STELLAR APARTMENTS
Eugene, Oregon
Multi-Family Passive House
TWO YEAR ENERGY MONITORING STUDY

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Bergsund DeLaney Architecture and Planning, P.C.

Passive House Northwest
Building a Carbon Zero Northwest
March 11, 2016
Passive House and Earth Advantage

6 Units in each Building
(2) 2-bdrm Flats
(4) 2-bdrm Townhouses
Design Challenges: Thermal Bridging

PASSIVE HOUSE

EARTH ADVANTAGE

Win Swafford, CPHC
Passive House & Earth Advantage Construction
Passive House Construction
Targeted Performance

**Passive House**

70% Better than code for overall energy performance

**Earth Advantage**

10% Better than code for overall energy performance
Energy Use: Monitored Circuits

- HEAT
- ERV (Passive House Only)
- WATER HEATER
- RANGE
- KITCHEN OUTLETS
- KITCHEN FRIDGE
- WASHER (Earth Advantage Only)
- DRYER
- OTHER PLUG LOADS

Passive House

- 38% savings
- 15%
- 13%
- 20%
- 0%
- 1%
- 4%
- 2%
- 4%

Earth Advantage

- 32%
- 20%
- 1%
- 5%
- 4%
- 8%
- 4%
- 26%
- 0%

HEAT
ERV (Passive House Only)
WATER HEATER
RANGE
KITCHEN OUTLETS
KITCHEN FRIDGE
WASHER (Earth Advantage Only)
DRYER (Earth Advantage Only)
OTHER PLUG LOADS
Energy Use: Predicted versus Monitored

MONTH AND YEAR
- Outdoor Temperature
- Passive House Heat Use (kWh)
- Earth Advantage Heat Use (kWh)

*INDICATES MONTHS THERMOSTAT WAS BROKEN IN A PASSIVE HOUSE UNIT
Heating: December 2013 PH and EA heating use + temps
Envelope: check on thermal bridging?

Passive House

Earth Advantage

Outdoor Temperature: 11 F
Passive House – Is it worth it?

• Construction costs 29% higher

<table>
<thead>
<tr>
<th>Passive House</th>
<th>Earth Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>$145 per sq ft</td>
<td>$112 per sq ft</td>
</tr>
<tr>
<td>$157,000 per unit</td>
<td>$121,000 per unit</td>
</tr>
</tbody>
</table>

• Design costs 11% higher

• Payback ~ 24 years
Passive House – Would the client do it again?

- Probably not
  - Certification is complicated and very difficult
  - Cost prohibitive
- Passive House informed
  - Air sealing/thermal bridging
  - Insulation
  - Better windows
### Insulation

<table>
<thead>
<tr>
<th>Attic (Flat Ceiling)</th>
<th>Glass Fiber Loose Fill - 27&quot;</th>
<th>R-84</th>
<th>Glass Fiber Loose Fill - 16&quot;</th>
<th>R-49</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>Glass Fiber Loose Fill - 5 1/2&quot;</td>
<td>R-23</td>
<td>Glass Fiber Loose Fill - 5 1/2&quot;</td>
<td>R-23</td>
</tr>
<tr>
<td>Ext Rigid Polyiso - 4&quot;</td>
<td>R-27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rims &amp; Headers</td>
<td>EPS Rigid Insulation - 2 1/2&quot;</td>
<td>R-11</td>
<td>EPS - 2 1/2&quot;</td>
<td>R-11</td>
</tr>
<tr>
<td>Raised Floor</td>
<td>Glass Fiber Loose Fill - 11 7/8&quot;</td>
<td>R-50</td>
<td>Batt Insulation - 11 7/8&quot;</td>
<td>R-38</td>
</tr>
<tr>
<td>Exterior Stem Wall</td>
<td>EPS Rigid Insulation - 4&quot;</td>
<td>R-18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior Stem Wall</td>
<td>EPS Rigid Insulation - 3&quot;</td>
<td>R-13.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior Acoustic</td>
<td>Sound Batt Insulation - 3.5&quot;</td>
<td>R-11</td>
<td>Sound Batt Insulation - 3.5&quot;</td>
<td>R-11</td>
</tr>
</tbody>
</table>

### Abbreviations

- EPS: Expanded Polystyrene
- XPS: Extruded Polystyrene (not used)
- Polyiso or ISO: Polyisocyanurate

- Typical R-Value
  - EPS: R-4 per inch
  - XPS: R-5 per inch
  - Polyiso or ISO: R-6.5 per inch

### Air Sealing

<table>
<thead>
<tr>
<th>Blower Door Test</th>
<th>.5 ACH (Required = .6 ACH)</th>
<th>3.5 ACH (Required = 6 ACH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>Plywood Sheathing with Siga Tape</td>
<td>Energy Star Thermal Bypass Checklist</td>
</tr>
<tr>
<td>Floor</td>
<td>Plywood with Siga Tape at crawl space</td>
<td></td>
</tr>
<tr>
<td>Ceiling</td>
<td>Plywood with Siga Tape at Ceiling</td>
<td></td>
</tr>
</tbody>
</table>

