Professors Bo Adamson (Sweden) and Wolfgang Feist (Germany)
- The first Passivhaus Standard dwellings were in Darmstadt in 1991

Passive House Institute US (PHIUS)

- Founded in 2007
- Goal: bring the passive house strategy back to the US
“Passivhaus or 'Passive House' is the fastest growing energy performance standard in the world with 30,000 buildings realized to date” – Passivhaus.org/uk
Introduction to Passive House

The Principles

Passive House is a performance based certification system – not a prescriptive path.

Based on:

- Superinsulation
- Airtightness
- Heat Recovery
- Ventilation
- Passive Solar Gain
Introduction to Passive House

Performance Criteria

Building Energy Demand:

- Heating = \textbf{4.75} \text{ BTU/hr-sf}

- Primary Energy Demand = \textbf{38} \text{ kBTU/sf-year}

- Airtightness = \textbf{0.6} \text{ ACH}_{50}
Introduction to Passive House

THE ANATOMY OF A PASSIVE HOUSE

From the pages of Dwell to the New York Times, to various other architectural journals, chances are you’ve heard about Passive House. Often touted as “boring noses you can deal with clay noses” Passive House buildings boast energy loads low enough to make even the most environmentally conscious homeowner drool. While the principles of the standard were born in North America in the 1990s, it was a German physicist, Dr. Wolfgang Feist, who developed the standard and built the first prototype in 1996.

Since then, the standard has taken off in many European countries and began to make inroads in the United States. Today, Passive House US has 97 projects registered, mostly single-family homes, but also small schools, community centers, churches, and commercial buildings.

REACH Community Development is exploring the benefits and challenges of applying Passive House building strategies to its development in Milwaukie, Oregon. Our Oregon station is divided. The fully realized Orchards of Oreonc development will provide 150 units of workforce housing built in 152. Phase One of the project, REACH will build a 57-unit Passive House-certified apartment building, thus demonstrating the applicability of Passive House concepts to affordable multifamily housing at a scale that is currently unprecedented in the United States. Here are some of the components that make up a Passive House:

Continuous Air Barrier
The Passive House standard has rigorous requirements for building air tightness. In order to allow this, Passive House buildings have continuous air barriers that all 100% of the air, due to infiltration during the design and construction of building, the design team and construction crew must be prudent in maintaining the continuity of the air barrier.

Insulated Stab
The ground floor slab uses a high-density foam insulation. The insulation contains sodium in the structural insulation and is part of the weather barrier to meet the air barrier.

Walls
The wall assembly is a critical piece of meeting the Passive House standard. The walls will usually have a "B" value rating with full insulation, the walls of Orchards will have 60% "A" rating combined with blown-in fiberglass insulation as well as a layer of exterior grade insulation.

Heat Recovery Ventilator
The mechanical ventilation system and heat exchanger are critical to the building's energy efficiency and indoor air quality. The heat exchanger is located in the kitchen and bathrooms with heat recovering air supplied to the user’s rooms, making it a standard of comfort.

Windows
Windows were the area of focus with a passive house ventilation system for improved performance. This is important to find windows that perform well. The windows at Oreonc are triple-glazed and are double-stacked, allowing the windows to move slightly through the double-hung or slider styles that are more common in the United States.

Solar Design
Solar design with regards to solar orientation is essential in being a Passive House building. Buildings must be designed in a way that allows the solar to hit the building in the summer and act as an integral part of the building's solar design.

It's All in the Details
In a super-insulated, single-family building, the design team and construction team work together to ensure every detail of the building is properly designed and constructed. Structural connections at becoming and other exterior elements, for instance, are often challenging areas that require careful attention and detail. For example, the roof in this image, courtesy of Green Hammer.

BENEFITS TO TENANTS
- Up to 90% reduction in energy bills
- Superior indoor air quality
- Balanced thermal comfort throughout the apartment
- Reduced outdoor noise inside apartments
- Innovative, forward-thinking living

OTHER SUSTAINABLE FEATURES
- Ample indoor bike parking
- Energy Star appliances
- Low flow plumbing fixtures
Introduction to Passive House

Compliance Tools & Verification

PHPP (Passive House Planning Package)

- Excel-format Spreadsheet
- Steady-State Heat Balance Calculations
- Monthly Climate Data Averages
- Simplified HVAC Efficiencies / Capacities
- Standard Schedules for Occupancy and Loads
- Validated Results in European Installations
Case Study
Orchards at Orenco
Orchards at Orenco

Why Passive House?

