Energy Trust of Oregon Net Zero Fellowship Research

Approaching Net Zero for Today’s Buildings

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Development Associate, MRED
Agenda

1. Research Goals
2. Research Approach
3. Case Study #1
4. Case Study #2
5. Conclusions
The Net Zero Fellowship aims to address potential barriers slowing the widespread adoption of net-zero design and to grow the community constructing these remarkable buildings.

Possible topics may include technical research, policy implications, economic benefits, market barriers and community-based net-zero projects.
Identify the most cost-effective energy improvements to approach net zero energy use for two real case study buildings:

Midrise Multifamily

Low-to-Midrise Office
Research Approach

- Analyze existing buildings that were designed for high performance and completed within last five years to understand their current and potential operational performance.

- Evaluate strategies to achieve net zero energy performance and analyze cost premiums, as well as overall economic feasibility, through a pro forma that includes operational energy savings.
Costing Approach

• Pricing is the direct cost of construction materials and labor, including standard markups.

• Work is priced in 2018 dollars in the City of Portland.

• Pricing assumes a competitive bid process with at least 3 bidders and no preference for union or non-union labor.
Market Context – Construction Costs are HIGH
Market Context – Construction Costs are HIGH

Image: Rider Levett Bucknall, Quarterly Construction Cost Report, Second Quarter 2018
## Market Context – Construction Costs are HIGH

<table>
<thead>
<tr>
<th>City</th>
<th>April 2017</th>
<th>July 2017</th>
<th>October 2017</th>
<th>January 2018</th>
<th>April 2018</th>
<th>Annual % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston</td>
<td>20,835</td>
<td>20,989</td>
<td>21,176</td>
<td>21,325</td>
<td>21,563</td>
<td>3.49%</td>
</tr>
<tr>
<td>Chicago</td>
<td>20,414</td>
<td>20,652</td>
<td>20,905</td>
<td>21,177</td>
<td>21,394</td>
<td>4.80%</td>
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<tr>
<td>Denver</td>
<td>14,097</td>
<td>14,187</td>
<td>14,337</td>
<td>14,513</td>
<td>14,649</td>
<td>3.92%</td>
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<tr>
<td>Honolulu</td>
<td>24,060</td>
<td>24,050</td>
<td>24,058</td>
<td>23,663</td>
<td>23,804</td>
<td>-1.06%</td>
</tr>
<tr>
<td>Las Vegas</td>
<td>13,510</td>
<td>13,614</td>
<td>13,777</td>
<td>13,922</td>
<td>14,081</td>
<td>4.22%</td>
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<tr>
<td>Los Angeles</td>
<td>19,997</td>
<td>20,326</td>
<td>20,586</td>
<td>20,874</td>
<td>21,010</td>
<td>5.07%</td>
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<tr>
<td>New York</td>
<td>24,499</td>
<td>24,698</td>
<td>24,927</td>
<td>25,104</td>
<td>25,387</td>
<td>3.62%</td>
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<tr>
<td>Phoenix</td>
<td>13,785</td>
<td>13,900</td>
<td>14,080</td>
<td>14,248</td>
<td>14,442</td>
<td>4.77%</td>
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<tr>
<td>Portland</td>
<td>14,830</td>
<td>15,044</td>
<td>15,302</td>
<td>15,524</td>
<td>15,768</td>
<td>6.32%</td>
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<tr>
<td>San Francisco</td>
<td>24,039</td>
<td>24,546</td>
<td>24,760</td>
<td>25,151</td>
<td>25,704</td>
<td>6.93%</td>
</tr>
<tr>
<td>Seattle</td>
<td>16,419</td>
<td>16,654</td>
<td>16,804</td>
<td>17,017</td>
<td>17,250</td>
<td>5.06%</td>
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<tr>
<td>Washington, DC</td>
<td>19,774</td>
<td>19,884</td>
<td>20,054</td>
<td>20,212</td>
<td>20,437</td>
<td>3.35%</td>
</tr>
</tbody>
</table>

Image: Rider Levett Bucknall, Quarterly Construction Cost Report, Second Quarter 2018
Financial Analysis - Basics

- Key variables for a project to move forward or “pencil”:
  - Cost to build ($$ paid by owner)
  - Income/Rents ($$$ to owner)

- Project must provide enough economic return to attract investors

\[
Return = \frac{Net\ Income\ (Rents)}{Net\ Cost}
\]