### Energy

<table>
<thead>
<tr>
<th>Ventilation</th>
<th>ERV &amp; ducting</th>
<th>No ERV/HRV; Trickle Vents in Windows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>Electric Resistance - Cove &amp; Cadet</td>
<td>Electric Resistance - Cove &amp; Cadet</td>
</tr>
<tr>
<td>Cooling</td>
<td>Operable Windows</td>
<td>Operable Windows</td>
</tr>
<tr>
<td>Water Heating</td>
<td>Heat Pump Hot Water Heater</td>
<td>Heat Pump Hot Water Heater</td>
</tr>
<tr>
<td>Dryer</td>
<td>Condensing Dryer hook-up, no duct</td>
<td>Standard Dryer hook-up</td>
</tr>
<tr>
<td>Exterior Doors</td>
<td>Therma-Tru Fiberglass Door</td>
<td></td>
</tr>
<tr>
<td>Windows</td>
<td>Cascadia 325 Series</td>
<td>Cascade 9000 Series</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>Vinyl</td>
<td></td>
</tr>
<tr>
<td>Triple Glaze</td>
<td>Double Glaze</td>
<td></td>
</tr>
<tr>
<td>Casement &amp; Fixed</td>
<td>Single-hung &amp; Fixed</td>
<td></td>
</tr>
<tr>
<td>U Value .21</td>
<td>U Value .29</td>
<td></td>
</tr>
<tr>
<td>SHGC = .50</td>
<td>SHGC = .29</td>
<td></td>
</tr>
</tbody>
</table>

### Abbreviations

- HRV: Heat Recovery Ventilator
- ERV: Energy Recovery Ventilator
- SHGC: Solar Heat Gain Coefficient

### Cost Breakdown

<table>
<thead>
<tr>
<th>SF Cost</th>
<th>$146 per sq ft</th>
<th>$113 per sq ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference</td>
<td>29% more for Passive House (includes actual material cost and bid labor)</td>
<td>$221,320 more for Passive House</td>
</tr>
</tbody>
</table>
Shout Outs

• St. Vincent de Paul Society of Lane County
• Bergsund DeLaney Architecture and Planning
• Meili Construction
• CPHCs: Win Swafford, Jan Fillinger
• SOLARC/Peter Reppe
• City of Eugene, EWEB
• UO NetZed Case Study Lab team, Alison Kwok
A primary consideration to the Owner (and design team) was to create really wonderful places to live... lots of light, warmth, honest use of materials, a very pleasant quality of life.

After achieving that, how can that space be as energy efficient as possible? Where would we all dream about spending a day... and allow that to happen every day.
Kiln underwent a “typical” design process of evaluating a number of design alternatives to meet a pro-forma:

- Single Loaded, narrow units
- Single Loaded, deep units
- Double Loaded w/ small units
- Double Loaded w/ larger units to eliminate one stair

Ultimately an elongated “L” scheme met the pro-forma needs.
SECOND + THIRD LEVEL FLOOR PLAN (ABOVE)
GROUND LEVEL FLOOR PLAN (BELOW)
INTERIOR VIEW OF KITCHEN AND DINING IN 708 SQUARE FOOT ONE BEDROOM APARTMENT
What did we learn?
Many of the architectural design elements required careful analysis to conform with the Passive House energy model.

This is an example of just one of those conditions that required additional evaluation. Others included:

- Foundation
- Moment Frame steel
- Roof

Architectural detailing of metal sunshade and subsequent analysis of thermal bridging and impact to energy model.
SKIN TO VOLUME RATIO 4.9 VS 7.9

This ratio describes the amount of exterior envelope vs amount of interior volume. Historically, we have always thought about this ratio from a cost of construction point of view. However, the ratio has a much larger impact in a passive house because the heat loss through the skin is the dominant driver of energy use.

Typical floor plan at the Janey.

Typical floor plan at Kiln Apartments.
Due to the high performing and very tight envelope of a passive house building, understanding moisture management is more involved. At Kiln, the team hired outside experts to run a number of moisture management scenarios to prove adequate drying of the building initially as well as over time.

Some of the analysis necessary to understand moisture management at Kiln Apartments (Moisture Generation Table, On-site moisture testing of wood framing, hygrothermal model of roof system)
CONSTRUCTION TOLERANCES ARE MUCH TIGHTER

For a mixed-use commercial building, the level of care and quality is significantly different than a “typical” commercial building. To date, almost all of the Passive House buildings in the NW have been homes and many of those have been built by either the designer or very small construction crews.

It is different to build with a crew of a dozen vs a crew of many dozens.

Example showing the level of care required for Passive House construction – in this example, underground insulation with gaps greater than ¼” were required to be spray foamed.
Meeting the blower door test is challenging, but not outrageous. However, we did learn a few things.

- Avoid exterior doors (Kiln has 12). That is a weak link in the system and very expensive to overcome.

- Condensing dryers are critical (or central washer/dryer room).
FINDING THE WEAK LINKS IN THE EXTERIOR ENVELOPE

A value engineering decision to eliminate fiberglass thermal isolation clips proposed in the exterior skin was a mistake. By requiring the exterior envelope sub-contractor to be very precise with very long fasteners, numerous holes were inadvertently created in the envelope. Remediating that condition was time consuming and expensive.