- Trends in Europe that show Passive House complexes offer better acoustics and air quality, see less turnover and lower maintenance costs
- Affordable living – not just affordable housing
- Reduced utility cost for building and tenants
- Assessing the Passive House strategy cost vs. benefits
- Allow development of the Passive House standard
Orchards at Orenco

Where is this project?
Orchards at Orenco

Project Statistics

- Three stories
- 57,750 square feet
- 7,500,000 Budget - $130/sf
- 57 apartments
- < $25,000 annual income
Orchards at Orenco
Rendering
Orchards at Orenco

Typical Floor Plan
Orchards at Orenco
Passive House Strategies

The Anatomy of a Passive House

From the pages of Dwell to the New York Times, Passive House has been called the 'hardest building to build,' a design that significantly reduces energy consumption and provides comfort in all climates. The building design achieves this by focusing on a few key components:

- The roof at Orchards at Orenco will have 12" of insulation, which is the thickest required by code. The white color of the roof reflects solar radiation, lowering temperatures in the building in the summer months.

- Windows are one of the weak points in a building's energy performance, so it's important that they be well insulated. The Orchards at Orenco Passive House will use a triple-glazed, argon-filled window frame, which ensures excellent thermal insulation. These windows will have European-style tilt and turn operation, allowing them to close tighter than most double-hung or slider types.

- Heat recovery ventilators are critical to the building's energy efficiency and indoor air quality. The heat exchanger recovers heat from the fresh air and exchanges it with the room's return air to make the room more comfortable.

- The sun deck is an integral part of the building's passive house design. It provides additional insulation and helps to reduce glare.

- Insulated slab: The ground floor slab is made of "crammed" concrete, which provides excellent thermal mass and helps to stabilize the indoor temperature.

- Water: The water system is a critical component of the Passive House standard. The water heater is designed to provide hot water for all the units, and the system is designed to ensure that all the water is used efficiently.

Benefits to Tenants:
- Up to 95% reduction in energy bills
- Superior indoor air quality
- Balanced thermal comfort throughout the apartment
- Natural outdoor view from the apartments
- Innovative, forward-thinking living

Other Sustainable Features:
- Ample indoor bike parking
- ENERGY STAR appliances
- Low-flow plumbing fixtures
Orchards at Orenco
Envelope Performance

→ R-39 Walls
→ R-81 Roof
→ R-18 Floors
→ R-6.4 Windows
→ 17% Glazing
Orchards at Orenco

HVAC Systems

- Electric Cove Heat
- Heat Recovery Units
- Heat Pump Heating / Cooling
Orchards at Orenco
Modeling Methodology

Modeling for Energy Trust Incentives:

- eQUEST model – v3.64
- Baseline HVAC System: PTHP (all electric)
- Bundled Envelope Measures & HVAC System Efficiency
- Infiltration (0.82 ACH\(_{50}\) vs. 0.6 ACH\(_{50}\))
- Low-flow Plumbing Fixtures
Orchards at Orenco

Typical Energy End Uses - Residential

- Lights: 15.0%
- Domestic Hot Water: 27.0%
- Pumps / Fans: 5.0%
- Misc Equipment: 22.0%
- Space Heating: 28.0%
- Space Cooling: 3.0%

Typical Residential Building: Baseline Energy Use
EUI = 72 kBTU/sf/year
Orchards at Orenco

Predicted Energy End Use

- Savings: 70.0%
- Lights: 6.0%
- Misc Equipment: 10.0%
- Space Heating: 3.0%
- Space Cooling: 1.0%
- Domestic Hot Water: 5.0%
- Pumps / Fans: 5.0%

Passive House Building

EUI = 20 - 24 kBTU/sf/year
Orchards at Orenco
Energy Use Comparison

<table>
<thead>
<tr>
<th>Category</th>
<th>Energy Use Index (EUI)</th>
<th>2010 Oregon Energy Code</th>
<th>Architecture 2030 Goal</th>
<th>Phase I Design Model</th>
<th>Solar Budget (PV on Roof)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic HW</td>
<td>16.3</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>16.3</td>
</tr>
<tr>
<td>Pumps/Fans</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Rejection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Cooling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Heating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misc. Equip.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lights</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average Building: 72
2010 Oregon Energy Code: 52
Architecture 2030 Goal: 22
Phase I Design Model: 22
Solar Budget (PV on Roof): 16.3
Orchards at Orenco
Passive House Energy Analysis