- Rents must be high enough and cost must be low enough to generate return

- Net Cost is cost less subsidies, grants, tax credit equity, etc.
Financial Assumptions

• Timing: the projects are in today’s construction costs with today’s rents
• Location: building location stays the same
• No additional rent premium for Path to NZ building versus Baseline LEED Platinum buildings
• However, we DO assume utility savings benefits proforma
Case Study 1: Midrise Office
Midrise Office Case Study: Vestas Headquarters

Meier and Frank Building:

• 170,679 square feet

• 5 floors

• Commercial office tenants: GE, Vestas, Urban Shift

• Certified LEED Platinum in 2012

• Historic renovation operational since 2013
Vestas Headquarters Sustainability Features

Envelope
• Thermal Mass – Exposed Concrete Floors
• Well-Insulated Roof (R30) Over Concrete
• Operable Windows

Efficient and Natural Lighting
• Daylighting through interior atrium
• Lighting controls and occupancy sensors
• Lower lighting power density 0.54 W/sf
Vestas Headquarters Sustainability Features
Windows: Benefits and Challenges
HVAC and Renewables

HVAC: Level 1
- Water source heat pumps
- Energy Recovery on Ventilation Air System

HVAC: Levels 3-5
- Underfloor Air Distribution (window height challenge)
- VRF with water cooled condensers in perimeter areas

Rooftop Solar 125 kW PV Array
Establishing Baseline

Vestas Energy Benchmarking
– EUI 36.58 kbtu/sf

• Verified through utility bills
• Gap between predicted and measured energy performance is 21.2%
• Onsite PV generation offsets 6-9% of building electricity usage
Establishing Baseline

Vestas Energy by End Use EUI Benchmarking (kbtu/sf)

- Cooling
- Heating
- Heat Rejection
- Fans
- Pumps
- Hot Water
- Interior Equipment
- Exterior Lighting
- Interior Lighting

ASHRAE 90.1-2007: 48.39 kbtu/sf
LEED Proposed Model: 28.81 kbtu/sf
Calibrated Model: 36.58 kbtu/sf

Total
Model calibrated within 5-12% range of electricity and gas reported in utility bills for 2016.
Vestas Existing Solar – 125 kW
Solar Needed – 750 kW, or 3x available rooftop

Vestas Existing Solar – 125 kW
Efficiency Strategies Considered

Envelope:
- Increase thermal performance of walls and windows
- Reduce window wall ratio
- Increase roof insulation
- Reduce glazing U value

Shading:
- Solar heat gain coefficient (SHGC)
- Use dynamic glass
- Automated blinds
- Increase shading on south/west facades

Daylight/Lighting:
- Switch from fluorescent to LED fixtures to reduce lighting power density from .57W/sf to .4W/sf
- Add skylight on Level 5

HVAC:
- Convert water heater from gas fired to heat pump
- Switch boiler/fluid cooler system to geothermal
- Radiant heating and cooling
HVAC Upgrades

Existing HVAC System, Floors 3-5
- UNDERFLOOR AIR WITH AHUS
- VRF SYSTEMS

Proposed HVAC System, Floors 3-5
- UNDERFLOOR AIR WITH DOAS
- GROUND SOURCE HEAT PUMPS
**Goal:** Reduce EUI to Under 20 kbtu/Square Foot

Comparison of Sensible Peak Cooling and Heating Gains

- **Sensible Air Cooling**
- **Cooling Internal Gains**
- **Cooling Envelope Losses**
- **Sensible Air Heating**
- **Heating Internal Gains**
- **Heating Envelope Losses**