Infrared thermal images. If the exterior envelope is sealed as intended, these images would have very little color variation. Darker colors identified areas for improvements.
The PHPP modeling did not accurately predict the amount the interior air temperature. Or more accurately, a PHPP model was not run on every type of apartment, nor was any other temperature predicting model run. During design, we opted not to run those simulations for budgetary reasons. A lot of money would have been saved had we.

Post Occupancy temperature modeling to understand predicted indoor air temperature given proposed renovations.
During design, a value engineering decision was made to eliminate horizontal mulling of windows to reduce costs of windows. Once that happened, the windows were 7’-0” tall, 4’-0” wide, and had a sill at 24” above the finished floor. However, the windows then needed 4” limiters. This one decision significantly reduced the ability for the building to be night flushed and passively cooled in the evening.

*Tilt / turn, triple pane European style windows.*
Aside from the inherent interest in living in a building attempting to “save mother earth”, residents have said:
1. Love the flooring!
2. Love the windows!
3. Love the big, wide open kitchen/dining/living space.
4. Would have liked a bigger kitchen, but it does work.
5. Exterior deck is great.
6. It is really quiet (big plus).

Note: Residents care about their life. It is nice to be responsible, but it is always about their day to day life.
Project Team

**Owner/Developer**

**Mechanical Engineer**

**Owners Representative**

**Structural Engineer**

**Architect of record**

**Civil Engineer**

**Passive House Consultant**

**Landscape Architect**

**General Contractor**

**Design Architect**
Project Overview
Aerial View from South

Image courtesy of Ankrom Moisan Architects
**WALL A**
- 11/8" TJI WALL FRAMING
- 1 1/2" BLOWN FG INSUL.
- UWR-VALUE = R-39
- MOISTURE: FAIR

**WALL B**
- 2X10 WALL FRAMING
- 9 1/4" BLOWN FG INSUL.
- 1 1/4" MINERAL WOOL EXT. INSUL.
- UWR-VALUE = R-40
- MOISTURE: GOOD

**WALL C**
- 2X8 WALL FRAMING
- 7 1/4" BLOWN FG INSUL.
- 3" MINERAL WOOL EXT. INSUL.
- UWR-VALUE = R-40
- MOISTURE: BETTER

**WALL D**
- 2X6 WALL FRAMING
- 5 1/4" BLOWN FG INSUL.
- 5" MINERAL WOOL EXT. INSUL.
- UWR-VALUE = R-47
- MOISTURE: BEST!

**WALL E**
- 2X6 WALL FRAMING
- 5 1/4" BLOWN FG INSUL.
- 7 1/2" BLOWN FG INSUL. OF 7 1/2" TJI TRUSS.
- UWR-VALUE = R-48
- MOISTURE: ?

*TRUSS*
Typical Roof Assembly: R-81
- 80 mil TPO roof membrane (fully adhered, white)
- 1/2” coverboard
- 12” polyisocyanurate insulation
- Self-adhered rubberized asphalt membrane vapor barrier (serves also as temp. roof)
- 3/4” plywood
- Prefabricated wood truss framing (trusses @ 24”o.c.)
- 5/8” gypsum wall board (2 layers)

Typical Exterior Wall Assembly: R-39
- Fiber cement siding w/ treated 1x wood furring @ 24” o.c.
- 1-1/2” rigid mineral wool insulation (8 lb. density)
- Spun-bonded polyolefin sheet water-resistant barrier
- 1/2” plywood with air sealing tape at all seams
- 2x10 wood framing (studs at 24” o.c.)
- 9 1/4” blown fiberglass insulation at all framing cavities
- Polyamide sheet vapor barrier
- 5/8” gypsum wall board

Typical Slab Assembly: R-19
- 4” concrete slab
- 15 mil polymer sheet vapor barrier
- 4” Type II expanded polystyrene insulation
- Gravel base with radon mitigation system piping

Enclosure Assemblies

Images courtesy of Ankrom Moisan Architects
HVAC Design

Orchards at Orenco
HVAC Systems

Heating & Partial Cooling

HRV

HEAT PUMP
Measured vs. Modeled (PHPP) Energy Use

- Modeled EUI: 22 kBTU/sf.yr (Plug loads per US norms).
- Measured (extrapolated): 23.5 kBTU/sf.yr (7% over Model)
- Large Commons Elec Use currently under investigation.
Measured vs. Modeled (PHPP) Energy Use
Lessons Learned

- Committed Owner with strong vision is essential…
- Integrated design process is key…
- Commercial doors more of a challenge than elevators
- Address direct exhaust appliances during schematic design
- Check efficiency of HRV at design flowrates
- Exterior shading is as important as insulation
- Airtightness of large buildings: a few weak links can be tolerated as long as system-wide components are robust
- Carefully consider construction sequencing of air barrier components

- Passivhaus cost premium was 11% ($158/sf)
Lessons Learned

• Would we/they do it again?
Lessons Learned

• Would we/they do it again? → **YES!**

• Phase II (58 units)…seeking PH certification, with lower cost…
Phase II