Orchards Phase I Energy Loads

Energy Use Index (EUI)
BTU/sf/yr

25.0
22.4
21
20
15.0
11.7
10.0
9.1
5.0
3.6
2.1
1.4
0.1
0.0
0.5
0.0
0.0

Anticipated Loads
(Expected Behavior)
Passivhaus Loads
(Conservative Behavior)

- Space Heating
- Space Cooling
- Ventilation
- Water Heating
- Lighting
- Appliance & Equip
- Plug Loads

4/25/14
Orchards at Orenco
Passive House Energy Analysis

The Orchards at Orenco - Phase I
Passive House Energy Analysis Summary
Permit Set / PHIUS Pre-certification Submission
5/8/2014

RESULTS:

<table>
<thead>
<tr>
<th>Space Heating Peak Load</th>
<th>2.46 kBtu/hr</th>
<th>Total Source Energy</th>
<th>36.0 kBtu/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive House Standard</td>
<td>3.17 kBtu/hr</td>
<td>Passive House Standard</td>
<td>38.0 kBtu/yr</td>
</tr>
<tr>
<td>Percent of Limit</td>
<td>78%</td>
<td>Percent of Limit</td>
<td>93%</td>
</tr>
</tbody>
</table>

ASSUMPTIONS:

**Envelope**

<table>
<thead>
<tr>
<th>Wells</th>
<th>2x1' x 1.5' external walls</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>Boarded T/I PVC insulated</td>
<td>6.4 R-value</td>
</tr>
<tr>
<td>Glazing</td>
<td>LITE 60/80 A1, SHGC=0.55</td>
<td>9.5</td>
</tr>
<tr>
<td>Glazing</td>
<td>LITE 50/70 A1, SHGC=0.25</td>
<td>7.5</td>
</tr>
<tr>
<td>Residential Doors</td>
<td>Boarded T/I Door PVC insulated</td>
<td>4.3 R-value</td>
</tr>
<tr>
<td>Glazing</td>
<td>ADA 4' (assured 4.0SF Living)</td>
<td></td>
</tr>
<tr>
<td>Lobby Doors (4)</td>
<td>Keypad/Pull Door</td>
<td>6.7 R-value</td>
</tr>
<tr>
<td>Glazing</td>
<td>Secto Sliding IGU</td>
<td>11.4</td>
</tr>
<tr>
<td>Corridor Doors (3)</td>
<td>Secto Sliding IGU</td>
<td>3.1 R-value</td>
</tr>
<tr>
<td>Glazing</td>
<td>Corrugated glass (6’x8’)</td>
<td>0.7</td>
</tr>
<tr>
<td>Roof</td>
<td>24 Plumbing areas, 18 roof areas, 3 wall areas, all remaining installed through roof</td>
<td></td>
</tr>
<tr>
<td>Skylight</td>
<td>10” x 10” floor area above carport</td>
<td></td>
</tr>
<tr>
<td>Thermal Mass</td>
<td>Standard drywall</td>
<td></td>
</tr>
<tr>
<td>Thermal Bridging</td>
<td>Interim split blocking at drawbars</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heating System</th>
<th>0% Heat Pump, COP = 4.3 (average all systems)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appliances</td>
<td>Refrigerator/freezer: 37.5 kBtu/yr ES rating or better</td>
</tr>
<tr>
<td></td>
<td>Dishwashers: 37.5 kBtu/yr ES rating or better</td>
</tr>
<tr>
<td></td>
<td>Clothingwashers: 36.5 kW/yr ES rating or better</td>
</tr>
<tr>
<td></td>
<td>Refrigerator: electric</td>
</tr>
<tr>
<td></td>
<td>Range/oven: electric</td>
</tr>
<tr>
<td></td>
<td>Blower: 4000 kW/yr</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cooling System</th>
<th>Central Heat: heat+Tone High Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHW System</td>
<td>Heat exchanger efficiency = 95% (normal)</td>
</tr>
<tr>
<td></td>
<td>ETo: TMY 1999/MACS</td>
</tr>
<tr>
<td></td>
<td>Hot Water Line Isolation: max. 3’4” continuous</td>
</tr>
<tr>
<td></td>
<td>Low-flow fixtures throughout</td>
</tr>
</tbody>
</table>

NOTES:

1. Floor area and window area inputs based on PHI CO drawings (1551.b) with following clarifications:
   - All door is 2’ x 8’ nominal

2. Envelope Configuration: Laundry room, elevator enclosure, and end wall storage areas are outside the Passivhaus envelope. No active heating is supplied to these spaces (units from 300W frost-prevention heater in the maintenance room).
   - Specified wall insulation, tightness layer, doors, and windows segregate these spaces from the building proper. Access to mechanical pits is assumed to be from interior ceiling hatch (within the thermal envelope). All roof hatch occurs at eave level, outside the thermal envelope.