**BaseRun (kbtu)** vs. **Design Alternative (kbtu)**
# EUI Reduction Strategies With Costs

<table>
<thead>
<tr>
<th>Bundled Strategies</th>
<th>EUI (kbtu/sf)</th>
<th>Annual Energy Savings</th>
<th>Annual Cost Savings</th>
<th>First Cost</th>
<th>Cost/sf</th>
<th>Cost/EUI/sf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building As Is</td>
<td>36.12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1: Envelope Upgrade</td>
<td>34.97</td>
<td>3.19%</td>
<td>$13,432</td>
<td>$1,034,718</td>
<td>$6.06</td>
<td>$5.28</td>
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<tr>
<td>2. Shading</td>
<td>35.38</td>
<td>2.05%</td>
<td>$8,182</td>
<td>$259,038</td>
<td>$1.52</td>
<td>$2.06</td>
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<tr>
<td>3. Lighting/Plug Load Reductions</td>
<td>33.90</td>
<td>6.14%</td>
<td>$7,261</td>
<td>$270,124</td>
<td>$1.85</td>
<td>$0.84</td>
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<tr>
<td>4. Heat Pump Water Heater</td>
<td>35.97</td>
<td>0.41%</td>
<td>-$4,057</td>
<td>$11,466</td>
<td>.07</td>
<td>$0.46</td>
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<tr>
<td>5. Ground Source Heat Pump</td>
<td>22.67</td>
<td>37.23%</td>
<td>$44,395</td>
<td>$1,526,850</td>
<td>$8.95</td>
<td>$0.67</td>
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<tr>
<td>All Strategies, Bundled</td>
<td>20.50</td>
<td>43.25%</td>
<td>$54,062</td>
<td>$3,148,117</td>
<td>$18.44</td>
<td>$1.18</td>
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</table>
## Resulting Economics – Vestas Office Building

- Target Return on Cost for Portland Office: 7.00%

<table>
<thead>
<tr>
<th>Vestas Office Building</th>
<th>No Historic Tax Credits</th>
<th>Path to Net Zero</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feasibility</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>Path to Net Zero</td>
</tr>
<tr>
<td>Total Costs in 2018 dollars</td>
<td>$82,080,000</td>
<td>$85,490,000</td>
</tr>
<tr>
<td></td>
<td>$454/GSF</td>
<td>$473/GSF</td>
</tr>
<tr>
<td>Additional Capital Incentives /GSF</td>
<td>$52.43</td>
<td>$66.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$473</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vestas Office Building</th>
<th>With Historic Tax Credits</th>
<th>Path to Net Zero</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feasibility</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>Path to Net Zero</td>
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<td>Total Costs in 2018 dollars</td>
<td>$82,390,000</td>
<td>$85,800,000</td>
</tr>
<tr>
<td></td>
<td>$456/GSF</td>
<td>$475/GSF</td>
</tr>
<tr>
<td>Additional Capital Incentives /GSF</td>
<td>$15.54</td>
<td>$28.02</td>
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<tr>
<td></td>
<td></td>
<td>$475</td>
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</tbody>
</table>
Case Study 2: Multifamily Residential

Image: Holst Architecture
Multifamily Residential Case Study

Beech Street Apartments

- 36,742 square feet (Building owned and managed by Home Forward)
- 4 floors
- 32 units of affordable housing for women and children
- New Construction (2014)
- LEED for Homes Platinum certified
Beech Street Apartments Sustainability Features

Envelope

• Exterior walls insulated to R16, roof to R50
• Low window wall ratio (16%) and high performance glazing

Efficient HVAC Systems

• VRF fan coil units and air cooled condensing units
• Make up air unit with heat recovery system

Lighting

• Fluorescent lighting, good daylight and operable windows
Awning Window Ventilation Challenges
Establishing Baseline

EUI 42.62 kbtu/sf

• Verified through utility bills

• Gap between predicted and measured energy performance is 22%

![Beech Street Energy Benchmarking](image)
Model calibrated within 5-10% range of utility bill data for 2016.
Establishing Baseline

Beech Street Energy by End Use EUI Benchmarking (kbtu/sf)

- Baseline Model (ASHRAE 90.1-2007): 50.89
- LEED Proposed Model: 33.22
- Calibrated Model: 40.10

- Cooling
- Heating
- Fans
- Pumps
- Hot Water
- Interior Equipment
- Exterior Lighting
- Interior Lighting
- Total
Sensitivity Analysis

Sensitivity Analysis, Adjusted For:

• Lighting operational hours
• Plug load operational hours
• Water schedule
(Re) Establishing Baseline for Cooling/Comfort

Occupant Feedback:

• 100% of occupants surveyed felt summer indoor air temperatures needed improvement

• Cooling added to the Baseline

Unmet Cooling Hours for Sample Unit 151
Efficiency Strategies Considered

**Envelope:**
- Insulate walls
- Insulate roof
- Window Wall Ratio
- Increase air tightness, .25 cfm/sf, 0.08 cfm/sf

**Shading:**
- Add shading devices on south/west facades
- Solar Heat Gain Coefficient
- Select low U value glazing

**Daylight/Lighting:**
- Replace fluorescent fixtures with LEDs to lower lighting power density from .65W/sf to .5W/sf.
- Turn off nighttime equipment use
- Add light shelves to units