3. Lighting, equipment, plug loads and hot water usage are based upon Passivhaus default values (used as the basis for PHI certification). Actual loads are anticipated to be higher which may present periods of occupant discomfort due to overheating. Strategies to encourage occupant behavior toward energy efficiency are highly encouraged (i.e. lobby dashboard reporting each units' red/yellow/green status toward their energy usage target with more info on how to decrease energy usage such as reducing internal loads and night-fall ventilation).

4. This analysis includes a thermal bridge analysis of a typical solid blocking detail assumed at exterior structural connections. Intermittent blocking (not continuous) assumed at disks, awnings, unconditioned wall junctions, etc. Also included is a thermal bridge at roof overhangs, assuming they are installed as they pass through the roof overhang. Vapor impermeable barrier should surround this insulation to avoid condensation.
Orchards at Orenco
Where do we stand?

<table>
<thead>
<tr>
<th>Building Energy Demand</th>
<th>Target</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating (BTU/hr-sf)</td>
<td>3.17</td>
<td>2.46</td>
</tr>
<tr>
<td>Primary Energy Demand (kBTU/sf-year)</td>
<td>38</td>
<td>36</td>
</tr>
<tr>
<td>Airtightness (ACH50)</td>
<td>0.6</td>
<td>TBD</td>
</tr>
</tbody>
</table>
Comparing Design Tools

PHPP & eQUEST
# Comparing Design Tools

## PHPP & eQUEST

<table>
<thead>
<tr>
<th>Category</th>
<th>eQUEST</th>
<th>PHPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>None</td>
<td>$$</td>
</tr>
<tr>
<td>Training</td>
<td>On line Forums &amp; User Groups</td>
<td>Training through PHIUS &amp; User Groups</td>
</tr>
<tr>
<td>Model Format</td>
<td>DOE-2 engine</td>
<td>Excel</td>
</tr>
<tr>
<td>Initial Set Up</td>
<td>Wizard</td>
<td>Drawing Take-offs</td>
</tr>
<tr>
<td>HVAC Systems</td>
<td>Complex / Modifiable</td>
<td>Simple – efficiency based</td>
</tr>
<tr>
<td>Parametric Analysis</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Accepted by ETO</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Hourly Simulation</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Comparing Design Tools
PHPP & eQUEST

- Who can use it?
- When each is most effective?
- What are the uses for each program?
- What do they not do?
Project Lessons Learned
Lessons Learned

Topics

- Importance of Passive House Boundary for Commercial Buildings
- Optimizing Ventilation
- Kitchen Hood Exhaust
- Balance Point & Overheating
- Material & Equipment Availability
- Passive House US & Passivhaus Differences
Project Lessons Learned
Importance of Passive House Boundary

Infiltration Testing:

- Stairs - Stack Effect
- Elevators & lobby – stack effect
- Laundry – exhaust & make-up air
- Garbage Rooms – exhaust & make-up air
Project Lessons Learned

Optimizing Ventilation

- Tightly sealed building requires complete ventilation system
- Heat recovery is necessary
- Higher airflow = more energy
- Balance IAQ with energy efficiency
- Providing sufficient exhaust
Project Lessons Learned

Kitchen Hood Exhaust

- Ducting kitchen hood exhaust duct outdoors is problematic
- Re-circulating hoods meet Passive House goals but are an IAQ concern
- Review kitchen hood ducting requirements with AHJ
Project Lessons Learned

Balance Point & Overheating

I DON'T WANNA SAY IT'S HOT IN MY ROOM...

BUT TWO HOBBITS JUST CAME AROUND AND THREW A RING IN IT
Project Lessons Learned
Balance Point & Overheating

Solutions:

- Reduce Internal Loads
- Shading
- Operable windows
- Cooling of ventilation air to take the edge off
PHI ratings for HRV’s differ from ratings by AHRI.

PHIUS will now accept AHRI rated efficiencies.
Project Lessons Learned
Material & Equipment Availability / Selection
Project Lessons Learned

PH vs. Passivhaus Institut
Summary

Next Steps

→ Complete Construction
→ Verify Performance
→ Final Passive House Verification
Summary
Conclusions

- We need more examples of Passive House being applied to different application.
- Push the “envelope”.
- The Passive House process is becoming more refined to reflect US conditions.
- More widespread adoption will reduce costs – just like what we saw happen with LEED.
Questions?