**HVAC/Hot Water**
- Convert gas fired water heater to heat pump water heater
- Reduce hot water usage
- Use heat recovery ventilators (HRVs) in units
- Use radiant heating and cooling in units
- Solar thermal to offset hot water heating
HVAC Upgrades

Existing HVAC System

Proposed HVAC System
<table>
<thead>
<tr>
<th>Bundled Strategies</th>
<th>EUI (kbtu/sf)</th>
<th>Annual Energy Savings</th>
<th>Annual Cost Savings</th>
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</thead>
<tbody>
<tr>
<td>Building As Is</td>
<td>36</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1: Envelope Upgrade</td>
<td>35</td>
<td>3.55%</td>
<td>$1,162</td>
<td>$425,621</td>
<td>$11.58</td>
<td>$9.78</td>
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<tr>
<td>2. 20% Lighting Reduction</td>
<td>35</td>
<td>3.29%</td>
<td>$1,153</td>
<td>$40,301</td>
<td>$1.10</td>
<td>$0.93</td>
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<tr>
<td>3. Nighttime Plug Load Reduction</td>
<td>35</td>
<td>2.36%</td>
<td>$828</td>
<td>$119,480</td>
<td>$3.25</td>
<td>$3.83</td>
</tr>
<tr>
<td>4. Heat Pump Water Heater and Hot Water Reduction</td>
<td>27</td>
<td>23.83%</td>
<td>-$1,539</td>
<td>$23,318</td>
<td>$0.63</td>
<td>$0.07</td>
</tr>
<tr>
<td>5. Add DOAS w/ HRU/VRF in Units</td>
<td>35</td>
<td>2.18%</td>
<td>$765</td>
<td>$342,576</td>
<td>$9.32</td>
<td>$11.91</td>
</tr>
<tr>
<td>All Strategies, Bundled</td>
<td>24</td>
<td>33.02%</td>
<td>$1,361</td>
<td>$951,297</td>
<td>$25.89</td>
<td>$2.24</td>
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</table>
Resulting Economics – Beech Street Apartments

- Target Return on Cost for Portland Multifamily: 5.75%

<table>
<thead>
<tr>
<th>Beech Street Apartments</th>
<th>Market Rate</th>
<th>Path to Net Zero</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Path to Net Zero</td>
</tr>
<tr>
<td>Feasibility</td>
<td>$13,000,000</td>
<td>$14,020,000</td>
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<tr>
<td>Total Costs in 2018 Dollars</td>
<td>8%</td>
<td>$380</td>
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<tr>
<td>Additional Capital Incentives/GSF</td>
<td>$104.76</td>
<td>$132.24</td>
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</table>

$/GSF
Conclusions
Conclusions of the Study

• Energy models predict building performance, not people. The initial gap to Net Zero was larger than predicted/designed.

• Typical project process doesn’t leave time for early energy analysis – but it probably should.

• The baseline for multifamily housing (especially affordable housing) does not currently include cooling. That creates increased energy draws from personal cooling solutions, and uncomfortable conditions for residents. Energy Trust is actively exploring these issues.

• The research provides new information about net zero strategies for common building types that the market is not designing to net zero – comparable net zero buildings were very hard to find.
Conclusions – Costing

• Commercially available technology today is readily available to build net zero buildings. The market conditions are not quite there yet.

• Increasing baseline standards for code or comfort will make the relative premium costs smaller.

• The current construction market pricing makes net zero buildings challenging. New financing options can make a difference.
Conclusions – Financial

• Increased demand on labor and materials, combined with not enough supply, has skyrocketed construction costs.
  - *Opportunity*: if/when costs settle down relative to market rents, the gap may not be as expensive. Subsidies or other gap financing would help make these project achievable.

• The relative costs for more energy efficient upgrades is still high.
  - *Opportunity*: as R&D continues and scale decreases relative cost of measures, Net Zero becomes more achievable.

• Making a net zero building design a reality can be a complex challenge in today’s construction market. Financial subsidies and technical resources can help, but there is still a gap.
Thank you!